FAMU-FSU 2012 Solar Car

Senior Design Final Report – April 2012

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I. Abstract

The Florida State University Solar Car Team of 2011-2012 is honored to present the first fully functional solar car to represent the FAMU/FSU College of Engineering. The solar car project was presented as a three year multi-disciplinary project to a team of electrical, mechanical, and industrial engineering students. This year's team was given five main objectives at the start of the project and a little over $4,000 in funds. The first task provided to the students was to have a vehicle that was capable of being powered purely by solar energy. Furthermore, the team was tasked to design a way to efficiently deliver the solar energy to the batteries with the use of a maximum power point tracker. The next objective was to redesign the previously non-operational regenerative braking system. The fourth objective was to have a latched top half to prevent the car from opening while driving, and to hinge the top half to the bottom half of the car to assist the driver and team in opening the car. The next objective was to enclose the driver in a cockpit to protect them from the outside elements. The final objective was to provide a means of air circulation within the vehicle. With these six objectives, the solar car would be completed after three years of design work.

The objectives quickly began to multiply when the previous year's motor fell apart due to improper mounting and neglect to determine the source of an undesirable noise and vibration from the motor. This drastically affected the scope of the project and left the engineering students with their first real-world engineering problem to solve. How will they complete the solar car with the current budget and the added problems? They decided to set new goals and allocate funds with caution and careful planning. Due to the inoperable motor, additional objectives had to be added to complete the project but the team was more than confident that they could accomplish the newly added goals. Following a well-planned schedule using a Gantt chart the team set out to achieve their goals, giving careful consideration to the budget. The students were able to quickly replace the motor, choosing a high efficiency motor at one eighth the price of the previous. However, this change drastically altered the mechanical and electrical systems of the car. The team took on the challenge, as any engineer would do, focusing on the task at hand while keeping the main goal in mind. The electrical engineers added three new objectives, which were to tackle a new control system, design a new battery arrangement, and rewire the whole car from scratch. The mechanical engineers added two new objectives to the project, which was to redesign the rear suspension from one that accommodated the "pancake"

style motor to one that would accommodate an outboard motor, and to design a drivetrain that would transmit the desired speed and torque from the motor to the wheel.

The solar team has completed all objectives set forth by the College of Engineering as well as the goals imposed on them to deliver an adequate final product. In addition the team would like to point out their unique additions to the vehicle. The car has an innovative solar array with the ability to charge the batteries even if over 95% of the array is shaded. The team built a maximum power point tracker that allows for the maximum amount of collected solar energy to be efficiently delivered to the batteries through a boost converter. In addition, the rear suspension was redesigned to integrate the DC motor with a chain-drive and is geared with a 4:1 ratio to increase the torque output from the motor to the rear wheel drive. The solar car incorporated a new motor controller that effectively fixed the regenerative braking problem. Furthermore, the steering column was raised to give more room for the driver's legs and an adjustable seat was added with a five-point seat belt to comply with safety regulations for the American Solar Challenge (ASC) competition in the future. The team would like to also acknowledge that the entire electrical wiring was redone to accommodate a 48V and 12V electrical system from the previous 96V system.

This year's group contributes its success to a well thought-out plan with room for flexibility and a well-monitored budget. The adept style of problem solving while under budget constraints portrays the qualities needed for a successful engineering team. This year's team went above and beyond what was asked and produced something that the FAMU-FSU College of Engineering can be proud of.

II. Introduction

Needs Assessment and "Needs Statement"

This year, a group of electrical and mechanical engineers will be finishing the three year solar car project. By the end of this year, the FSU College of Engineering should have a fully functional solar car. However, the state of the car as given to us had serious mechanical problems. The very expensive "pancake" motor upon starting had several pieces of copper winding fall out of the rotor. Due to budgetary concerns, this year's group was required to procure a means of allocating funds, which the team did not have as of the beginning of this project to purchase a new motor.

There are several mechanical and electrical issues that had to be resolved, as well as issues that were desirable to be resolved. A problem that occurred in previous operations was that at high speeds the lid would lift up and the driver was forced to hold it in place, forfeiting steering and handling. Therefore, a latching system had to be implemented to stabilize the lid so that the lid could be secured from the inside and outside of the car. The students were further tasked with designing and securing the solar array and mounting it to the shell of the vehicle. Furthermore, a braking issue that was required to be resolved was to integrate and control the regenerative braking with the mechanical braking system. The breaking system had to be analyzed from both mechanical and electrical standpoints. Solar panels vary output current and voltage to the battery, thus designing a max power point tracker (MPPT) to function between the battery and the solar array had to be implemented to solve this problem. The next requirement was to redesign an aerodynamic bubble to encase the driver. Finally, the driver cockpit would be equipped with an outside air circulation and ventilation system that would additionally cool the rest of the car including the solar panels.

There are some issues that were not necessarily required but were desired to be resolved. The height of the steering column was increased as well as the supporting rod so that it can allow the driver to move more freely inside the cockpit. Prior to the redesign, the supporting rod was a safety hazard for the driver as well as an inconvenience when operating the vehicle. The final desired objective was to replace the brackets that bolted the rear suspension onto the car, however this objective was changed from a desired goal to a required goal after the original motor became inoperable.

Required Capabilities

- RCAP-001: the vehicle must run entirely on electric power provided by batteries and solar cells
- RCAP-002: when there is no motor load the solar cells should charge the battery
- RCAP-003: when there is a motor load the solar cells should act as a parallel source along with the batteries to run the motor.

- RCAP-004: a regenerative braking system must recapture power during light to moderate braking and engage the standard braking system during moderate to heavy braking.
- RCAP-005: Latching system for lid
- RCAP-006: Integrate and control regenerative braking with mechanical brake system
- RCAP-007: Design bubble for driver encasement
- RCAP-008: Driver cockpit equipped with an outside air circulation and ventilation system
- RCAP-009: Rear wheel bolt attachment to be redesigned.

Desirable Capabilities (in order of highest to lowest priority)

- DCAP-010: the driver should be able to lift the top of the car or the enclosure and exit the vehicle without outside assistance.
- DCAP-011: the top of the vehicle should be capable of being positioned at an angle to maximize exposure to the sun (this system may be integrated with the driver assisted lifting)
- DCAP-012: the vehicle should conform to as many safety standards as possible (brake lights, turn signaling, rear view mirrors)
- DCAP-013: Extend height of steering column and stabilizing rod
- DCAP-014: Extend length of rack & pinion in steering mechanism
- DCAP-015: the controller in the car should record the state of the vehicle to be analyzed later.

Operational Description

Upon entering the "cockpit," the driver should execute a startup procedure to bring the car into a drivable state. The driver uses a forward/reverse switch to choose the longitudinal direction of the vehicle and the steering wheel to control the latitudinal direction, one pedal on the right of the cockpit floor to control acceleration and another on the left to control braking. There will also be a kill switch within reach of the driver that will remove power from all of the electrical systems. All other systems are automated, but should report their state to the driver where applicable.

Problem Description

The problem set forth by the College of Engineering for this project was to design and build a solar car capable of competing in future events such as the North American Solar Challenge as well as being a catalyst to start an alternative energy organization within the College of Engineering. The solar car design is required to be lightweight and capable of running entirely on solar energy. Therefore, the car should use solar panels to charge the batteries that will in turn energize the motor to run the car. Currently, the solar car is in its third year of production and this year's team was presented with the challenge of completing the previous year's design. The students were tasked to address problems from the previous phases and improve upon aspects to satisfy any requirements for future competitions, as well as satisfy requirements for the continued operation of the vehicle and safety of the driver.

Goal Statement

The obstacles the students faced this year were numerous, including replacing a broken motor and designing and integrating the solar panel array. The students amalgamated the solar panels and the batteries so they could work together to power the vehicle. In addition to replacing the existing motor, the rear suspension was redesigned to incorporate a different size motor with different operating mechanics, as well as a redesign of the rear wheel attachment for better stability. A latching/hinging system was designed so that the body of the car will be fastened together for stability during operation as well as being able to open and close from the inside and outside of the car. To enclose the driver during operation, a driver encasement bubble design was simulated and designed for minimal drag on the vehicle. An air circulation and ventilation system was designed for the cockpit to aid in driver comfort and as a means to cool the electronic components in the entire vehicle. Furthermore, the entire electrical system was converted from a 96V system to a 48V and 12V system. This change required the entire electrical system to be redesigned.

List of Objectives

Table 1 - Objectives for phase three of solar car

Objectives	Progress
⊸Fund Raising	100%
⊸Solar Array	100%
⊸MPPT/Boost Converter	100%
⊸Motor	100%
⊸Regenerative Breaking	100%
⊸Driver Encasement	100%
⊸Latch and Hinge	100%
⊸Air Circulation	100%
⊸Rear Suspension	100%
⊸Solar Car Completion	100%

Testing Environment

The solar car shall be able to operate in standard North American climates. The car is able to withstand normal wear and tear with seasonal changes that a commercial automobile would encounter in this area. The car is resistant to rain, dust, debris, etc. The cars electronics are protected and able to operate in wet 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; however the car can handle up to a 12 percent grade, which can be found on residential roads.

The vehicles current progress in meeting all testing environment requirements is 90 % completed. It was not this phase of the projects objective to meet all environmental requirements but was considered in all decisions made. This year's team has determined that future teams must complete three tasks to make the vehicle completely resistant to all environments. The first task is to add a final protective layer over the entire top of the solar array. The next task would be to add a top lip that circumferences the vehicle at its joint, preventing water and debris from entering the vehicle from the top. The third task next year's team could complete is adding wheel wells in the vehicle to stop road debris and water from entering from the bottom of the vehicle.

List of Constraints

- CONS-001: The solar array surface area is limited to the surface area of the existing body ($6m^2$ or $64ft^2$), which equals 70 solar modules.
- CONS-002: The solar modules used must be from the previously purchased solar modules (PT15-300) to stay within budget.
- CONS-003: The existing frame, chassis, suspension, and solar modules, and batteries must be used because replacing any one of these components will severely drain this year's budget.
- CONS-004: The cost of materials and components must not exceed $4,093.
- CONS-005: The solar array and MPPT/converter system must operate at the voltage levels of the batteries and solar modules (converter must go from 30V upto to 50 V).
- CONS-006: The batteries have an over voltage of 4.25 V and an under voltage of 2.5 V. The batteries have an over current of 120A and an over temp of 75 C.
- CONS-006: The microcontroller shall be used to control the max power point tracker.
- CONS-007: The quiescent energy usage of the car in solar charge mode shall be less then 25W (This is equal to 25% exposure in low sun light, roughly 10% of max solar power generation).
- CONS-008: The overall dimensions for the car must be 5.0 m in length, 1.8 m in width, and 2 m in height. No major changes will be made to the physical appearance of the vehicle as far as the shape and size of the car.
- CONS-009: The footprint of the bubble should be no bigger than 11.6 ft^2 and no smaller than 5.42 ft^2. The bubble should be no heavier than 25 lb nor should the bubble exceed a height of more than 16 in.
- CONS-010: Constraints on the cockpit are to have a 5-point seat belt. Also, to maintain aerodynamic properties of the bubble, the friction due to drag is low as possible, with the coefficient of drag below 0.2.

Functional Diagram

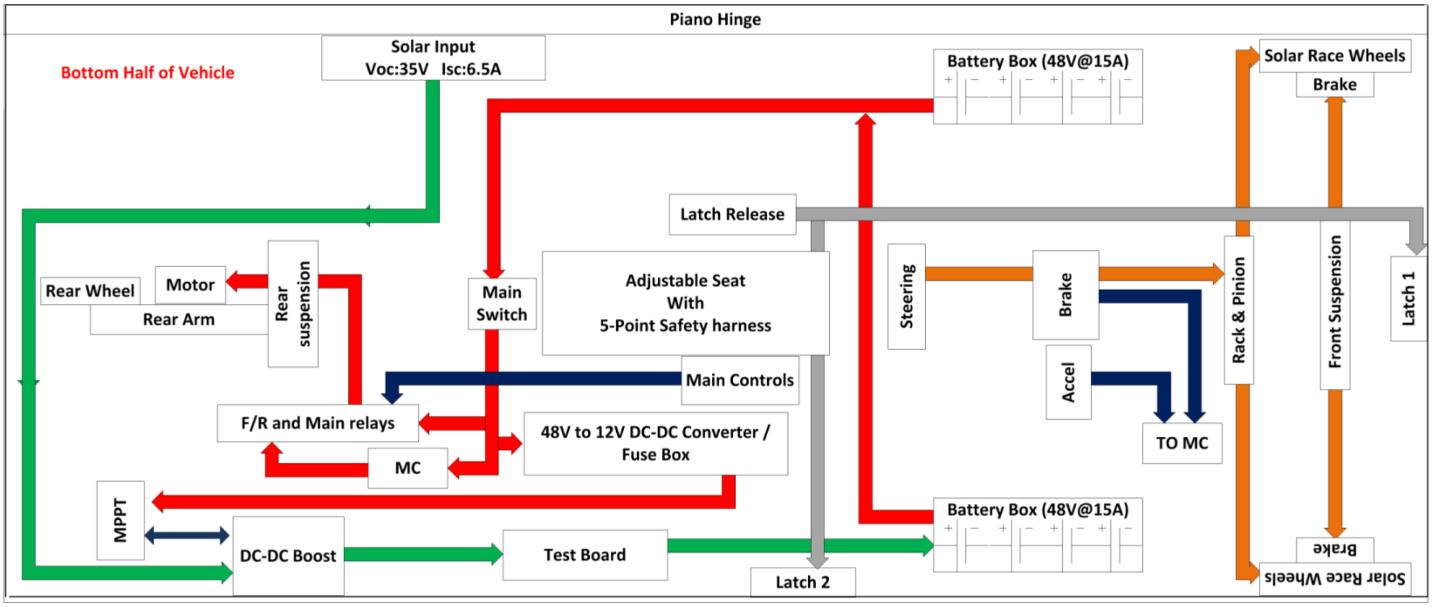


Figure 1 - Top Level Functional Diagram

Project Plan

The goal of the project this year was to improve upon the solar car that had been built by senior design teams over the last two years. The car has 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. Much of the mechanical design was already in place and required some modification, however many design flaws were present and needed to be addressed along with added functional requirements that were not present in the past designs.

The goal for the project was to have a working solar vehicle by the end of the year. This was necessary for future fundraising and allowed for the car to be handed off to the Sustainable Engineered Solutions (SES) club. This club will allow future vehicles to have the manpower and funding needed to compete in the American Solar Car challenge. The design the team has decided upon meets that goal due to the solar array that has been placed on the vehicle and set up to manage the new battery layout and motor configuration. The design of the bubble and rear suspension will ensure longevity in the solar cars life which will help meet the goals the vehicle as well as a base line for future vehicles.

III. Concept Generation

Motor and Motor Controller Design

The motor chosen to replace the previously used SCM-150 and its controller is the Lynch Motor Company model LEM200-127 DC brushed motor and the Kelly Controller KDZ48201. This choice was made due to the unrealistic cost of replacing the SCM-150 at $16,000. The LEM200-127 fit within the constraints of the existing system with some minor modifications. For example, the previous battery array consisted of thirty 3.3V $LiFePO_4$ batteries in series for a nominal voltage of 96 V. This has been changed to an array consisting of 32 sets of two panels in series, in parallel for a nominal voltage of 48V. This works because the controller is essentially a buck converter and the nominal voltage of the motor is 48V. The motor controller has a built in regenerative braking controls and will be controlled by the existing accelerator and brake pedals. It can be shown that at 100% duty cycle of a boost converter, the output will receive close to the full input voltage from the batteries and at 0% duty cycle it will receive zero voltage. This allows for a direct voltage control of the DC motor with a linear input from the accelerator. This portion of the project requires very little design work and all decisions to purchase these parts were weighted most heavily by cost effectiveness.

Rear Suspension Design

Upon inspection of the solar car at the beginning of the semester, multiple problems could be identified with the rear suspension. As seen below in Figure 2, the design is mainly a frame set up to support the original in-line motor. It is supported by a large V-frame to help stabilize the suspension arm under turning conditions. The problems that have been encountered were affecting the performance of the vehicle; for example the base plate that connected the suspension frame to the car had holes that were not parallel to each other, therefore causing the main support that attached to the body to be slightly crooked.

The old suspension was made to fit a specific motor, one which is beyond repair. This setup had the electric motor attached to the wheel and thus needed a large space to mount within the suspension. The motor was directly connected to the rear suspension offering little accessibility if a change in the wheel design was required. Given the design, a single pin or axle was not able to be used which means each side of the wheel-motor assembly had to be attached to the rear suspension separately. Even with precise measurement, this can lead to unnecessary forces acting against the motor due to non-concentric rotating parts. One theory is that the slow breakdown of the old motor was contributed by this misalignment. With the wheel spinning at a slight angle, gravity was pulling the magnets into the center of the motor which caused bits of the magnet to break off slowly and finally led to it becoming inoperable. The past teams thought the sound was normal and never addressed the problem.

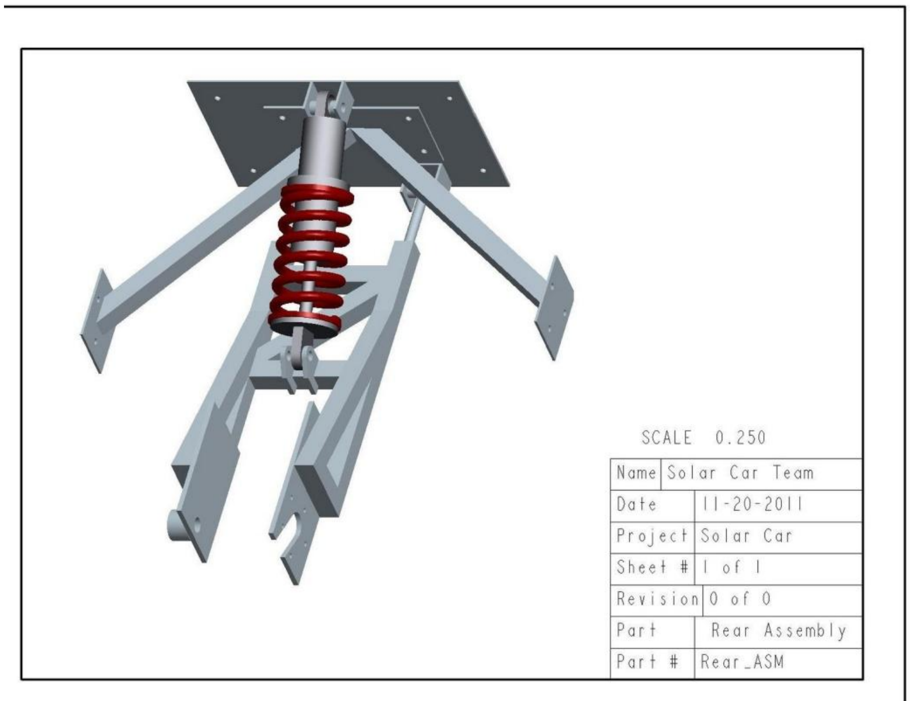


Figure 2 - Pro-Engineer model of the old suspension.

The first concept of the new design for the rear arm, shown in Figure 3, has been modified from the previous design by making the entire assembly more stable and easier for installation and removal of the tire. Also, the new design allows the tire to rotate freely on a shaft that goes through the entire arm, through tapered roller bearings and is to be secured in place by a castle nut with a cotter pin. There are 3 inch slots on each side of the arm to allow for the wheel to be adjusted in order to keep tension in the chain used to transfer the rotation of the motor shaft to the wheel shaft via sprockets on each shaft. Aside from the changes in the design of the rear arm, changes have been made to the thickness of the plate that is connected to the car behind the driver seat for additional structural integrity. The u-shaped brackets that connect to the strut and the arm will be made to have two holes spaced one inch apart, instead of one hole in the center which was part of the previous design. This will help to prevent any moments that could be presented in each connection, therefore preventing any torque on the rear arm itself.

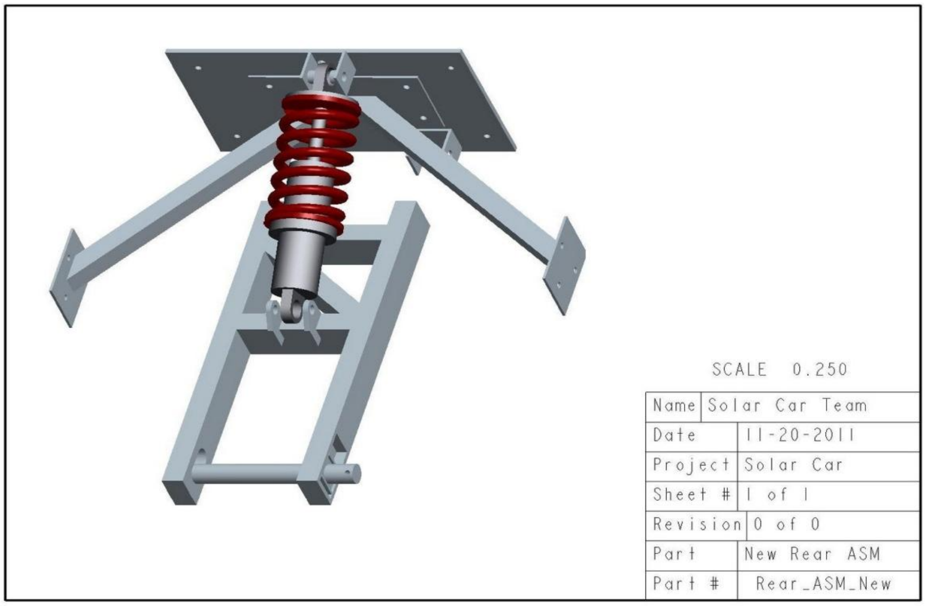


Figure 3 – Pro-Engineer assembly of the first suspension design concept.

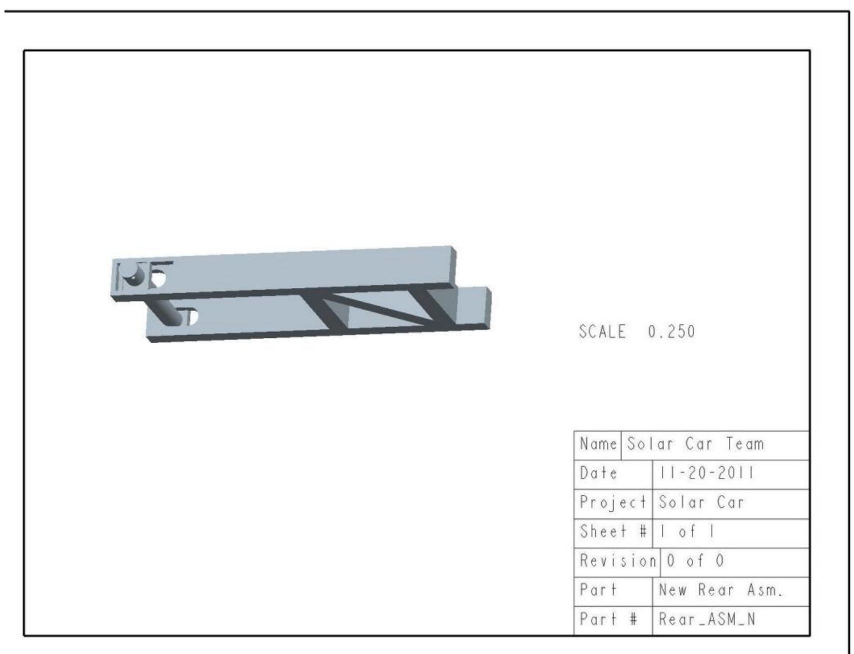


Figure 4 - Pro-Engineer model of the first rear arm design concept.

Latch and Hinge System Design

The process in designing the latch and hinge system involved researching the different types of hardware and their operation, and determining which system would be most applicable on the solar car. Several types of hardware were compared for each component. The latch types considered were remote-release cable latches, draw latches, and fixed-rod multi-point latches. The main operation of remote-release cable latches involves the actuation of a plastic T-handle which pulls flexible cables to allow the latch to be pulled around corners or other obstructions. This type of latch is mounted using the included mounting plates and can be bolt or surface mounted. A remote-release cable latch would be ideal for latching the front and rear of the car because it can be ordered as a double point latch and would be able to move around the various obstructions in the inside of the car.

Another type of latch that was considered was the draw latch. This type of latch is commonly used on tool boxes, chests, cabinets, and for other light duty applications. A draw latch would be ideal for latching the side of the vehicle, but would not suffice for securing the entire lid because the distance between the driver's seat and the front and rear of the vehicle is too large for the driver to be able to latch and unlatch the lid. The idea was considered to have an extension rod connect to the latch from the driver's seat; however it seems that there is no possible way to include an extension rod with this type of latch. Therefore the decision was made that even though the cost is much lower than other types, it is not feasible for this latch to be utilized in the front or rear of the vehicle.

The third latch considered is a fixed-rod multi-point latching system. This latch is commonly used in cabinets and doors that need several latch points. The system includes a latch and actuator with two rod assemblies. There can be two or three latching points controlled from a single actuation point, which would be ideal for latching the front and rear of the vehicle simultaneously. The only drawback in this design is that the rod would have to be clear of any equipment in the vehicle and would need to be carefully aligned as to not hit any of these obstructions during operation.

The first hinge considered was a take-apart or lift-off hinge. This design allows for the hinge to be separated and lift apart so that a lid or door may be removed easily. This type of hinge would be useful in the case that the lid needs to be removed for solar panel repairs or other component repairs. Although this type of latch is inexpensive and easy to take apart, it may not be ideal for this application because of the small size of the latch. For this design to be implemented, our team would need several hinges along the edge of the lid to be hinged, and they would need to be very accurately aligned. This also concentrates the force in several small spots which could cause the lid to crack in these areas.

A different hinge was considered as an alternative to the last design. One or more piano, or continuous, hinges could distribute the force applied to the lid during hinging and would prevent cracking in areas of the lid. This design also allows for better alignment due to the increased length of the hinge across the side of the car. A few drawbacks exist with this hinge type including high cost and that it is less likely to be removed as easily as the take-apart hinge. A custom continuous hinge could have been designed to meet all of our needs. A company called Midlake specializes in designing custom hinges and could potentially combine a continuous hinge with a take-apart hinge. The only negative aspect of this design was that it could potentially have a high cost and would be somewhat of a threat to the budget.

A decision matrix was utilized for both the latch and the hinge separately to determine the best design for each component. Scoring of each design ranged from 1 (lowest) to 10 (highest) and was weighted according to the importance of each of the criteria in the overall decision. Each design was rated based on low cost (the lower the cost, the higher the score), durability, ease of installation, ease of operation, and applicability. The applicability criterion is used to determine whether the system will be functional given the constraints of the interior of the vehicle. The decision matrix shows that the remote-release cable latch and the piano/continuous hinge are the best choices for this system design.

Table 2 - Decision matrices for three latch types

Remote Release Cable Latch			
Criteria	**Weight**	**Score**	**Weighted**
Low Cost (ranks high)	20%	3	0.6
Durability	10%	7	0.7
Ease of Installation	20%	7	1.4
Ease of Operation	30%	10	3
Applicability	20%	10	2
TOTAL	**100%**		**7.7**

Draw Latch			
Criteria	**Weight**	**Score**	**Weighted**
Low Cost (ranks high)	20%	10	2
Durability	10%	7	0.7
Ease of Installation	20%	7	1.4
Ease of Operation	30%	7	2.1
Applicability	20%	2	0.4
TOTAL	**100%**		**6.6**

Fixed-Rod Multi-Point Latch System			
Criteria	**Weight**	**Score**	**Weighted**
Low Cost (ranks high)	20%	5	1
Durability	10%	7	0.7
Ease of Installation	20%	5	1
Ease of Operation	30%	7	2.1
Applicability	20%	9	1.8
TOTAL	**100%**		**6.6**

Table 3 - Decision matrices for three hinge types.

Take-Apart/Lift-off Hinge			
Criteria	**Weight**	**Score**	**Weighted**
Low Cost (ranks high)	20%	10	2
Durability	10%	8	0.8
Ease of Installation	20%	9	1.8
Ease of Operation	30%	7	2.1
Applicability	20%	3	0.6
TOTAL	**100%**		**7.3**

Piano/Continuous Hinge			
Criteria	**Weight**	**Score**	**Weighted**
Low Cost (ranks high)	20%	3	0.6
Durability	10%	9	0.9
Ease of Installation	20%	8	1.6
Ease of Operation	30%	9	2.7
Applicability	20%	9	1.8
TOTAL	**100%**		**7.6**

Custom Continuous Hinge			
Criteria	**Weight**	**Score**	**Weighted**
Low Cost (ranks high)	20%	2	0.4
Durability	10%	9	0.9
Ease of Installation	20%	8	1.6
Ease of Operation	30%	9	2.7
Applicability	20%	9	1.8
TOTAL	**100%**		**7.4**

Figure 5- Double Point Remote Release Cable Latch

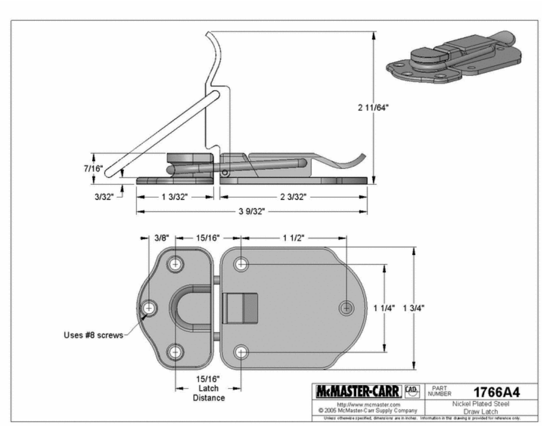


Figure 6 - Draw Latch

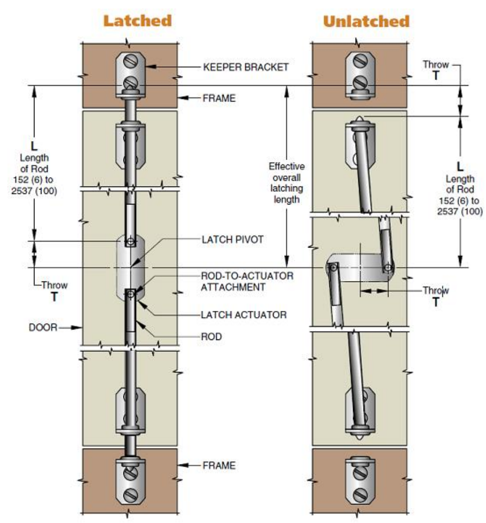


Figure 7 - Fixed-Rod Multi-Point Latch system

Figure 8 - Take-Apart/Lift-Off Hinge

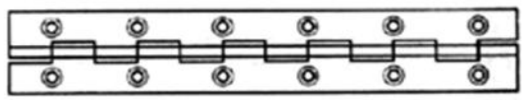


Figure 9 - Piano/Continuous Hinge

The latching system will allow for a single person to open and close the lid of the car. The latch will be accessible from the inside and outside of the car. Two hinges will be attached to the left side of the car, while the latches are attached to the right side. Therefore, if the driver needs to get out during operation, he/she will exit the vehicle to the right side and away from traffic. This allows for much higher operational safety as it will keep the body of the car secure and stable under operation. The aerodynamics will also be improved as the top part of the body will be more secure and allow airflow to pass over the nose of the car with minimal flow separation. The lid will be set at certain angles to be orthogonal to the sun while charging. Much like propping open a car hood, it will have multiple notches allowing for incremental degree changes. This will be useful if the driver has to pull over to the side of the road to recharge the batteries in the fastest time possible.

The outcome of the latching/hinging system will allow the lid of the car to be securely fastened during operation and allow for ease in entering and exiting the car. Several options exist for both the latch and the hinge which will be discussed in detail in further sections of this report. The criteria being considered in the decision between these different options are low cost, durability, ease of installation, ease of operation, and applicability.

Driver Encasement (Bubble)

Several simulations will be performed on proposed design shapes to see which will provide the highest performance while remaining economical. The geometries used for the simulations will range from spherical to airfoil shape. This is due to the fact that a spherical shape is the most simplified form and easiest to calculate as well as being easier to manufacture, while an air foil shape is the most ideal aerodynamic geometry but may be hard to implement as a bubble in the required parameters. The final design will most likely be in the middle at a point where the form and function are both at local maximums. Material selection has yet to be determined but it will be similar to the polycarbonate beads used in motorcycle visors so as to be shatter resistant while maintaining a high level of clarity.

The bubble will complete the top of the vehicle and will protect the driver and electrical components from the outside environment. Also, the design of the bubble will be as aerodynamic as possible to reduce the drag force as well as being able to meet our dimensional constraints to leave enough space for the solar panels on the top. The bubble will be made of shatter proof polycarbonate plastic. If possible we would like to have the bubble made from a Solar Control Gray colored polycarbonate plastic. This type of color on the material will be make the inside of the car cooler because it blocks more UV and IR wavelengths, which would help us control the temperature inside the car a little easier.

The design for the bubble has been modeled in Pro-Engineer and simulated in Comsol to calculate the air flow over its surface in order to reduce the force experienced due to drag. There have been three-dimensional simulations performed in Comsol of the air flow for the bubble design as well as for simple geometries such as a sphere, to compare the results and confirm that our model has a reduced drag force. The simulations in Comsol were set at a constant speed of 20 meters per second, which is approximately 45 miles per hour. The design of the bubble is compared to the air flow around a sphere to evaluate how aerodynamic our design is to a simple sphere shape. The drag coefficient of a sphere is 0.50 for laminar flow, which is what the simulations in Comsol have been run as, while the calculated drag coefficient of the designed model of the bubble is approximately 0.15. This is a significant drop in the force that will be seen by the bubble as the vehicle is moving at 45 miles per hour.

There have been other designs of the bubble that were made but are less likely to be used even though they are most likely more aerodynamic. The main drawbacks to those designs are that the dimensions of these designs would not be able to fit around the seat of the car and the driver's would not have space to move around. There is an example of one of these designs along with a two dimensional analysis of the air flow in the figure below. Another important component of the bubble is its attachment to the car. The process to attach the bubble would be to attach a small channel around the inside of the square cutout on the top so that the base of the bubble will be able to slide in and be bolted on so that it can be secured to something rigid.

The material for the bubble that was ordered and delivered was a sheet of polycarbonate. However, upon visiting a local custom plastic shaper it was determined that shaping polycarbonate could be quite costly and near impossible. Additional research is being performed to determine whether the group can utilize the polycarbonate that has been ordered in a different way (i.e. Cutting it into the shape desired versus molding it), if a pre-made "teardrop canopy" can be ordered, or if the local plastic shaper can make a similar bubble design out of Plexiglas or fiberglass which then the group can add a shatter-resistant coating on top.

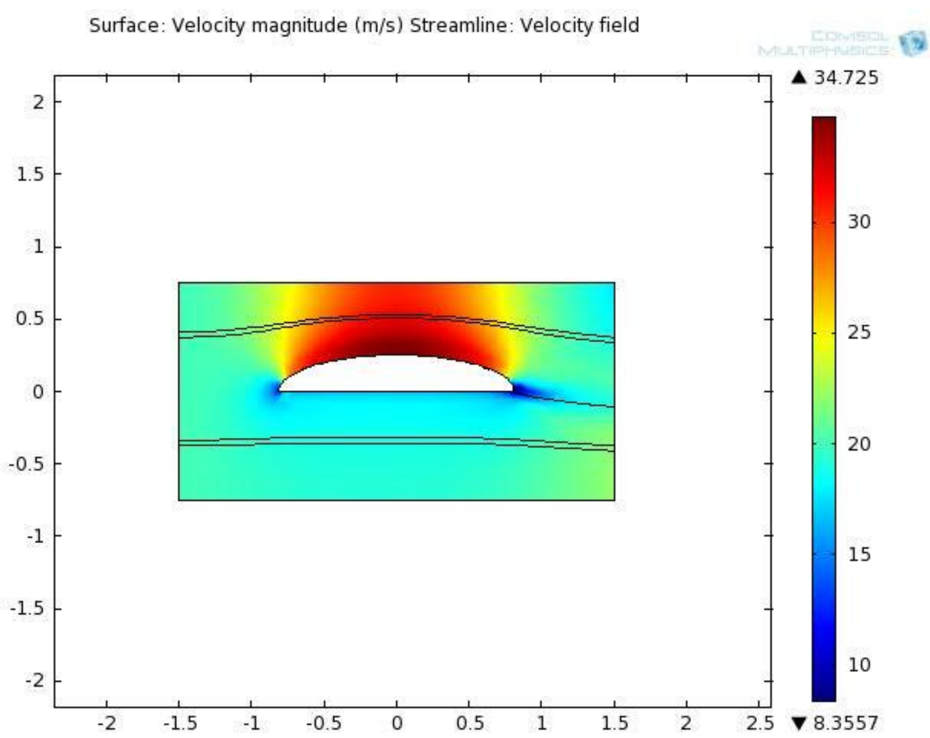


Figure 10 - COMSOL simulation of airflow over one of the proposed bubble designs.

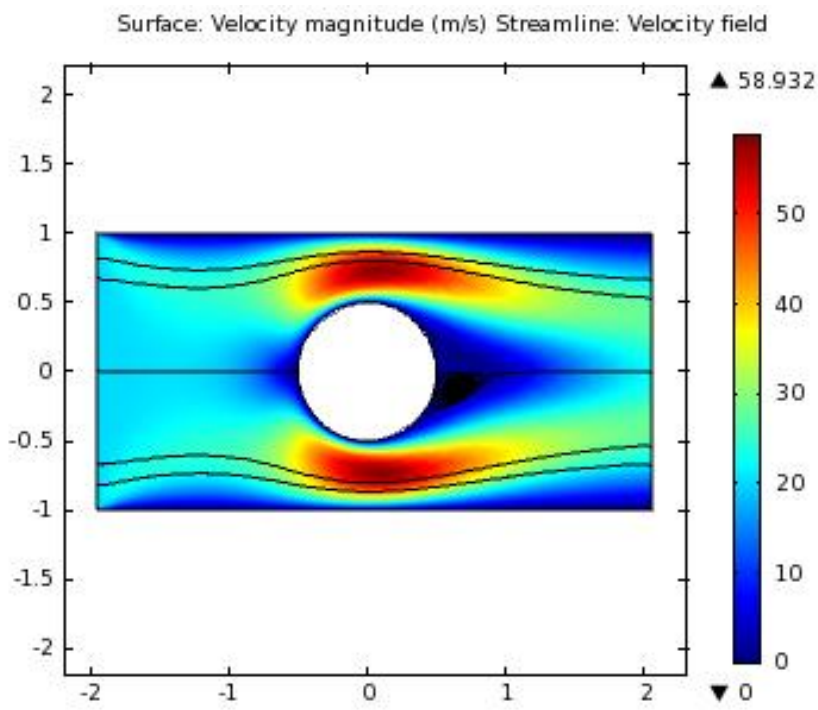


Figure 11 - COMSOL simulation of airflow over a cylinder.

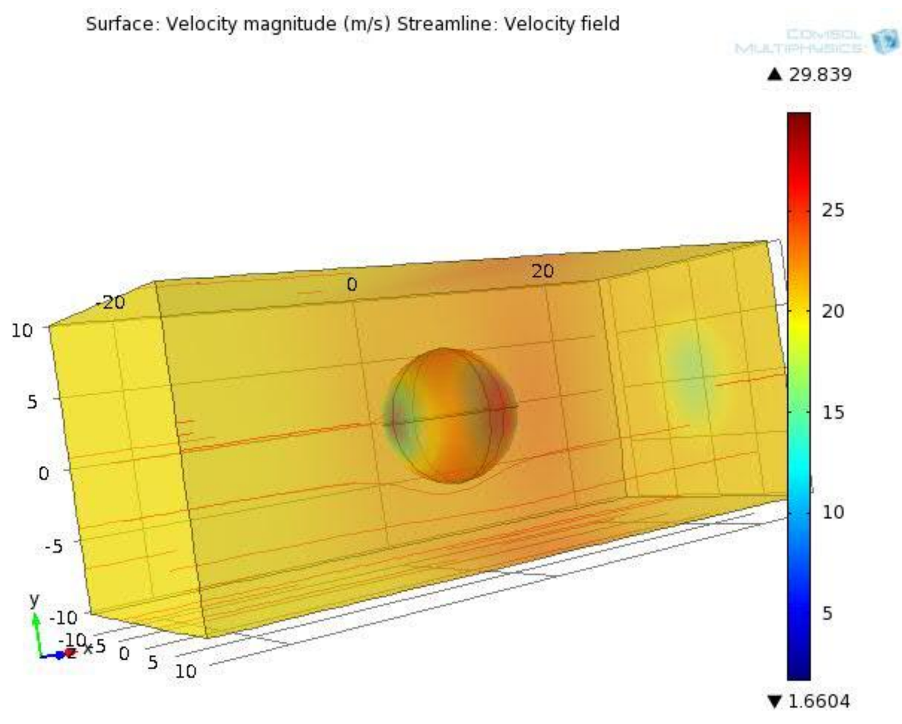


Figure 12 - COMSOL simulation of airflow over a sphere.

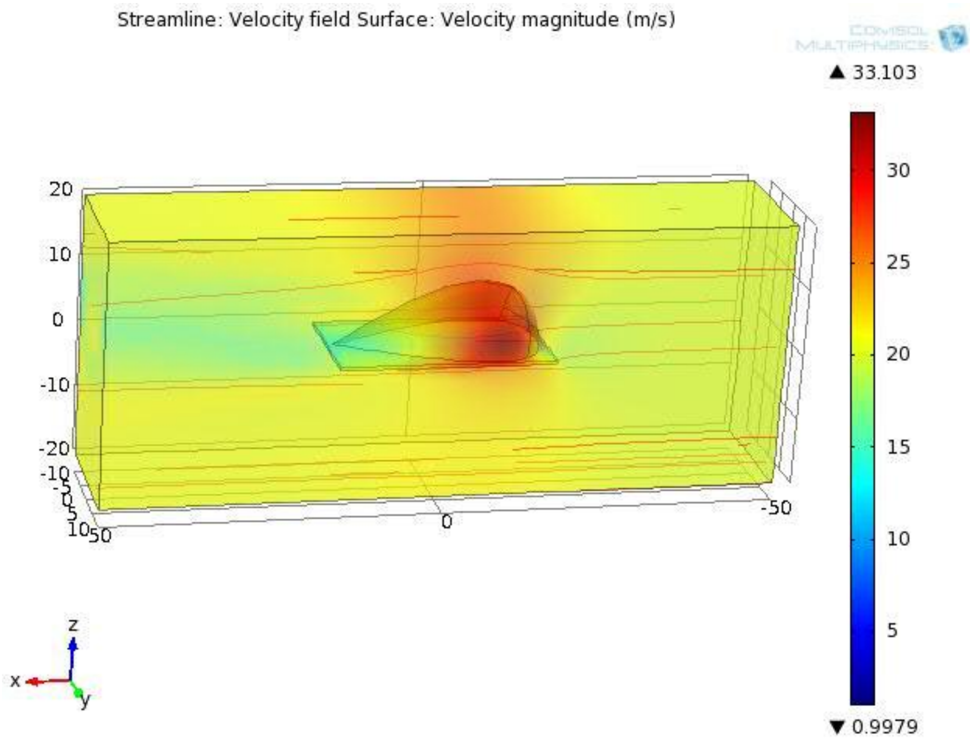


Figure 13 - COMSOL simulation of airflow over one of the proposed bubble designs.

Air Ventilation

Two main goals were kept in mind when determining the optimum air ventilation system. The team wanted something that would draw very little, if any power at all, from the system and that would be as lightweight as possible. Another goal was to keep alterations to the body as minimal as possible. The temperature within the car must stay below 95°F to keep the driver and electronics functioning properly.

The major component for the air ventilation was to be a 10 ½ inch wide solar powered air vent. It can be manually installed to ensure a watertight fit. On a full solar charge it is capable of running for 48 hours and also comes with NiHm backup batteries good for a 24 hour emergency situation. It can be mounted on any surface in a square or circle cut-out. The vent is rated to provide 1,000 cu.ft. of air flow per hour. This makes it an ideal choice for the solar car application as it is self sufficient, lightweight, and easy to install. A schematic for the airflow is shown below in Figure 12.

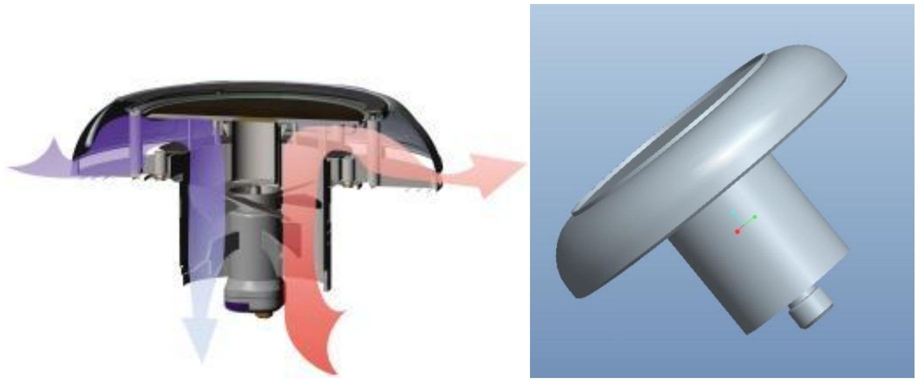


Figure 14 - Left: Cutout view of the solar vent considered. Right: Pro-Engineer model used in the initial design.

An onboard air circulation system was another concept to be implemented to keep both the driver and electronics cool. Circulation ducts made using lightweight tubing to direct airflow to certain areas of the car that most require cooling. This will be mainly to all electronics and to the driver in order to keep them within a safe operating temperature of 40˚F – 95˚F. The system would use disposable batteries so that it does not drain energy from the solar cells and decrease their efficiency. While the extra fan and batteries will add weight, the need to keep the electronics and the driver cool is extremely important.

In addition to the solar vent, a panel of small vents can be installed on either the top or side of the car. The final placement has been narrowed down to two locations and is dependent on the final solar array placement. These vents will direct airflow to the driver and main electrical components and will be most effective while the car is in motion while moving against the wind.

Solar Array

The design process for the solar array is focused first by the constraints and then adjusted within the given parameters. First concept constraint is that the panels were previously purchased and are too expensive to change. The next constraint to consider is the size of the batteries, chosen to run at 48V. Possible configurations are 2 series panels or three series panels. The next concept design made was how to install the solar panel to the car. Possible ideas considered were all adhesive that are commonly found at local hard wood stores along with solar mounting tape. The solar array has many configurations for outputting power. When deciding on solar voltage values it was necessary to consider the MPPT capabilities. The more efficient way to operate the converter is to increase the solar voltage allowing for current to the battery voltage.

Maximum Power Point Tracker

Choice of MPPT design.

In applications such as the Solar Car, it is important to maximize the power being delivered by the solar array in order to maximize the distance the car can travel for a single battery charge, and also to more quickly charge the batteries between driving sessions. This requires monitoring the current and the voltage of the PV array and adjusting them to maximize the power being delivered. For a solar array and battery combination, the design must consist of a DC-DC converter with a microcontroller adjusting the input level of the solar array that is stepped up or down to match the battery voltage. This is achieved by altering the duty cycle of the switch in the DC-DC converter, which is the parameter that dictates the magnitude of the change in DC voltage in a DC-DC converter.

The first option for completing this task was to purchase a pre-made DC-DC converter with maximum power point tracking capability. This device must be usable within a range of battery voltages and solar array voltages that may occur during the design on the electrical systems in the Solar Car. One such model is the Drivetek MPPT-Race v4.0 at a current exchange rate of 1195 U.S. dollars.

The second option for completing this task was to custom build a DC-DC converter to fit within the parameters of the rest of the Solar Car's electrical system and use a microcontroller to control the duty of the converter.

Choice of MPPT algorithm.

There are two common algorithms for maximum power tracking. The Perturb and observe method involves periodically perturbating and comparing the terminal voltage to its previous value. If the power of the previous data point is not equal to that of the current data point, the voltage is compared to its previous value and an adjustment in duty cycle is made accordingly. The flowchart for the perturb and observe control algorithm is found in Figure 18.

A second method for tracking the maximum power point is the Incremental and Conductance method. This method involves comparing the derivative of the power curve with respect to voltage to zero. If the derivative is positive then the current point is on the left of the max power point on the V-P curve and the duty cycle is adjusted up. If the derivative is negative then the current point is on the right of the max power point on the V-P curve and the duty cycle is adjusted down. The flowchart for this algorithm is shown in Figure 19.

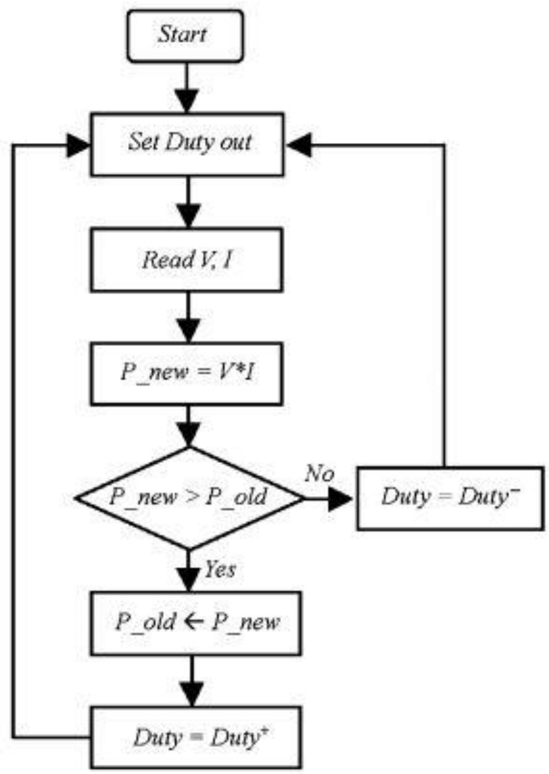


Figure 15 - P&O algorithm flowchart.

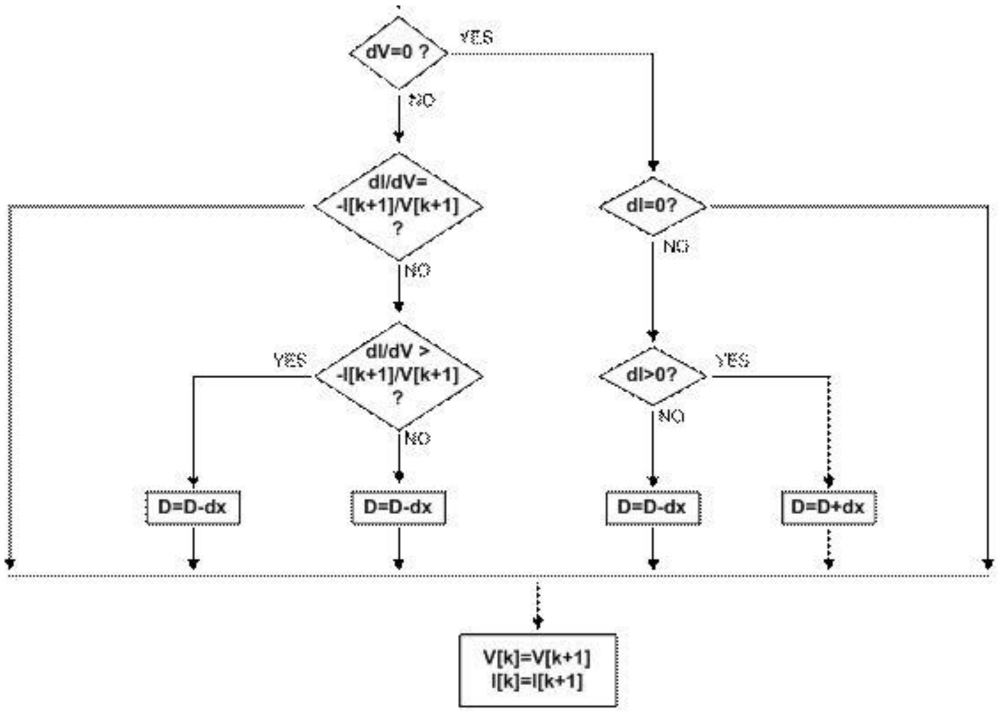


Figure 16 - Incremental and Conductance algorithm flowchart.

Batteries

At the start of the project the battery voltage was set at 96V. After the team decided the motor could not be reused the group had several different battery configurations to choose from 72V, 60V, 48V and, 24V. The most common motor configurations are 96V, 48V and, 24V. With the motor that was previously stated a 48V battery system was the best choice not only because it was the easiest to implement but at 48V the team could split the batteries and supply 30A which with the 4 to 1 gear ratio chosen could give more than enough torque to overcome the stall torque needed to propel the vehicle in a given direction. The batteries can also be charged within 8 hr, with this given parameters this gives the team an approximate drive range with in 24 Hrs of about 400 Miles at a speed of approximately 40 miles per hour two stops to charge the batteries from 50% capacity to 85% capacity.

IV. Final Concept

Motor and Motor Controller

The motor (LEM200-127) is a 48 volt rated motor. We choose this motor due to its relative efficiency given the cost of the motor. At $1,750, the Lemco lynch motor is roughly an eight of the price of the motor previously used. However, this motor carries several setbacks for the team, aside from a decrease in efficiency, the entire rear arm suspension had to be redesigned due to the specifications of the new motor. The rated efficiency of the Lemco motor that was purchased is 88% at peak efficiency. However, this is a moot number because we will never be providing the motor enough current to reach the peak efficiency of the motor. This motor is rated at 215 amps and in peak conditions our system will only be able to output 35-30 amps. However, we do not want to discourage the reader, at 30 amps in the right conditions the vehicle will be capable of traveling at a rate of 40 mph. It should be noted that the lack of efficiency is directly proportional to the funds allocated for the motor. The motor was mounted to the rear suspension and connected to the rear wheel via belt drive with a 3:1 gear ratio for maximum torque at startup.

The motor controller chosen was the Kelly Motor Controller (KDZ48201) with an input of 48V. The Kelly Motor Controller was chosen not only for its compatibility with the LEM200-127 motor but also because of its ability to utilize regenerative breaking. To avoid giving the motor controller an excess amount of current upon start up, the engineers have designed a pre-charge circuit consisting of a large resistor that prevents the motor controller from receiving an excess amount of current. The motor controller is used as a middle man between the batteries and the motor. The motor controller uses reads the potentiometers in the foot pedals at a voltage range from 0-5V and infers how much voltage to provide the motor. The brake pedal works the same way with an exception. The brake pedal has a switch installed on it, when the pedal is pressed, a circuit is closed that tells the motor controller to use the motor as a generator. Because electrical motors and electrical generators are essentially the same machinery, the motor controller is capable of using the electrical energy generated as the motor turns and feeding that power back to the batteries.

The motor chosen to replace the previously used SCM-150 and its controller is the Lynch Motor Company model LEM200-127 DC brushed motor and the Kelly Controller KDZ48201. This choice was made due to the unrealistic cost of replacing the SCM-150 at $16,000. The

LEM200-127 fit within the constraints of the existing system with some minor modifications. For example, the previous battery array consisted of thirty 3.3V $LiFePO_4$ batteries in series for a nominal voltage of 99 V. This has been changed to an array consisting of two-parallel, fifteen in series batteries for a nominal voltage of 48V. This works because the controller is essentially a buck converter and the nominal voltage of the motor is 48V. The motor controller has built in regenerative braking controls and will be controlled by the existing accelerator and brake pedals. It can be shown that at 100% duty cycle of a boost converter, the output will receive close to the full input voltage from the batteries and at 0% duty cycle it will receive zero voltage. This allows for a direct voltage control of the DC motor with a linear input from the accelerator. This portion of the project requires very little design work and all decisions to purchase these parts were weighted most heavily by cost effectiveness.

Figure 17 - Left: LEM200-127 DC brushed motor. Right: Kelly controller KDZ48201

Solar Array

The solar array is mounted to the upper surface of the vehicle and wired beneath the shell with by-pass and protection diodes. The modules were mounted with spray adhesive and solar mounting tape. Each tab of the modules has been color coded for ease of installation. There are 31 parallel-paired modules in the array string, supplying 30.8 rated volts at 6.2 rated amps.

The solar car utilizes the PT15-300 solar module with a voltage rating of 15.4V and 200mA rated current. Test on all modules were completed and can be seen in Table 4. The available space on the solar car only allowed for 62 modules to mount properly and still leave space for a driver enclose and hood scoop. 62 modules use a total of 4.5m^2 of solar cells. The solar module measurements can be seen in Figure 23. Solar race rules allow for 6m^2 allowing for the team to mount up to 20 additional modules that could be attached at stops to the dc bus allowing for faster charging. The modules are paired up and parallel stringed to deliver 191W of rated power without the added panels. The additional modules would bring the array's rated power up to 253W. The solar panels consisting of two modules each share a printed circuit board consisting of three diodes. The diodes were chosen to provide protection to the solar array and were sized accordingly. Two diodes will be used to solve partial shading and loss of delivered power and the third diode will serve as a protection diode for the unwanted flow of current back into the modules. The solar module diode schematic can be seen in Figure 21.

The team has mounted the modules in the most efficient space saving pattern while allowing ample room for the bubble to fit within. The design of module placement and drill hole placement can be seen in Figure 24. The array mounting was accomplished by stringing strips of modules in rows and marking out a path placement for all the modules. The modules have been label color coded in order to successfully place correctly for wiring. The placement of the modules and their color-coded position can be seen in Figures and 25, 26, and 28. The mounting was accomplished using spray adhesive and solar mounting tape, which can be viewed in Figure 27, and approved by solar race regulations. The team has left it up to the next year's team to put a final protective layer over the car to stop potential damage to the modules. The solar module tabs were color-coded so when wiring from underneath there will be less chance of wiring incorrectly. The color-coded tabs are seen in Figure 25 and make diode wiring efficient. This decision was also made so that next year's engineers could easily discern the wiring and make it possible for quick replacement of modules that are under performing. The final completion of solar module placement was implemented and can be seen in Figure 29.

The printed circuit board designs have been finalized and have been fabricated by Donte Ford. The diodes used will be Schottky barrier rectifiers that can handle a maximum of 80V and 10A. The diodes have been installed onto the board. The circuit boards have been wired with color-coded wires. The circuit boards have been installed into the car and wire has been run from the board to the dc bus bar. The wires are connected to the rails and rails mounted to car. The bus rails have a positive and negative wire that lead to a control switch through a test board and then to the MPPT. Testing and retesting of the entire PV system has been compared to the simulation and verifies the power output is within expected Watt range.

The team has the solar array and MPPT in simulation on Matlab using the Simulink software. The simulation components can be viewed in Figures 30 and 31. Testing of the simulation has been completed. The simulation allowed for the team to input measured data from tesing and input those data points along with different irradiation levels that can be seen in Figure 32. This graphical representation of the measured data shows that in normal insolation in the Tallahassee area, which is 700-1000 kW/m^2 of irradiation, the solar car will be able to charge the batteries with the expected power from the Max power point tracker.

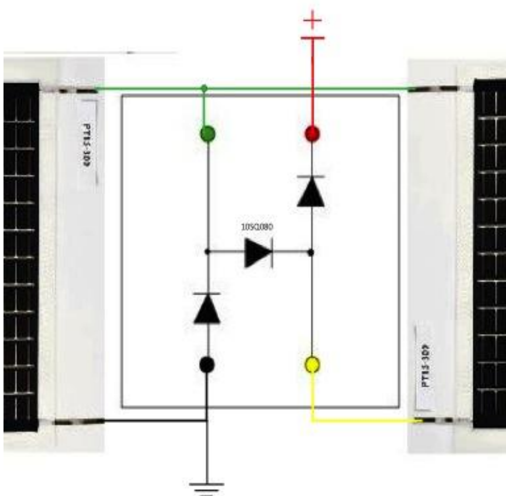


Figure 18 - Module diode schematic.

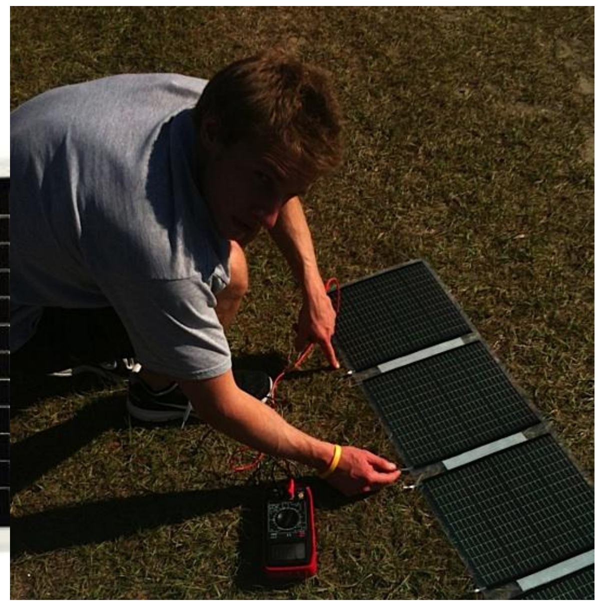


Figure 19 - Solar module testing.

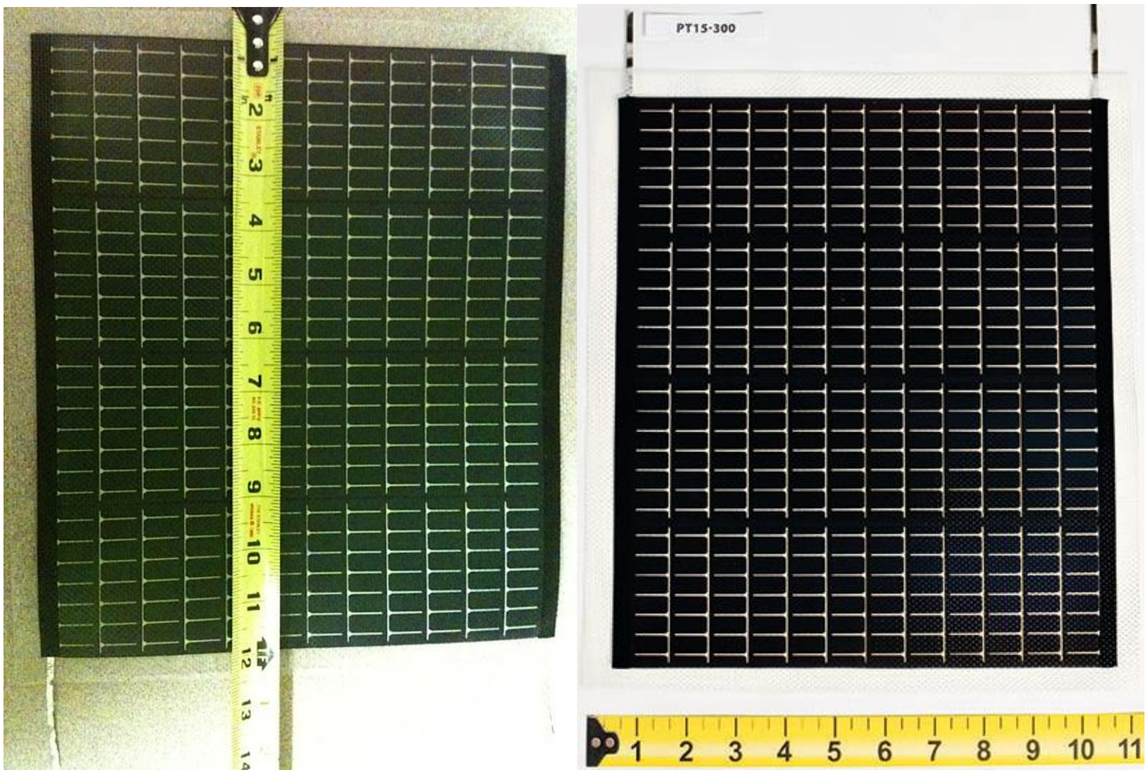


Figure 20 - Solar module measurements.

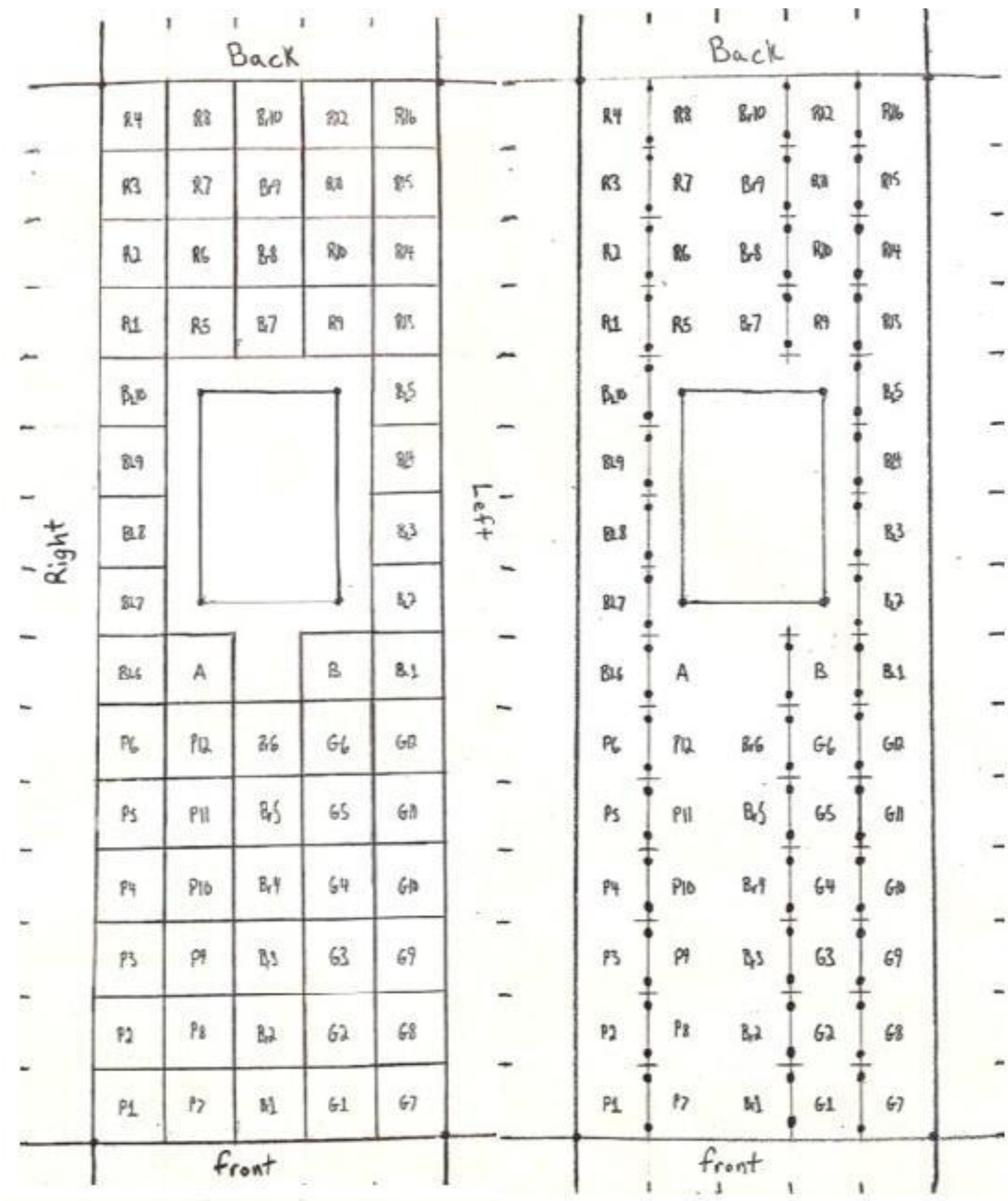


Figure 21 - Solar module position and drill hole placement for solar array.

Figure 22 - Implementation of design for position and drill holes.

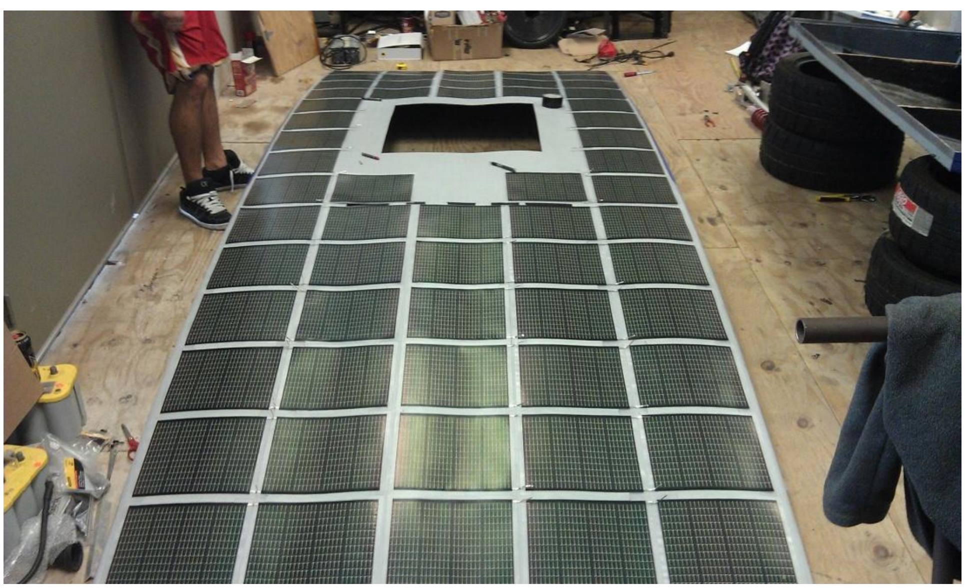


Figure 23 - Implementation of design placement.

Figure 24 - Mounting modules with spray adhesive and mounting tape (color-coded placement).

Figure 25 - Color-coded tabs for modules to be wired to diode circuit.

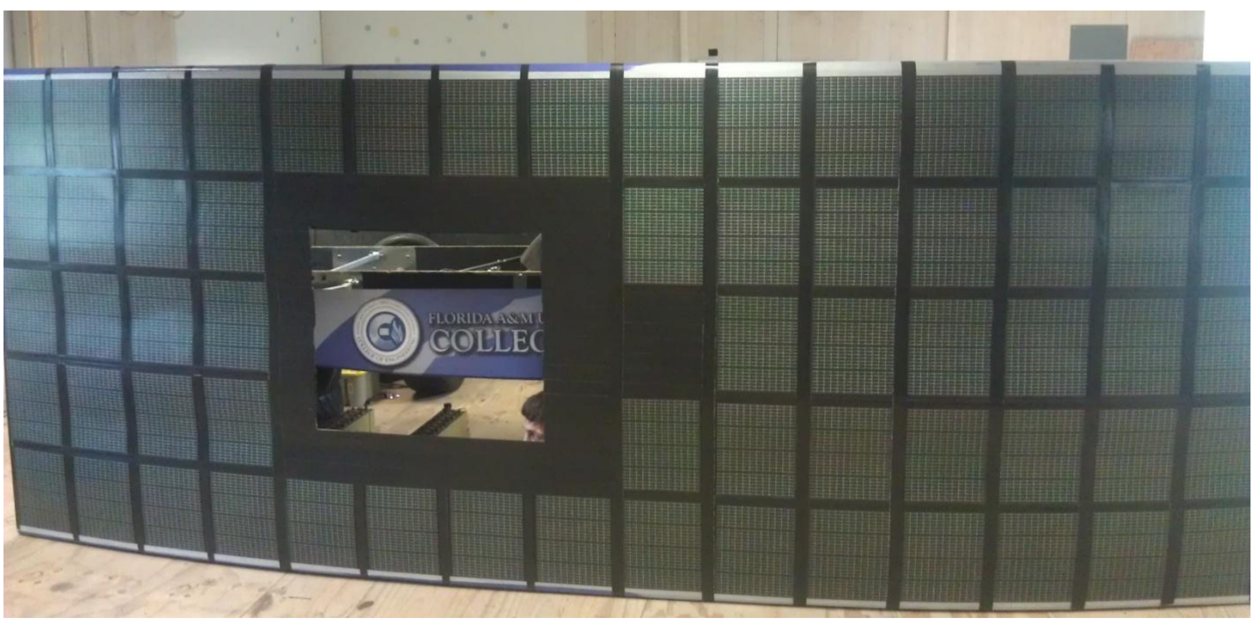


Figure 26 - Final module mount completion.

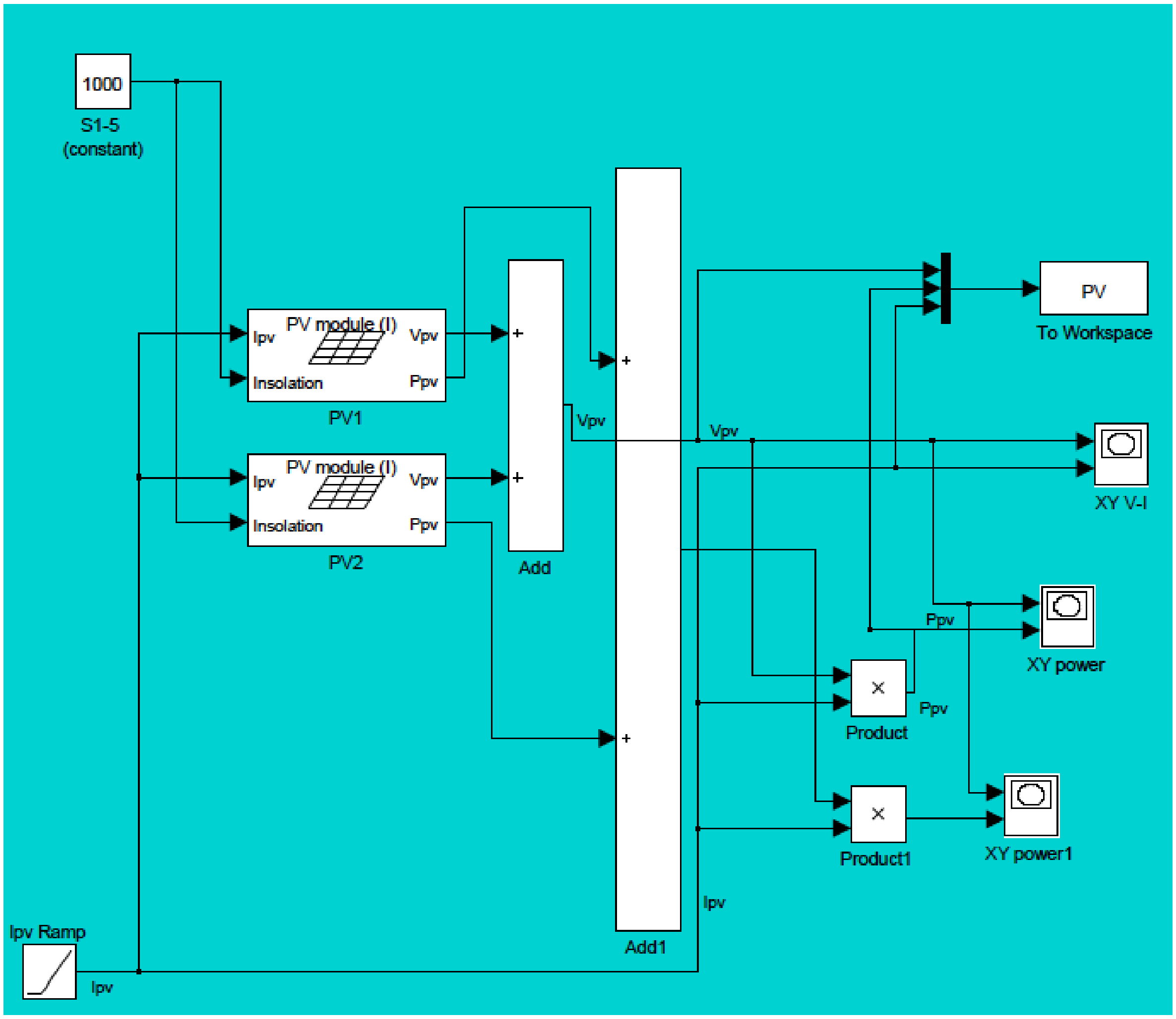


Figure 27 - Simulation for two series connected modules.

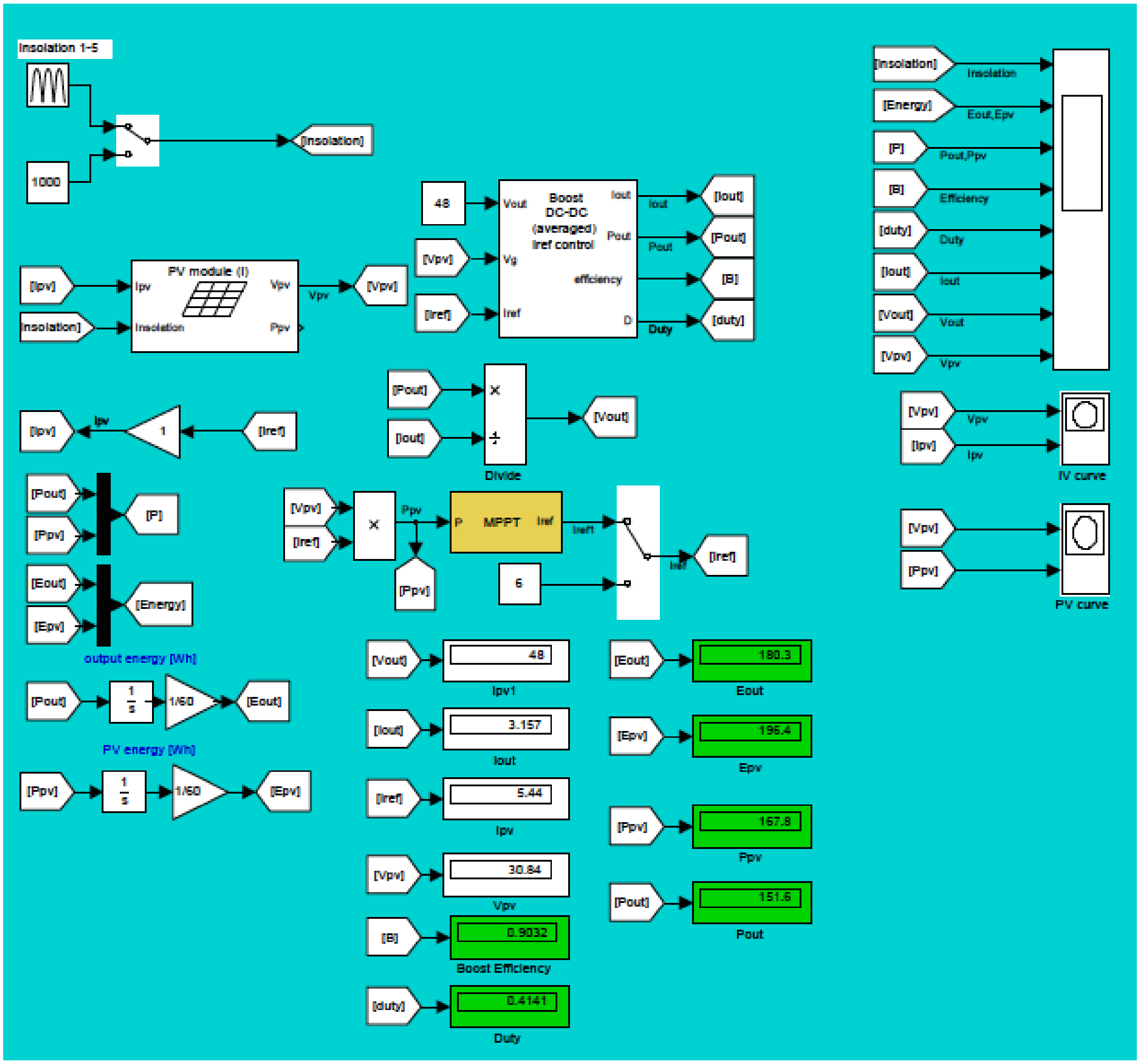


Figure 28 - Solar array simulation and MPPT tracking.

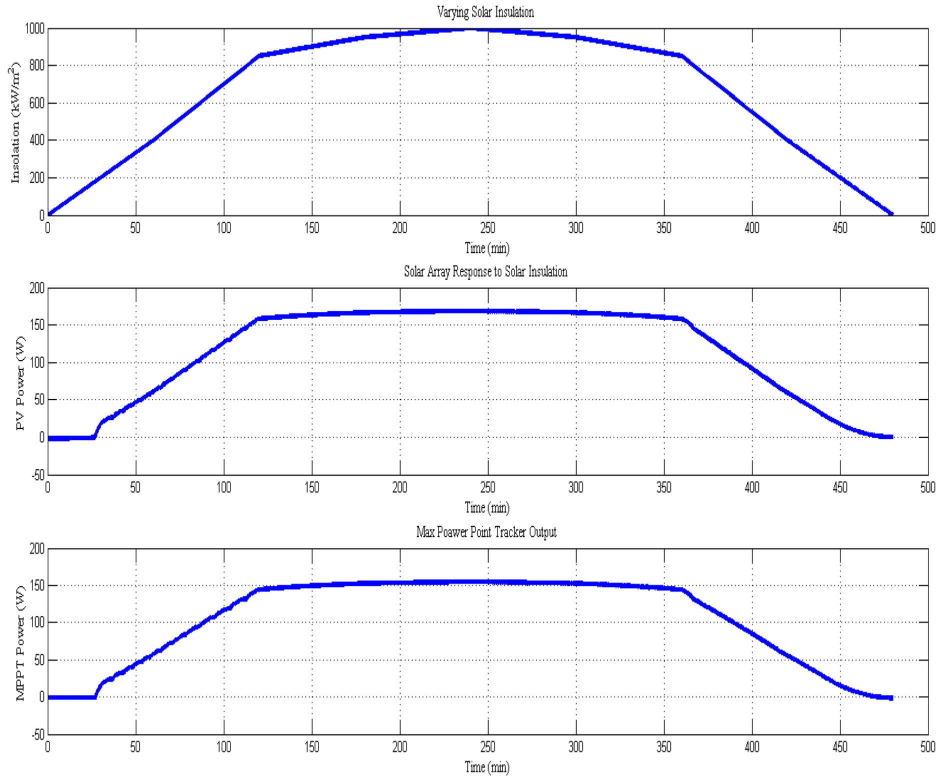


Figure 29 - Solar array testing results and MPPT tracking under varied insolation.

Maximum Power Point Tracker

Boost Converter Topology

Due to the fact that the largest constraint of the Solar Car project was budgetary, it was decided that a custom boost converter would be designed and constructed for an estimated 125 dollars. The boost converter parameters were dictated by the battery voltage and the panel voltage, which required that those components be designed prior to the boost converter.

The boost converter is used to bring the voltage of the solar array (32.4 V nominal) up to the voltage of the batteries (48 V nominal) in order to act as a dual source during operation of the solar vehicle, and to charge the batteries when the vehicle is not in use. Fig. 3.71 illustrates a typical boost converter circuit topology, including a DC input, an inductor, a switch, a diode, a capacitor, and a load.

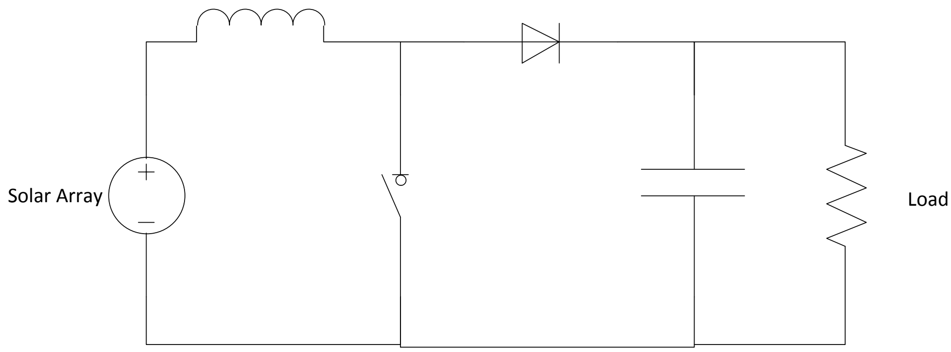


Figure 30 - Boost Converter topology.

The Boost converter was realized using a 1.8 mH inductor, rated at 15 amps with a core saturation rating of 10 amps; a NTE2394 power mosfet, rated at 100 Volts and 10 amps; a 10SQ080 diode, rated at 10 amps; a 1.5 mF capacitor, rated at 250 volts with a ripple current rating of 4 amps peak to peak.

The boost converter is controlled by the PWM from an Arduino Uno microcontroller, which also reads the voltage of the panels using a simple voltage divider, with a maximum loss of 25 mW, and the current of the panels using a current transducer which provides a maximum of 3.3 V output when reading 10 amps. The arduino board is powered by the 12 Volt auxiliary that was made available during the design of the electrical system of the Solar Car. The wiring diagram of the boost converter and the Arduino Uno is seen in Figure 34.

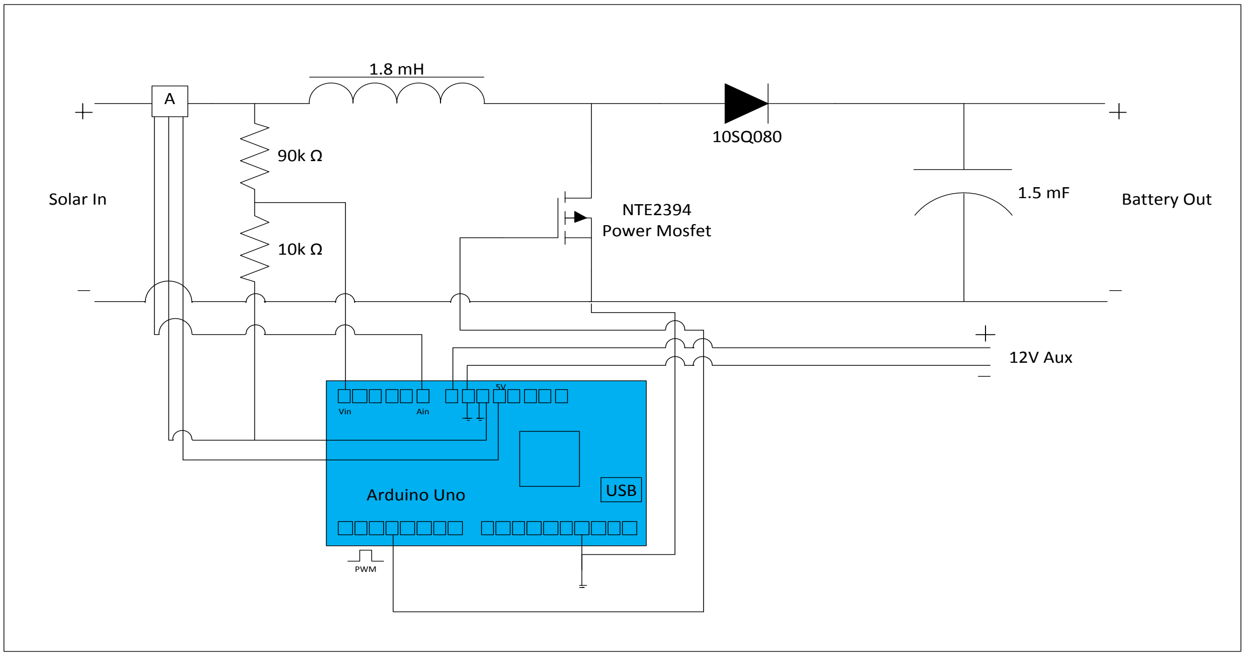


Figure 31 - Wiring diagram of boost converter and Arduino Uno.

The Arduino board utilizes a simple perturb and disturb algorithm that calculates the current power output of the panels and compares it to the previous power output. If the current output is the same or lower than the previous output the duty cycle is lowered by approximately 1%, if the current output is higher the duty cycle is increased. This cycle continues indefinitely and is capable of oscillating around the actual maximum power output of the solar array. The perturb and observe control algorithm was chosen for its ease of implementation and its ability to operate without regard to degradation within the solar array.

Figure 35 provides a picture of the final construction of the boost converter and controller. The components were placed onto a prototyping board and standoffs were used to mount the Arduino Uno and the boost converter to a non-conductive base board. All of the components were housed within an aluminum casing complete with cooling fans which are powered by the 12 Volt auxiliary power from the electrical system.

Figure 32 - Final construction of boost converter and controller

Rear Suspension and Drivetrain

The final design of the rear arm was modified to lighten the weight of the arm and also allow for easier machining by the machine shop at the college. The final design of the rear arm consists of one inch by one inch square aluminum tubing with a thickness of 0.125 inches, similar to the frame of the previous arm. The main changes are the two by one inch aluminum tubing pieces that create a raised surface attach the motor to the arm and to allow clearance for the wheel and shock to. Two pieces of square aluminum tubing, the same size and thickness as the frame of the arm, are welded across the width of the arm so that the motor bracket can be secured in a position that aligns the gear and sprocket. Also, two 0.25” thick plates 8 inches in length have been welded to the ends of the tubing to allow a 1 inch shaft to slide through the entire assembly of the wheel. Spacers will be used to keep the wheel assembly from any lateral motion. Finally, instead of adjusting the distance of the wheel to keep tension in the chain another gear will be added and attached to the arm to maintain the tension.

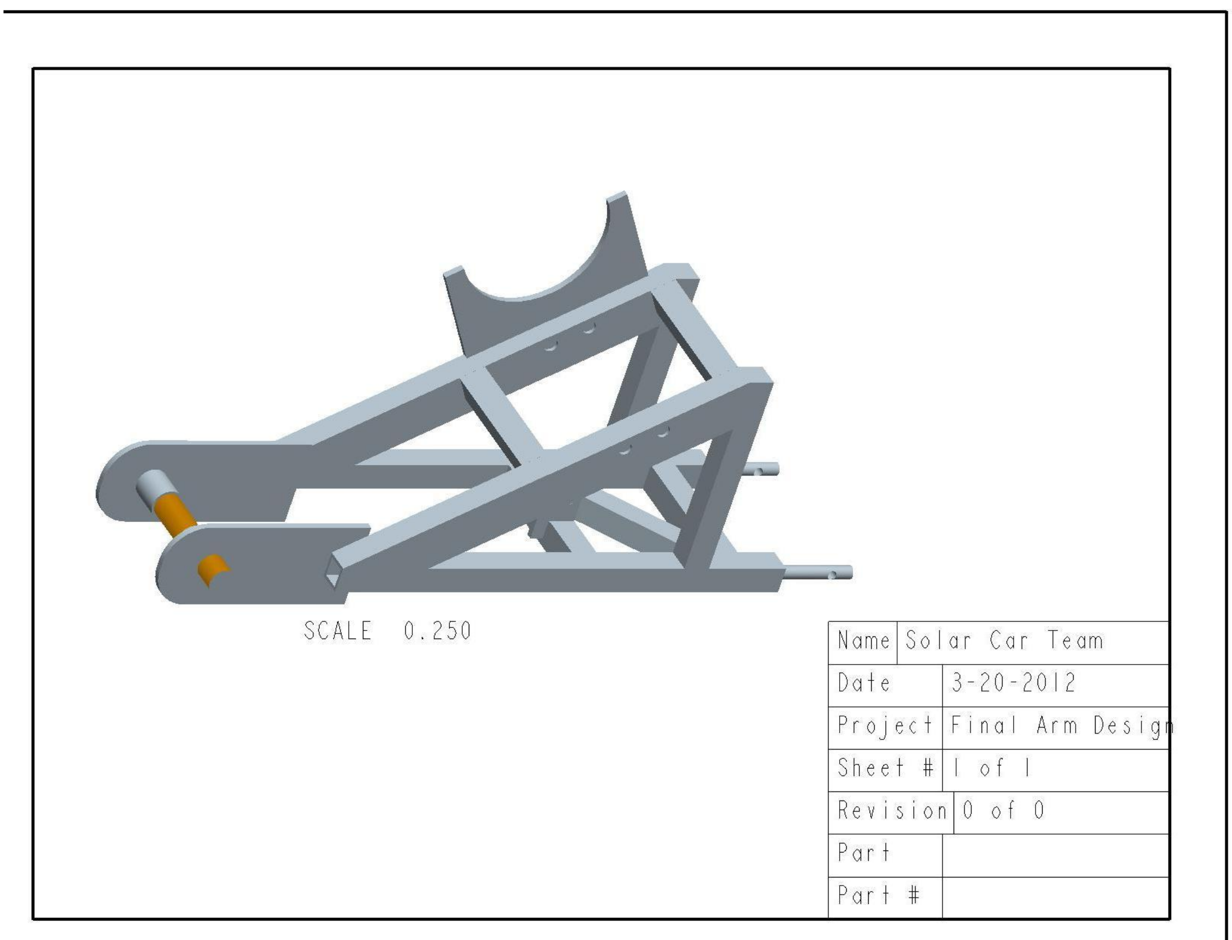


Figure 33 - Pro-Engineer model of the second rear arm design concept.

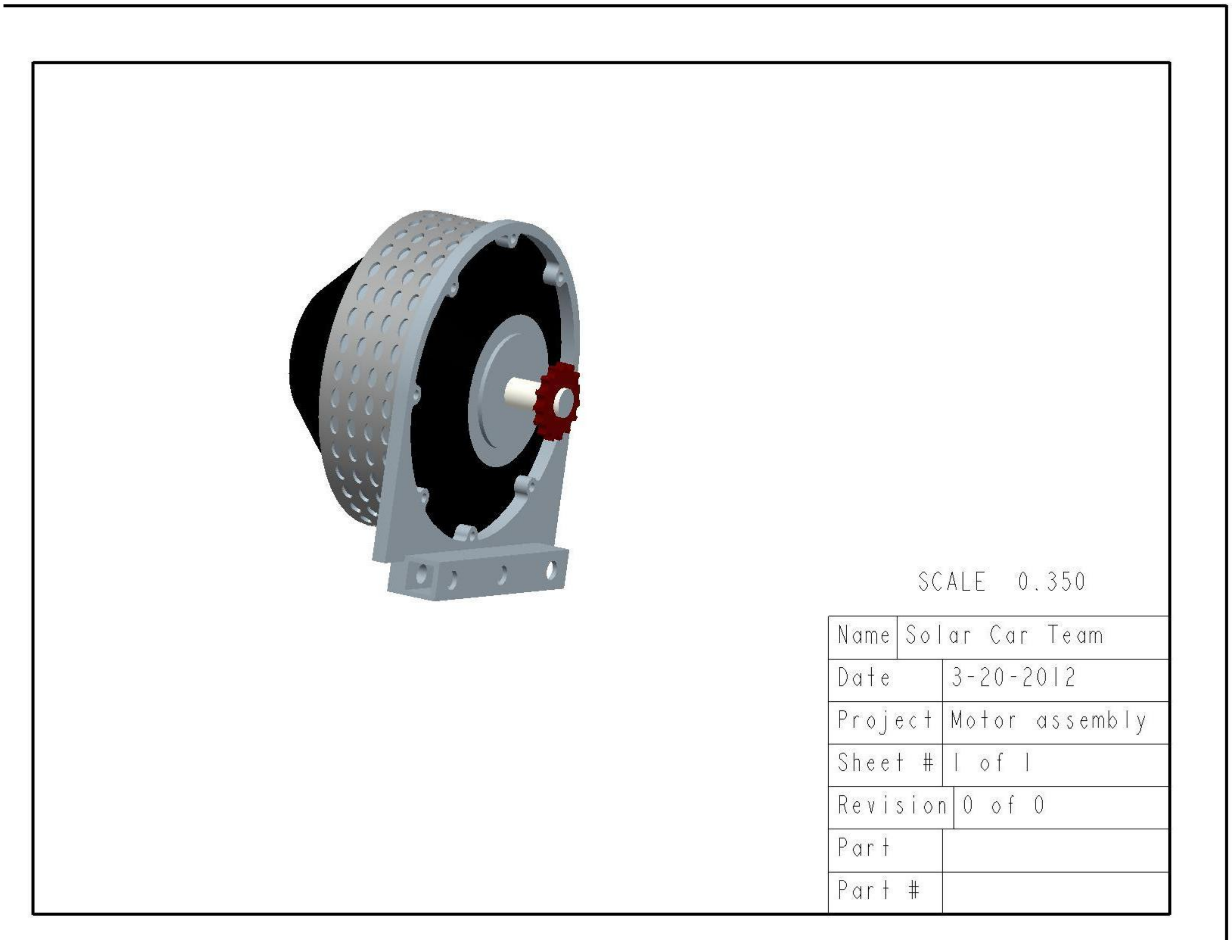


Figure 34 - Pro-Engineer model of the motor mounted on the motor bracket.

In addition to the rear arm redesign the back plate was also changed from its initial design. Instead of bolting one long bracket to the bottom of the plate to take away the rotational action that occurred in the previous arm. It was suggested that inserts be made to be welded to the plate in the same positions as the older plate. The welded bracket inserts would allow for a more similar design to the old plate, which was more desired, while taking away the rotational effects on the arm. Finally, the thickness of the plate was doubled to provide more support for the wood that is in the car that the plate is attached to.

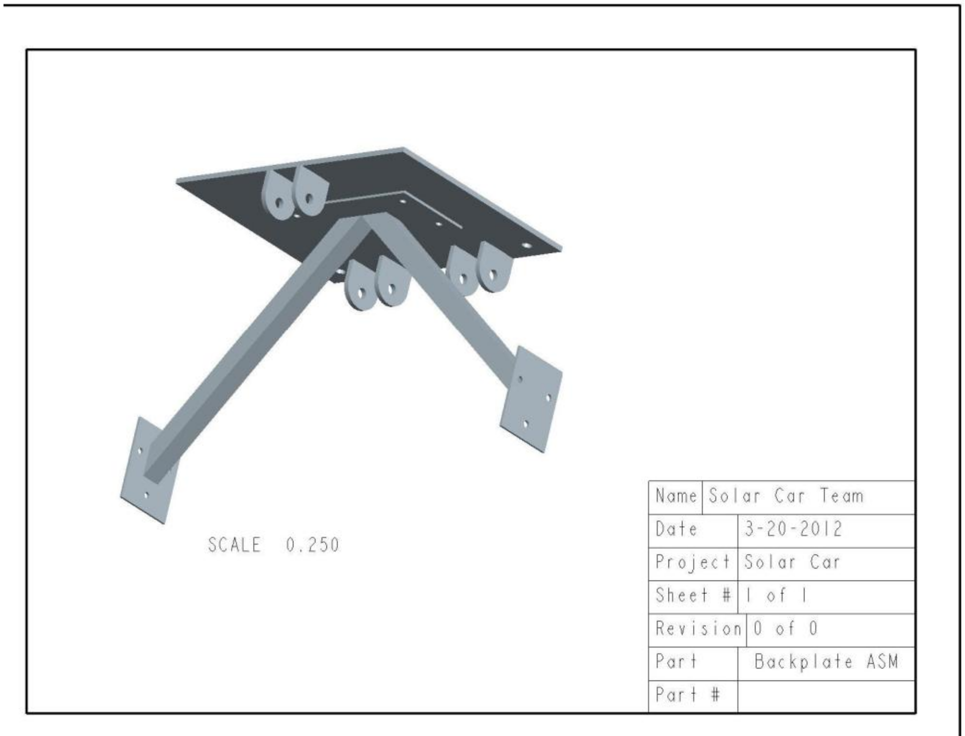


Figure 35 - Pro-Engineer model of the back plate and v-arm assembly.

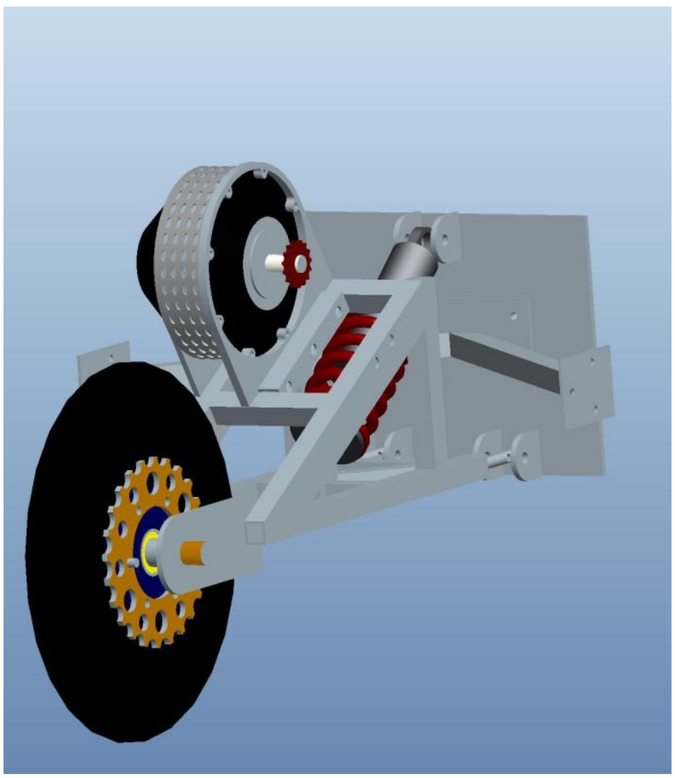


Figure 36- Pro-Engineer model of the final rear suspension design.

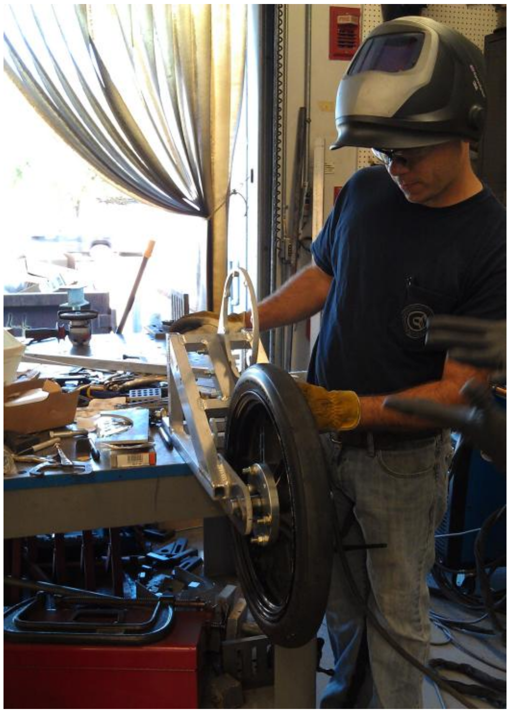


Figure 37 - Jeremy (machine shop manager) about to weld the motor bracket on the rear arm.

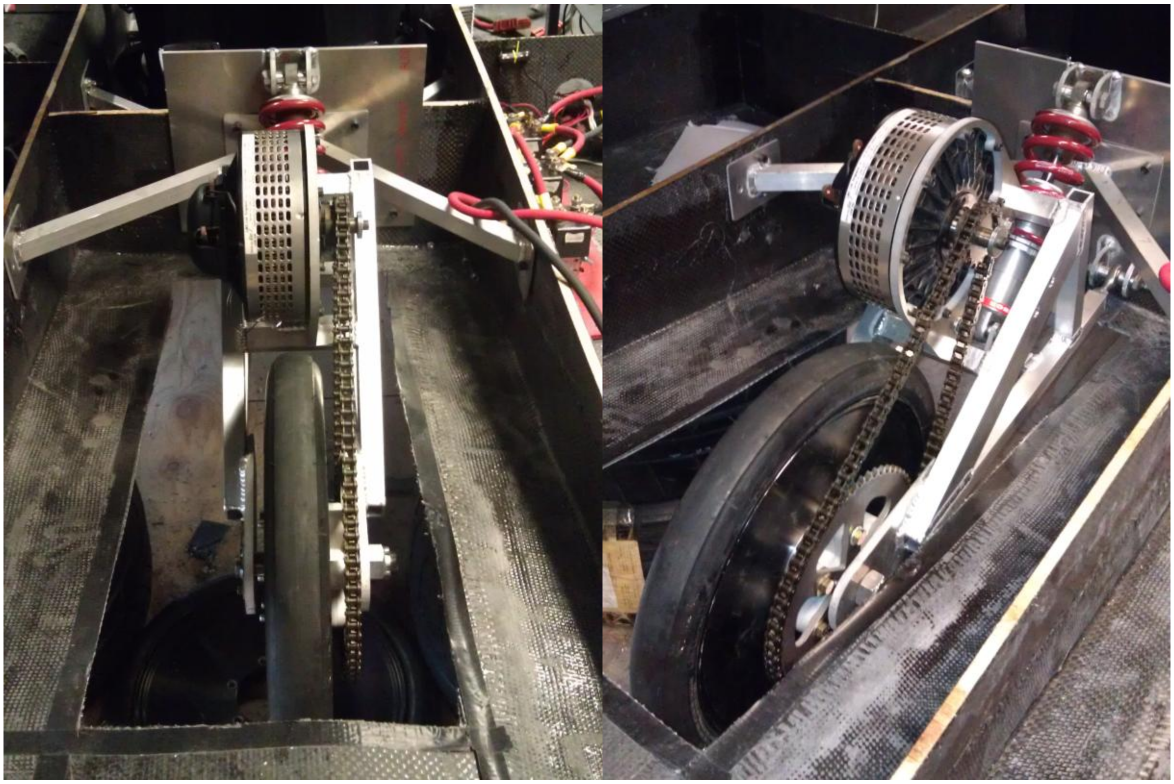


Figure 38 - Rear suspension and drivetrain mounted on the car.

Latch and Hinge System

The final design selections for the latch and hinge system were the remote release cable latch and the piano/continuous hinge based on the decision matrix calculations in Tables 1 and 2. It was determined through additional research that the piano/continuous hinge could also be customized for the length of each hinge. The decision was made to order two 4-foot long piano/continuous hinges that would be bolted on the side of each of the two halves of the car. To increase the structural integrity of the body, 1/8" aluminum L-brackets were be bolted between the body and the hinge. This will prevent any potential cracking in the body and will lessen the loading on the body during hinging. The L-brackets were also added along the rim of the top and bottom of the car in certain places to aid in their alignment due to the cutting errors made when last year's team cut the body in half.

Figure 39 - Top: Latch actuation handle. Bottom: Latch point.

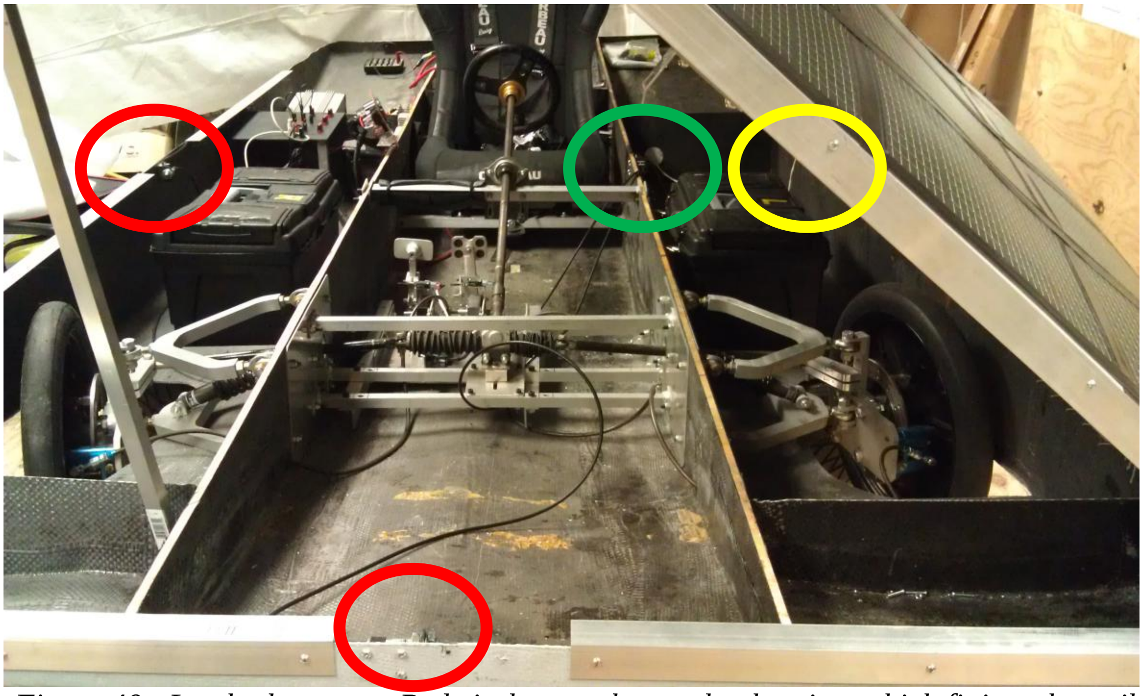


Figure 40 - Latch placement: Red circles are the two latch points which fit into the strike plates (one in yellow circle) and the green circle is the latch actuation handle. Also shown are some of the L-bracket locations on the car.

Figure 41 - Hinge placement.

Air Ventilation

The design process began with research of all of the available options. Several different types of ducts and ventilation fans were considered as well as a drastic body modification to install a hood scoop and possible channels for air flow. Below in Figure 36 is a block diagram of the ventilation system to be implemented and a design shape.

Figure 42 shows the top level diagram for the hood scoop. On the right is the first concept design shape.

The main component of the air ventilation is a hood scoop. It will be used to draw in fresh air directly onto the driver and main electrical components while the car is in motion. Using the scoop allows for zero power to be drawn from the system to operate ventilation and little if any parts to maintain. Also given the problems encountered with the old motor and insufficient budget, the lower priority components had a high desire to be cost effective. Given the scenario where these two elements will not keep the inside cool enough, a simple handheld and mountable evaporation fan will be used. These are small, lightweight, battery powered, and more than capable of keeping the small compartment of the solar car at cool enough temperature. The picture below in Figure 37 shows the placement of the hood scoop directly in front of the driver.

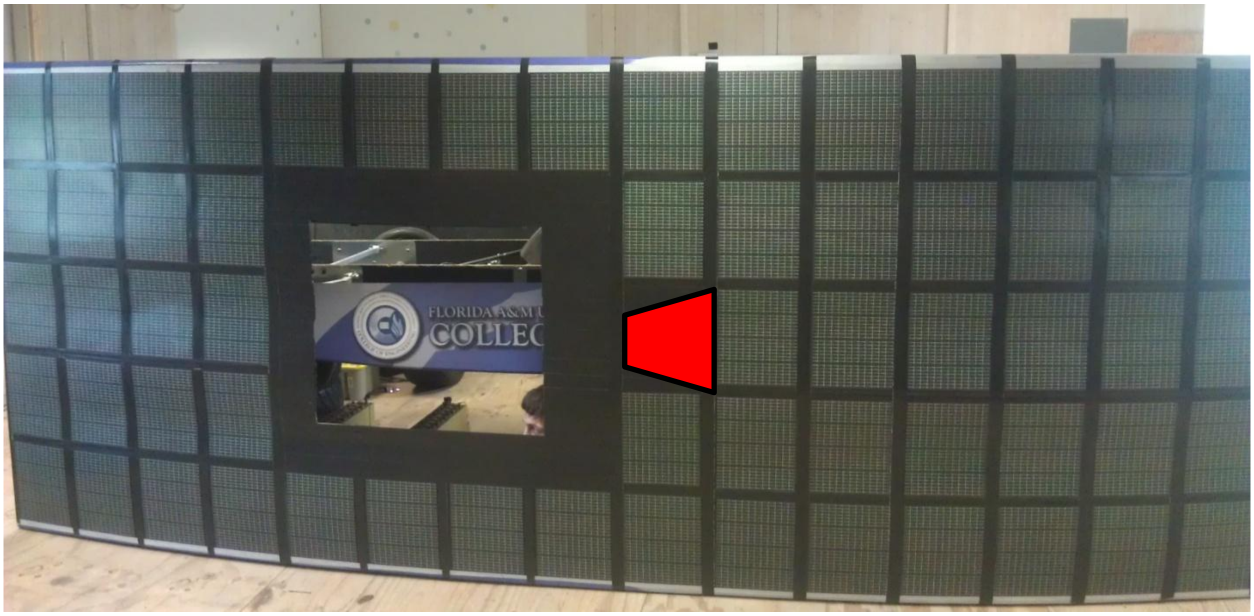


Figure 43 shows the placement that was decided upon for the hood scoop.

The hood scoop was mounted with two 6mm bolts on the front lip and 3M tape all around the base. Automotive tape was also used to seal the scoop to the frame from the bottom side. This kept any dirt from sneaking in. The scoop has a mesh screen to prevent debris from entering the cockpit and directs airflow directly onto the driver and main electrical components.

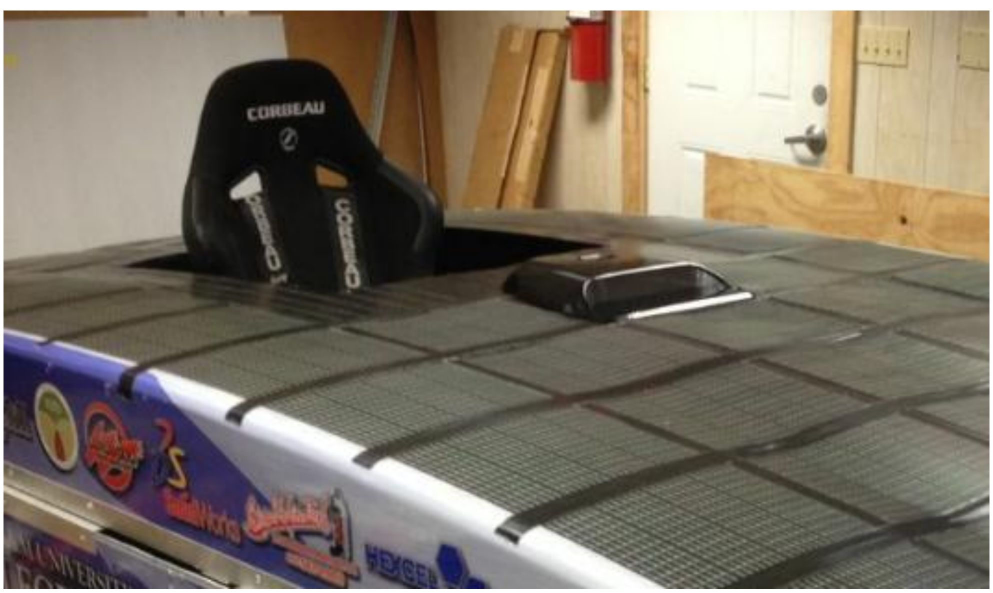


Figure 44: Hood scoop mounting.

Driver Encasement (Bubble)

The final design and manufacturing of the bubble was decided to use the bubble that was left from the previous team and modify the attachment to the vehicle. The base of the previous bubble was taken off and the dome was taken to the local plastic shop that was previously visited to form the new bubble. What was done is a 4” plexi-glass base around the circumference of the bubble. With the installation of a new seat the bubble needed to be raised about three inches so the plexi-glass base was attached to a 2”x4” piece of wood and mounted on the outer part of the car to be able to clear the seat. Finally, the wood and plexi-glass was painted black to match the outer color of the car.

Figure 45 - Bubble placement

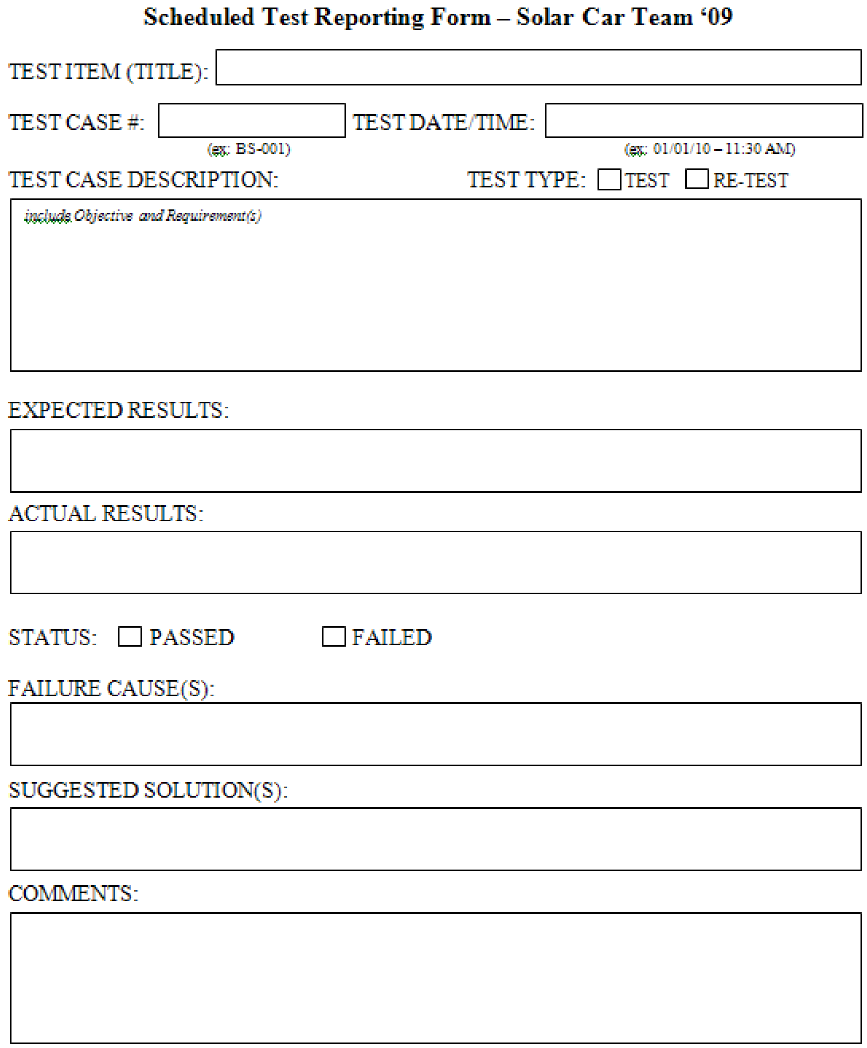
V. Engineering Economics

Sponsors		**Total**
Last year leftovers	$848	
ECE Department	$750	
Dean Perry's Office	$2,500	**$4,098**
Expenditures		
Motor, motor controller, MPPT	$2,289	
Drive-train, latch, hinge, ventilation	$1,146	
Miscellaneous	$404	**$258**

VI. Results and Discussion

Test Plan

A test plan document was created by the members of the previous phase as seen in Figure 39. In order to keep consistency this phase of the project this team will also implement the same test plan document. This template displays all the pertinent information about each test, including what is being tested, the goals of the tests, and final results. A well-organized system for testing will yield a more successful product in the end.



Scheduled Test Reporting Form – Solar Car Team '09

TEST ITEM (TITLE):

TEST CASE #: (ex: BS-001) TEST DATE/TIME: (ex: 01/01/10 – 11:30 AM)

TEST CASE DESCRIPTION: TEST TYPE: ☐ TEST ☐ RE-TEST

include Objective and Requirement(s)

EXPECTED RESULTS:

ACTUAL RESULTS:

STATUS: ☐ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS:

Figure 46 - Test plan template.

System and Integration Test Plan

Mechanical Part Integration

For streamline integration, it is imperative for part to be assembled and tested before implementation into the vehicle. Testing of all parts will be performed for fit, strength and proper performance. Each test plan will be conducted using proper documentation as per requirements. Some parts may require construction to be tested; notes will be made with an estimated test date.

Electrical Part Integration

The electrical system integration will begin with the testing of the main power system, ensuring that all of the components are thoroughly tested for correct wiring and are receiving power. The System will then be configured to operate the motor in discrete mode to verify the functionality of the motor and motor controller. After the motor has been fully tested, the motor controller will be integrated with the MCU and retested using the serial mode controls. The test plans for power generation system consists of testing the solar array system, MPPT, and the regenerative braking. The solar array system will be tested of all its series sets and parallel arrays; it will also be tested for manufacture rated open-circuit voltage and short-circuit current. The efficiency of the solar cell and isolation level of Tallahassee will be taken into account when measure these parameters. The MPPT is basically a DC: DC converter; so it will be tested for input and output voltages. The current coming from the MPPT into the battery shall be tested and measured using the state of charge device. The regenerative braking system will be tested to ensure the brake is applied when the system is asserted; it will also be tested to ensure if charge is being supplied to the battery system when the regenerative brake is asserted. Most of the testing will be performed using a digital multi-meter; care should be taken to ensure proper settings in the multi-meter before measurement.

Table 4 - Summary of test plan status

Test Name:	**(Pass / Fail) or N/A**	**Completed on/by:**
SA-01	Pass	11/12/2011
SA-02	Pass	11/14/2011
SA-03	Pass	1/15/2012
SA-04	Pass	1/31/2012
SA-05	Pass	2/4/2012
BB-01	Pass	2/15/2012
AC-01	Pass	4/1/2012
AC-02	Pass	4/1/2012
BR-01	Pass	3/28/2012
DT-01	Pass	3/21/2012
LH-01	Pass	2/15/2012
LH-02	Pass	2/17/2012
RS-01	Pass	2/15/2012

RS-02	Pass	2/15/2012
SB-01	Pass	3/28/2012
ST-01	Pass	3/28/2012
TP-01	Pass	3/28/2012
BMS-01	Pass	2/12/2012
SAS-01	Pass	2/21/2012
SAS-02	Pass	2/21/2012
MIC-01	Pass	2/18/2012
MIC-02	Pass	2/18/2012
BCP-01	Pass	2/29/2012
BPC-02	Pass	2/29/2012
BCM-01	Pass	2/29/2012
MTC-01	Pass	1/27/2012
MTC-02	Pass	3/1/2012
PB-01	Pass	1/08/2011

VII. Environment, Health, and Safety

Overall Risk Assessment

Technical Risk ME 1: Frame and Latch Stability

Description:

During operation the car can experience stresses that may have been overlooked. This could lead to a large amount of stress on a major component of the latch and hinge system. The pins holding the parts in place could potentially snap under a substantial load.

Probability: Very Low

While such a risk is possible and precautionary steps to prevent it must be taken, this type of situation has a very low chance of occurring. The materials used in this type of hardware are rated for extremely high shear stresses and should be strong enough to outperform the tasks presented to it.

Consequences: Moderate

Depending on the speed the car is traveling, the occurrence of the top lid becoming unsecure could cause significant damage. If the car is traveling at high speeds, the lid could slide off and injure the driver in the process.

Technical Risk ME 2: Air Ventilation

Description:

Taking account the high temperatures existing in Florida is always a top priority when considering the well-being of both the driver and onboard electronics. In the current design there is the potential for hot air to get trapped inside the vehicle, leading to an overall temperature increase. Overheating of the driver could lead to heat stroke and other ailments, while overheating of the electronics could melt and damage vital components.

Probability: Moderate

On some days, the temperature in North Florida can be in the 90°-100°+ range with the humidity close to or at 100%. Constant attention must be paid from the design team in these situations to ensure a safe operational temperature of the vehicle.

Consequences: Severe

If some electrical components become damaged from the heat, it could lead to increased budget costs to replace equipment and longer overlay times for accomplishing tasks. Also, if the driver experiences heat stroke in extreme heat while under operation it could potentially be fatal to the driver.

Technical Risk ME 3: Bubble Defects

Description:

A defect in the bubble could cause unforeseen accidents to occur. If it is not designed properly, it could cause an increase in the drag and decrease the overall efficiency of the vehicle. If it is not manufactured from the correct material it could crack if it is hit with debris from the road and potentially shatter in the vicinity of the face of the driver.

Probability: Low

Simulations are being conducted on the bubble to ensure the least amount of drag will be applied on the vehicle during operation to maintain the efficiency of the system. By applying the proper materials selection process and by researching respected material companies, the probability of a shatter is very low.

Consequences: Low

The effects of drag on the current bubble design should be minimal and should not have a noticeable negative effect on the airflow while moving. Given the advances in visor material technology that are present in modern manufacturing companies, the material would be more likely to crack and not shatter completely which could affect the budget and overlay times.

Technical Risk ME 4: Suspension

Description:

With the new motor arriving and an all new suspension design, precaution must be taken to ensure a secure mount and stable frame to support the motor. The motor weighs approximately 25 pounds and needs to be properly seated in the car.

Probability: Low

Problems with the existing suspension will be mitigated with a new temporary fix that is not catered to the old or new motors. This allows for a low probability of problems in the future.

Consequences: Severe

If the rear suspension is damaged or does not function properly, the car will not have a means to propel itself through the rear wheel and will have problems with stability. It is possible that it could detach or disassemble while in operation, which would lead to greater damage to the bottom of the car as well as the frame.

Technical Risk EE 5: Solar Array

Description:

Improper mounting of solar array could allow them to be exposed to the elements. This includes wind, precipitation and sun damage.

Probability: low

The chances of the vehicle being exposed to bad weather at this stage in the project are low. This is due to the vehicle being stored and only removed for testing in acceptable conditions. The vehicle in the next stage will be given a final protective layer to further protect it from potential damage.

Consequences: Moderate

In the current stage the solar modules will be held by mounting tape so that testing can be done with ease of removal for damaged modules. There would be a loss of power from the damaged modules but this is just a small technical issue that can be easily fixed.

Technical Risk EE 6: Electrical wiring

Description:

The wiring of the solar array, MPPT, motor controller, and motor are all subject to the risk of failure. The improper wiring or improper choice of wiring can cause the wires to burn up. Improper use of components outside the ranges specified within the data sheet could allow for high voltage or high currents delivered to other components in the system.

Probability: Moderate

This risk is apparent in every decision made because the replacement of a damaged component is not feasible. Since the team is well aware of the risk it is less likely to happen.

Consequences: Severe

The consequences could be severe possibly damaging all electrical components if something were to be wired incorrectly or gauged incorrectly. This would also lead to budget and scheduling risks.

Schedule Risks

There is an overabundance of risks that can affect our project which the team has grouped into several different categories illness, Delays in the delivery and ordering processes, Motor, Rear suspension, Bubble, MPPT, Regenerative braking, and Funding. All of these areas have some effect on the team's ability to meet the milestones mention in the above sections. In this section there is a brief description of the problem a scale of how likely the risk is to occur, the consequences of that risk on the project

Schedule Risk 1: Illness

Description

There is a chance that someone on the group or multiple members in the group may become ill and unable to participate with the rest of the group working on the vehicle due to his/her illness. The team member(s) would be better suited staying away from the group as to not get other members ill which could endanger the projects estimated completion time.

Probability: Very High

The probability of this schedule risk is very high due to the time frame in which this project will be completed. Being flu season members and their families will be at a high risk of illness and should not endanger other members of getting sick and should not participate working on the vehicle while them or their family member are ill

Consequences: Minor

The consequences to the project of this risk were to occur would be minimal. With all research and information gathered and well documented by each team member and placed in a central location (i.e. Dropbox or file exchange) no one member has all the information with them. This allows the project to be continued without the member present. The only major consequence is that the milestones would not be met on time and would be delayed a couple of days.

Strategy

The most useful strategy would be prevention by each team member keeping themselves in good health. In the event that that doesn't work the other team members will be able to take over the work of that individual(s) work. The team uses a system that keeps everything well documented and places at least two people of each task to help minimize the effects of this risk. In the event someone is ill the team can use the documented plan the ill team member has and the task can be delegated to another team member(s) and the task can be complete on schedule.

Schedule Risk 2: Delivery of Components

Description

With most of the necessary parts already received the chances of a schedule risk due to a late delivery is very minimal. All parts should be delivered by the end of February and thus eliminated this risk unless a component fails. There are also the possibilities that wrong parts could be sent and time would be taken to send them back and wait for the correct parts to be shipped

Probability: Low

The probability that the components that are ordered would be delayed is unlikely, most companies do well with shipping and the percentage of package loss for UPS and FedEx is around .75% and the chance that a company sends the wrong parts also has a low probability

Consequences: Moderate

The consequence of having parts shipped late or not arrive on time is hardly noticeable. There are many other parts of the vehicle that can be worked on while parts are en route. If a component is delivered that is wrong the consequences could be catastrophic depending on how the company deals with situations

Strategy

To deal with this risk the team has set up a modular approach and has multiple portions of the project that can be worked on simultaneously which would lessen the impact on the project until the parts arrived. For missing or undelivered parts the team would have to call the company and try to get an expedited shipment of the parts or a refund and purchase the parts locally but for a much higher cost if there is room in the budget for it. If not the team would have to come up with a way to implement the component without the parts ordered or simulate and design using CAD software the steps needed so that I can be implemented at a later date when the correct part arrives.

Schedule Risk 3: Motor

Description

The largest component in the vehicle to make it a vehicle is the motor. If any form of damage or usability occurs then the project could be a devastating setback for the team. With the team already dealing with this risk with the bad motor from the previous year the new motor should help limit this risk.

Probability: Low

The probability of the motor being bad or broken is very low with it being a new motor and controller extra care will be taken to ensure that proper usage of the components is used.

Consequences: Catastrophic

This would be detrimental to the projects outcome. The entire design is based around the motor and without it the vehicle becomes a solar paper weight instead of a solar car. Therefore the project would not be able to continue until the motor situation was resolved.

Strategy

The strategy to prevent this from happening is to ensure the quality of the motor on arrival and ensure that the motor is in a working condition. With safety circuit elements in place such as fuses the team will be able to ensure the safety of the motor. If there is a situation where the motor we received is wrong measurements can be taken so that when the new motor arrives the rear suspension is already built and only the bolt patters have to be drilled out. The learning curve of the new motor should be minimal because multiple members will be entrusted with learning how the motor works and how its controller is to be used.

Schedule Risk 4: Rear Suspension

Description

With the rear suspension being changed there are some risks that it might not be complete on time or be unable to be completed with the budget available. This would cause the team to not meet the major milestones that have been set and delay the usage and final testing of the vehicle.

Probability: Low

The likely hood of this affecting our schedule is low because we can reuse the old rear suspension if absolutely necessary and the designs for the suspension have already been made. The only steps left are to get all the parts machined with accurate dimensions of the motor and find out how to install the component into the vehicle.

Consequences: Moderate

Without having a rebuilt and redesigned rear suspension the team could be forced to adapt the old suspension to work with the new motor and system. This could cause delays because the mechanical engineers would have to go back and almost completely redesign the suspension using the components the team already possesses.

Strategy

The approach to this design is to simulate as many different suspension designs with as accurate of measurements the team had for the motor and space available in the car. The team is also going to send the design to the machine shop as soon as possible. This will help mitigate delays due to a large number of orders and also allow the team to review the piece and make changes if necessary.

Schedule Risk 6: MPPT

Description

One of the most vital components of the project next to the motor and PV array is the maximum power point tracking system (MPPT). Without this component the vehicle would remain a divided two part system with the solar cells and the battery/motor being separate.

Probability: Low

The probability of this component and its sub parts setting the vehicle behind is low. Mostly because of the extra care and caution the team has when deciding on the parts that are going to be used to make this major subsystem in the vehicle.

Consequences: Catastrophic

While the probability of the MPPT or its sub-components failing is low the consequences of the system does fail could be catastrophic to the outcome of the vehicle and delay the milestones that are set. If the system or its components fail the car would not be able to be a complete system and would consist of a battery and motor with solar cells that are connected to nothing. If any subsystem of the MPPT ails it could damage other portions of that system and with a strict budget could cause the design to go unfinished. Without this major component our vehicle will not be able to do anything using solar energy.

Strategy

The strategy the team has come up with to keep the probability low is to simulate, simulate, and re simulate to ensure that all the parts used to build the MPPT will work together and have no chance of failing and damaging other components. Other methods of preventing this would be to test each of the components to make sure the team isn't putting a damaged component into the vehicle.

Schedule Risk 8: Funding

Description

There is a chance that the team can't get all of the funding that was supposed to get at the start of the academic year or if the funding it have get doesn't dispersed into our account in time for the team to order the parts needed to complete the project could set the project back immensely.

Probability: Low

The team has enough funds to start the project with more funding that is guaranteed coming in the near future the only problem with that is if the finding comes later than anticipated or not at all (which is covered in the budget risk section) and most of the money that is in the works is starting to trickle in which is the reasoning for the low probability of occurrence.

Consequences: Medium

If the funding arrives late or not in time to for the team to meet the milestones that have been set the project will fall behind schedule. This would cause some of the work that had been planned to either be postponed or abandoned if deemed unnecessary to turn what the team has now into a working vehicle.

Strategy

The teams' strategy to overcome this risk includes prioritizing the components needed to make the project a success. In this case objects like the motor, rear suspension, and diodes to name a few are more important than getting tie wraps and expensive cables to save on weight. Objects like a hinge and latching system are needed for the safety and security of the driver and the equipment inside. Other methods of avoiding this risk includes using the shops at the engineering school itself to fabricate parts instead of ordering prefabricated parts as well as getting as much of the expensive equipment donated if at all possible and spending more on higher quantities would save incase components brake and would reduce last minute purchases which tend to be more costly than planned expenditures.

Budget Risks

Budget risks rank high on the teams concerns. As stated in the Executive Summery the budget currently sits at $1600. The purchasing of a new motor will consume our entire budget as it stands. At the present time the College of Engineering, FSU, and FAMU are delegating on granting the team an additional $1000-$4000. Fundraising efforts are being employed to mitigate budget risks by advertising with a promising expected return of $500-$1000 in the short term.

Budget Risk 1: Gaining additional funds

Description

The FAMU/FSU College of Engineering is deliberating on granting the solar team additional funds at Dr. Frank's request. As our budget is currently so low, this grant is a major factor in the success of this project. With the budget at $1600, The College of Engineering grant could more than double our budget. As it stands our budget is less than the cost of the new motor that necessary for the project. The team has also approached Envision Credit Union about a $500 grant as well.

Probability: Moderate

As calculated above the minimum budget needed to complete this project is just under $4,000. The current budget is only 40% of what the team will need to complete the project. That being said, this is a very high risk budget concern. Hopefully the University will take that into account when decided whether to grant this team additional funds.

Consequences: Catastrophic:

The consequences of not getting the additional funds could be catastrophic. The new motor will cost around $2,000. With our budget at $1,600, the team does not even have enough money for our first priority. If the team chose to put the funds town the remaining priorities (MPPT, latch, hinge, bubble, etc.); the team could end up having a solar car with no motor, which would be catastrophic to the cars completion this year.

Strategy

In order to mitigate this risk, The team will be trying to allocate additional funds from outside sponsors. Currently in the works are several possible small sponsorships from a few private businesses. There is a possible $500 donation from an independent bank that the solar team is working on procuring. The team is also designing a brochure for the Solar Car that can be used to gain additional sponsorship. The strategy to minimize the risk of not getting a large grant from the University to is to procure multiple smaller grants from private businesses.

Summary of Risk Status

Due to the enormity of the solar car project there are bound to be a plethora of risks involved. The budget risk is the most daunting of the anticipated risks for the project. Even though the budget is listed as a risk, at this point it is more of a certainty. The project as a whole is grossly under budget. The team is seeking donations, both material and capital, to bridge this gap in estimated costs. Luckily, the major components have already been ordered and delivered. The technical risks for the project are also very real, though not necessarily as detrimental to the completion of the project. The industrial engineering team has introduced design methodologies that have greatly increased the scope of details for the project. This expanded view has facilitated every step of the design process and will reduce the chance of missing steps. The other side of the technical risks is the injury to individuals on the solar car project. These risks can be managed with utilizing proper safety techniques, such as using proper personal protective equipment (PPE) or utilizing material safety datasheets (MSDS) when working with materials, during any fabrication or integration stages.

Finally the schedule risks are the least likely to impact the success of the project. This is largely due to the fact that there are several individuals working on this project. If one or even two members become ill it is possible that the group could divide up the work and still make steady progress towards the completion of the project. There are many risks to the success of the project.

VIII. Conclusions

This year's solar car team is proud to present the first fully operational solar car at the FAMU-FSU College of Engineering. The team was presented with several expected and unexpected obstacles, but through hard work and dedication they were able to work together to overcome these hurdles and reach their goals. All of the requirements for this year's project were met, and several extra additions were added to improve the functionality of the car. It is the team's hope that the car will be passed down to engineering students that will be willing to work hard to get the solar car into the American Solar Challenge competition in future years, and that they will have the same learning experiences that this year's team received in which they will be able to apply the knowledge and skills learned in the classroom to is a real-world engineering problem.

IX. Acknowledgements

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

- Dr. Michael Frank for administrative and technical guidance
- Dr. Chris Edrington for electrical engineering technical guidance
- Dr. Patrick Hollis for mechanical engineering technical guidance
- FAMU-FSU College of Engineering for financial contributions to the project
- The review committee including Dr. Chris Edrington, Dr. Victor DeBrunner, and Dr. Bing Kwan
- Donte Ford for fabricating printed circuit boards
- Jeremy and Dana in the machine shop for all of the work they did to help assemble the rear suspension and drivetrain.

X. Appendix

The following items can be found in the appendix section of this report:

- Test plan documents for each test corresponding to Table 3
- Engineering drawings submitted to the machine shop of some of the major components in the design of the rear suspension.

Test Plan – Solar Car Team 2011-2012

TEST ITEM (TITLE): Motor Controller

TEST CASE #: MTC-001

TEST DATE: 12/27/2012

(ex: BS-001) (ex: 01/01/12 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ■ TEST ☐ RE-TEST

In order to test the motor controller, The team will apply the required voltage and test to make sure that the motor controller turns on and initializes.
-Step one is to make sure that the lights turn on.
-step two is to make sure that the configuration tool recognizes the controller.

EXPECTED RESULTS:

The expected results for the motor controller are that the lights on the motor controller turn on and that the configuration tool recognizes the controller.

ACTUAL RESULTS:

The lights on the motor controller did turn on, and was configured to the needed settings

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS:

•

Test Plan – Solar Car Team 2011-2012

TEST ITEM (TITLE): Motor Controller

TEST CASE #: MTC-02
(ex: BS-001)

TEST DATE: 1/6/2012
(ex: 01/01/12 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ■ TEST ☐ RE-TEST

This test is to make sure the motor controller responds as is desired. The following tests will be performed:
-Accelerating
-Braking & Regenerative Braking
We want to test the motor controller when it's idling.
We want to test the motor controller at its full range from min and max braking resistance and make sure that its sufficient.

EXPECTED RESULTS:

We expect that the motor controller will idle correctly and that the motor controller will react to varying resistances on the pedal.

ACTUAL RESULTS:

Motor Controller output the proper voltages for all directions and preformed as expected

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS:

Test Plan – Solar Car Team 2011-2012

TEST ITEM (TITLE): Motor Controller

TEST CASE #: MTC-003
(ex: BS-001)

TEST DATE: 1/4/2012
(ex: 01/01/12 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ■ TEST ☐ RE-TEST

In order to test the motor controller, The team will apply the required voltage and test to make sure that the motor controller turns on and initializes.
-Step one is to make sure that the lights turn on.
-step two is to make sure that the configuration tool recognizes the controller.

EXPECTED RESULTS:

The expected results for the motor controller are that the lights on the motor controller turn on and that the configuration tool recognizes the controller.

ACTUAL RESULTS:

Motor controller was turned on successfully and programmed according to specifications

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS:

Test Plan – Solar Car Team '11

TEST ITEM (TITLE): Protection board

TEST CASE #: PB-01
(ex: BS-01)

TEST DATE/TIME: 01/08/2011 - 9:00AM
(ex: 01/01/10 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ■ TEST ☐ RE-TEST

Check all edges of circuit board for sharp edges or corners. Take multi-meter and turn dial to measure ohms. Test various points on board for resistance readings. Check that individual contact points have a resistance range of 0.3-0.5 ohms. Test that all wires posses no electrical path with any other wire or the board around it (isolated wires).

EXPECTED RESULTS:

Because there is no power switch on the MCU, it should turn on as soon as the power supply is plugged in, and should cycle power when the reset button is pressed. When the boot switch is in debug mode, the power should come on, and the LEDs should light up in a sequence from left to right. When in run mode the LEDs should light up left to right and then right to left.

ACTUAL RESULTS:

When the power was supplied to the MCU, the speaker beeps and the LEDs flashed from left to right. The Boot mode was switched to run mode and the reset button was pressed. When the reset button was pressed, the speaker beeped again and the LEDs flashed from left to right and then from right to left.

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE (S):

SUGGESTED SOLUTION (S):

COMMENTS:

The MCU can also be powered by a 9V battery connected to the external power terminals.

Test Plan – Solar Car Team 2011-2012

TEST ITEM (TITLE): Rear Suspension

TEST CASE #: RS-01
(ex: BS-001)

TEST DATE: 2/15/02 – 2PM
(ex: 01/01/12 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ■ TEST ☐ RE-TEST

Use Pro-Engineer to perform FEA of the strut with the expected loads that it will be subjected to. Also, perform actual tests of the suspension with someone operating the car.

EXPECTED RESULTS:

The strut will be able to maintain the weight of the car and driver while keeping the car at least 9 inches above the ground.

ACTUAL RESULTS:

strut was able to maintain the weight of the car and driver while keeping the car at least 9 inches above the ground

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS:

Test Plan – Solar Car Team 2011-2012

TEST ITEM (TITLE): Rear Arm

TEST CASE #: RS-02
(ex: BS-001)

TEST DATE: 2/15/02 – 2PM
(ex: 01/01/12 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ■ TEST ☐ RE-TEST

Use Pro-Engineer to perform FEA of the strut with the expected loads that it will be subjected to from the motor, driver and the car.

EXPECTED RESULTS:

The arm will be able to maintain the weight of the car, driver and motor.

ACTUAL RESULTS:

Arm maintains the weight of the vehicle driver and motor

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS:

Test Plan – Solar Car Team '12

TEST ITEM (TITLE): Solar Module Test

TEST CASE #: SA-01 (ex: BS-001)

TEST DATE/TIME: 11/12/2011 (ex: 01/01/10 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ■ TEST ☐ RE-TEST

This test is to check all 64 solar modules for Voc and Isc to land within 15-20V and 140-240mA respectively. This will ensure that all modules being used are working properly before installation on the car. The test will be conducted in clear weather mid day.

EXPECTED RESULTS:

All modules will output as specified on the data sheet.

ACTUAL RESULTS:

All modules tested within range.

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS:

Note: One module had a damaged tab. This module will be designated as an alternate.

Test Plan – Solar Car Team 2011-2012

TEST ITEM (TITLE): Protection Circuit Continuity Test

TEST CASE #: SA-02
(ex: BS-01)

TEST DATE: 1/14/12
(ex: 01/01/12 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ■ TEST ☐ RE-TEST

There are three parts to this test to be repeated for all 35 circuits:
Part 1 is to make sure that there are connections between the different nodes.
Part 2 is to make sure there is no connection between the nodes and the rest of the board.
Part 3 is to make sure there is no connection if there is any reverse current.

EXPECTED RESULTS:

Part 1: There is a connection between the nodes in forward bias
Part 2: There is no connection between any of the nodes or traces to the rest of the board.
Part 3: There is not a conncetion between the nodes in reverse bias

ACTUAL RESULTS:

Part 1: There was a connection between the nodes in forward bias for all circuits.
Part 2: There was no connection between any of the nodes or traces to the rest of the board for all circuits.
Part 3: There was not a conncetion between the nodes in reverse bias for all circuits.

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS:

Each circuit was testing multiple times to ensure there weren't any faulty or erroneous readings

Test Plan – Solar Car Team '12

TEST ITEM (TITLE): Protection Circuit Test on Single Solar Panel Set

TEST CASE #: SA-03 (ex: BS-001)

TEST DATE/TIME: 1/15/2012 (ex: 01/01/10 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ■ TEST ☐ RE-TEST

This test checks that the designed protection circuit is functional and outputs desired voltage and current for two series modules.
Part 1: Test Panel Voltage and Current with no shading.
Part 2: Test Module 1 Voltage and Current with 2 shaded.
Part 3: Test Module 2 Voltage and Current with 1 shaded.

EXPECTED RESULTS:

The design is functional and allows for partial shading of panels with out total loss of power output. Voltage will be affected by shading but current will stay the same.

ACTUAL RESULTS:

The voltage was within range showing that both modules were connected correctly and the protection circuit was designed correctly. Current readings were constant with partial shading but voltage was affected.

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS:

Note: This was tested on one protection board to analyze that the circuit was designed correctly and it would provide partial shading capabilities.

Test Plan – Solar Car Team 2011-2012

TEST ITEM (TITLE): Solar Array Test

TEST CASE #: SA-04
(ex: BS-01)

TEST DATE: 1/31/12
(ex: 01/01/12 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ■ TEST ☐ RE-TEST

There are three parts to this test to be repeated for all 31 solar arrays:
Part 1 includes testing each array for voltage in direct sunlight.
Part 2 includes testing each arrays current output in direct sunlight.
Part 3 includes partial shading current output.

EXPECTED RESULTS:

Part 1: Voltage off the array should be between 34V and 40V.
Part 2: Current output for each array should be between .2A and .3A.
Part 3: When a single module in the array is shaded the current output should not change.

ACTUAL RESULTS:

Part 1: Voltage on 30 of the arrays was in the acceptable range above
Part 2: Current output for 30 arrays was with the acceptable ranges listed above;
Part 3: Current output while a single module was shaded

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS:

Test Plan – Solar Car Team '12

TEST ITEM (TITLE): Solar Array completed bus bar test for current and voltage

TEST CASE #: SA-05
(ex: BS-001)

TEST DATE: 2/4/2012
(ex: 01/01/10 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ■ TEST ☐ RE-TEST

This test is designed to measure the total output of the array under full sunlight. The array must output within 30-40V and a current range of 6 to 8A.

EXPECTED RESULTS:

Expect to have values within range specified.

ACTUAL RESULTS:

Solar array output acceptable voltage and current values

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS:

Test Plan – Solar Car Team 2011-2012

TEST ITEM (TITLE): Solar Array current signal test

TEST CASE #: SAS-02
(ex: BS-001)

TEST DATE: 2/21/2012
(ex: 01/01/12 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ■ TEST ☐ RE-TEST

A test of the current signal of the solar array shall be performed to ensure that the voltage level does not exceed the 3V maximum of the microcontroller’s ADC at a maximum current of 15 A.

EXPECTED RESULTS:

The current signal will not exceed 3V DC

ACTUAL RESULTS:

Current signal was under 3V

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS:

Test Plan – Solar Car Team 2011-2012

TEST ITEM (TITLE): Seat/ Seat Belts

TEST CASE #: SB - 01
(ex: BS-001)

TEST DATE: 03/28/12 – 4:00 PM
(ex: 01/01/12 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ■ TEST ☐ RE-TEST

This test will determine the condition of the driver seat and test the strength of its safety belts. Since crash tests cannot be conducted, the seat will go through testing outside of the car. With it secured stationary, the seat belt and seat will be pulled and pushed testing its stability.

EXPECTED RESULTS:

The seat is in a good condition and will hold up to the abuse.

ACTUAL RESULTS:

Seat is excellent working condition

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS:

Test Plan – Solar Car Team 2011-2012

TEST ITEM (TITLE): Steering

TEST CASE #: ST-01
(ex: BS-001)

TEST DATE: 3/28/02 – 2PM
(ex: 01/01/12 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ☐ TEST ■ RE-TEST

The objective of this test is to verify the vehicle's steering capabilities. The steering system was untouched in this phase, but a re-test is desired to ensure that the car is still able to steer as desired.

EXPECTED RESULTS:

The car will be able to steer successfully around obstacles and corners during the road test.

ACTUAL RESULTS:

Car steers with an acceptable turning radius

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS:

Test Plan – Solar Car Team 2011-2012

TEST ITEM (TITLE): Tire Pressure

TEST CASE #: SB - 01
(ex: BS-001)

TEST DATE: 03/28/12 – 4:00 PM
(ex: 01/01/12 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ■ TEST ☐ RE-TEST

The test objective is to verify that the tires do not lose pressure while being used. Before and after each trial run of the car the tire pressure will be taken. If a tire is shown to be leaking it will first be subjected to repair. If the tire continues to lose pressure it will be discarded and replaced with one of the spare tires.

EXPECTED RESULTS:

The tires are not expected to cause problems once properly seated.

ACTUAL RESULTS:

Tires hold air better and deflate after 2-3 days of non operation

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS:

Test Plan – Solar Car Team 2011-2012

TEST ITEM (TITLE): Air Circulation

TEST CASE #: AC - 02
(ex: BS-001)

TEST DATE: 04/01/12 – 1:00 PM
(ex: 01/01/12 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ■ TEST ☐ RE-TEST

The test objective is to determine if the correct amount of airflow is present during operation. This test will be conducted alongside test AC – 01 and will be a simple judgement of the driver whether airflow is excessive and distracting, or effective enough to assist in cooling the inside of the solar car. Closable vents for the hood scoop should be within reach of the driver and easily accesible.

EXPECTED RESULTS:

Airflow is not disruptive and is able to be adjusted using the vents.

ACTUAL RESULTS:

Air flows through vehicle while in motion

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS:

Test Plan – Solar Car Team 2011-2012

TEST ITEM (TITLE): Temperature

TEST CASE #: AC - 01
(ex: BS-001)

TEST DATE: 04/01/12 – 1:00 PM
(ex: 01/01/12 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ■ TEST ☐ RE-TEST

The test objective is to determine if the driver and electronics are within an acceptable temperature range. Once the other major components of the solar car are installed, temperature readings will be taken during test runs. Temperature readings will also be taken for an hour after operation to simulate road-side charging. An excessive amount of heat should not disrupt the driver or damage the equipment.

EXPECTED RESULTS:

Comfortable conditions will be present for both the driver and electronics.

ACTUAL RESULTS:

Cock pit is within acceptable temperature range

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS:

Test Plan – Solar Car Team 2011-2012

TEST ITEM (TITLE): Bubble

TEST CASE #: BB-01
(ex: BS-001)

TEST DATE: 2/15/02 – 2PM
(ex: 01/01/12 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ■ TEST ☐ RE-TEST

Test a small sample piece of the polycarbonate plastic material by impacting it with different objects to ensure that it will not shatter.

EXPECTED RESULTS:

If and when the piece breaks it will not shatter.

ACTUAL RESULTS:

Bubble is impact resistant

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS:

Test Plan – Solar Car Team 2011-2012

TEST ITEM (TITLE): Boost Converter Physical Test

TEST CASE #: BCP-01
(ex: BS-001)

TEST DATE: 2/29/2012
(ex: 01/01/12 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ■ TEST ☐ RE-TEST

A test of the realized boost converter shall be performed

EXPECTED RESULTS:

The boost selected capacitor and inductor must operate within the steady state conditions of a boost converter, more specifically, the current across the inductor and the voltage across the capacitor should not fall to zero before rising again during any time period of the PWM.

ACTUAL RESULTS:

Boost converted works within acceptable parameters

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS:

Test Plan – Solar Car Team 2011-2012

TEST ITEM (TITLE): Boost Converter Physical Test

TEST CASE #: BCP-01 (ex: BS-001)

TEST DATE: 2/29/2012 (ex: 01/01/12 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ■ TEST ☐ RE-TEST

A test of the realized boost converter shall be performed to verify that the capacitor ripple current does not exceed the rated ripple current of the capacitor.

EXPECTED RESULTS:

The ripple current should not exceed 3 A peak to peak.

ACTUAL RESULTS:

Ripple was less than 3A Peak to Peak

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS:

Test Plan – Solar Car Team 2011-2012

TEST ITEM (TITLE): Boost Converter Physical Test

TEST CASE #: BCP-02
(ex: BS-001)

TEST DATE: 2/29/2012
(ex: 01/01/12 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ■ TEST ☐ RE-TEST

A test of the realized boost converter shall be performed to verify that the inductor current does not exceed the rated current of the inductor (15 A).

EXPECTED RESULTS:

The inductor current should not exceed 15 A DC

ACTUAL RESULTS:

Inductor current is less than 15A

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS:

Test Plan – Solar Car Team 2011-2012

TEST ITEM (TITLE): BMS test

TEST CASE #: BMS-01
(ex: BS-001)

TEST DATE: 2/21/2012
(ex: 01/01/12 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ■ TEST ☐ RE-TEST

A test of the battery management system shall be performed to ensure that the battery power is disconnected in the even that any single battery voltage drops below 3.4 V or rises above 4.2 V.

EXPECTED RESULTS:

The voltage levels will remain within the given parameters.

ACTUAL RESULTS:

STATUS: ☐ PASSED ■ FAILED

FAILURE CAUSE(S):

Current BMS does not work with current system

SUGGESTED SOLUTION(S):

Motor controller configured to shut down if set min voltage is reached.

COMMENTS:

Test Plan – Solar Car Team 2011-2012

TEST ITEM (TITLE): Braking

TEST CASE #: BR-01
(ex: BS-001)

TEST DATE: 3/28/02 – 2PM
(ex: 01/01/12 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ☐ TEST ■ RE-TEST

The objective of this test is to verify the vehicle's braking capabilities. The braking system was untouched in this phase, but a re-test is desired to ensure that the car is still able to brake as desired. The test will include sudden stops as well as gradual stops.

EXPECTED RESULTS:

The car will be able to brake successfully during the road test.

ACTUAL RESULTS:

Car brakes within reasonable distances.

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS:

Test Plan – Solar Car Team 2011-2012

TEST ITEM (TITLE): Drive train

TEST CASE #: DT-01
(ex: BS-001)

TEST DATE: 3/21/02 – 2PM
(ex: 01/01/12 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ■ TEST ☐ RE-TEST

The objective of this test is to verify that the drive train is functioning properly under loaded conditions. Tests will be performed to verify that there is adequate tension in the chain and that it is able to operate effectively. The rear suspension will also be tested with the drive train intact to verify that the suspension travel will be equivalent under loaded conditions as well as un-loaded conditions.

EXPECTED RESULTS:

The drive train will function properly with the desired chain tension and suspension travel.

ACTUAL RESULTS:

Drive train functions properly

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS:

Test Plan – Solar Car Team 2011-2012

TEST ITEM (TITLE): Latch

TEST CASE #: LH-01
(ex: BS-001)

TEST DATE: 2/15/02 – 2PM
(ex: 01/01/12 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ■ TEST ☐ RE-TEST

The test objective is to verify the functionality of the latch. A driver will sit in the driver's seat and pull the latch release handle. The driver should be able to release the latch and re-latch it with ease. The latch should be bolted in place correctly and the cables should be cut down to the desired length to give the correct amount of tension as the driver pulls the latch release handle. The driver should not have to reach very far while in the driver's seat to operate the latch mechanism.

EXPECTED RESULTS:

The driver should be able to release the latch and re-latch it with ease.

ACTUAL RESULTS:

Diver can release and re-latch the vehicle

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS:

Test Plan – Solar Car Team 2011-2012

TEST ITEM (TITLE): Hinge

TEST CASE #: LH-02
(ex: BS-001)

TEST DATE: 2/17/02 – 2PM
(ex: 01/01/12 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ■ TEST ☐ RE-TEST

The objective of this test is to verify that the lid can effectively be hinged to the bottom piece of the car. Another objective is to verify that the body of the car can withstand the loads that will be put upon it, primarily around the areas where the hinges will be bolted to the body. The lid will be lifted and the hinges and surrounding areas on the body will be visually inspected for loading capabilities, and stresses and strains in the body material. The hinges will be able to function properly and the body material will not crack and will be able to withstand the loads required. The hinges will be bolted on the body in several places and will need to be securely fastened. Also, the hinges will need to be level and have the capability for the lid to be smoothly lifted from the bottom of the car body with a minimal amount of effort from the driver.

EXPECTED RESULTS:

The hinges will be able to function properly and the body material will not crack and will be able to withstand the loads required.

ACTUAL RESULTS:

Hinges function properly

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS:

Test Plan – Solar Car Team 2011-2012

TEST ITEM (TITLE): Microcontroller ADC test

TEST CASE #: MIC-01 (ex: BS-001)

TEST DATE: 12/15/2011 (ex: 01/01/12 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ■ TEST ☐ RE-TEST

A test of the supplied Dragon development board shall be performed to verify the functionality of the analog to digital converters. This test will be performed using variable voltage supplies in the senior design lab while using the debugging feature in codewarrior to verify a linear relationship between voltage input and the value given to the microcontroller by the ADC. At least two ADCs are required to measure the power delivered from the solar array.

EXPECTED RESULTS:

At least two ADCs will function properly.

ACTUAL RESULTS:

Used arduino board instead of dragon board and all functions work properly

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS:

Test Plan – Solar Car Team 2011-2012

TEST ITEM (TITLE): Microcontroller PWM test

TEST CASE #: MIC-02
(ex: BS-001)

TEST DATE: 12/15/2011
(ex: 01/01/12 – 11:30 AM)

TEST CASE DESCRIPTION:

TEST TYPE: ■ TEST ☐ RE-TEST

A test of the supplied Dragon development board shall be performed to verify the functionality of the pulse width modulator. This test will be performed using an oscilloscope in the senior design lab while using the debugging feature in codewarrior to alter the period and duty cycle of the PWM.

EXPECTED RESULTS:

The PWM will function properly.

ACTUAL RESULTS:

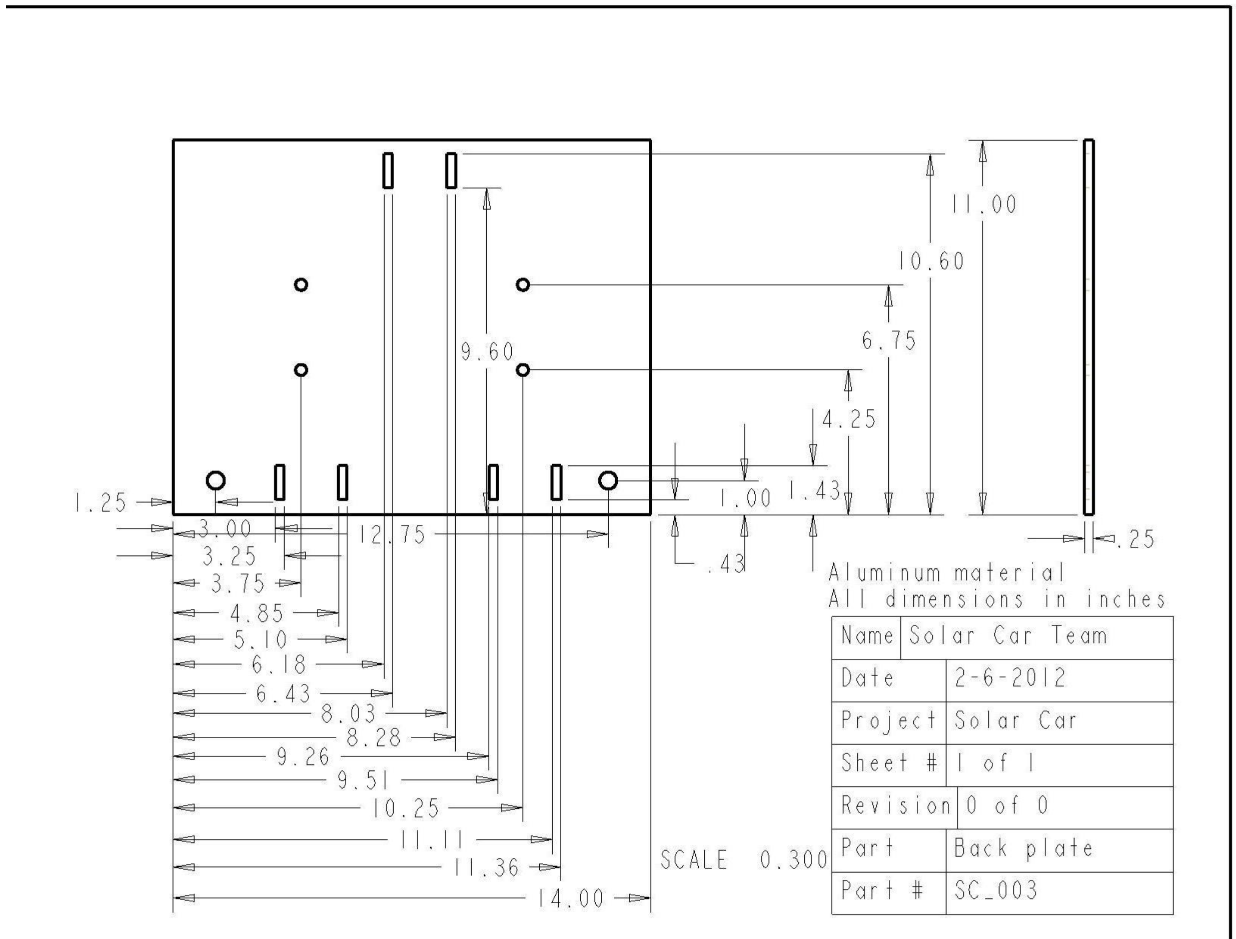
PMW functions properly

STATUS: ■ PASSED ☐ FAILED

FAILURE CAUSE(S):

SUGGESTED SOLUTION(S):

COMMENTS: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9.60
6.75
4.25
1.43
1.00
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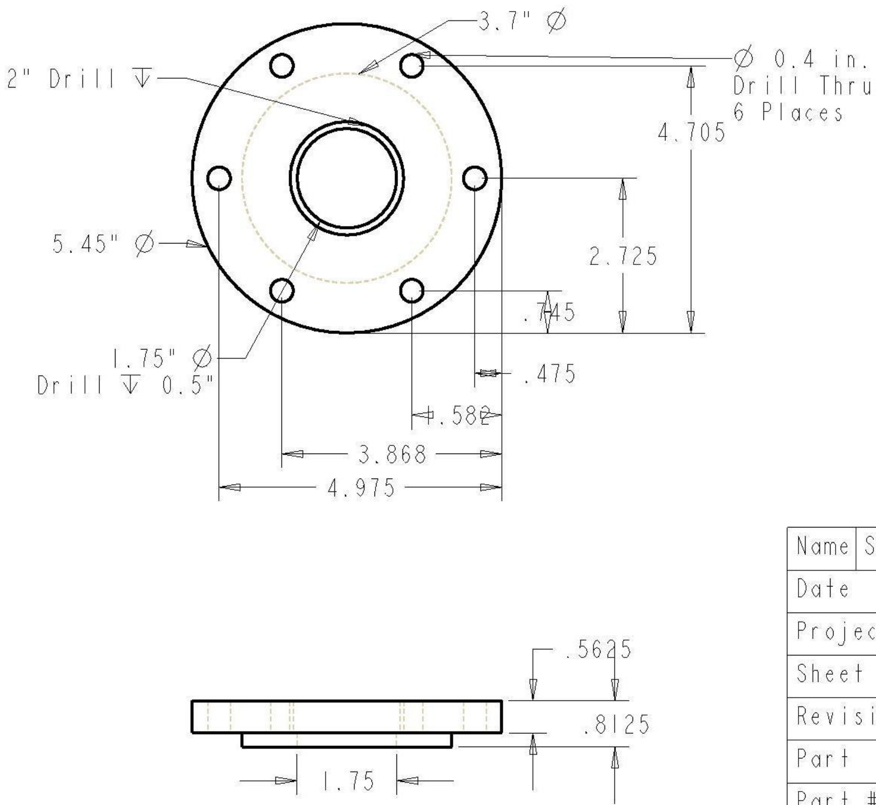
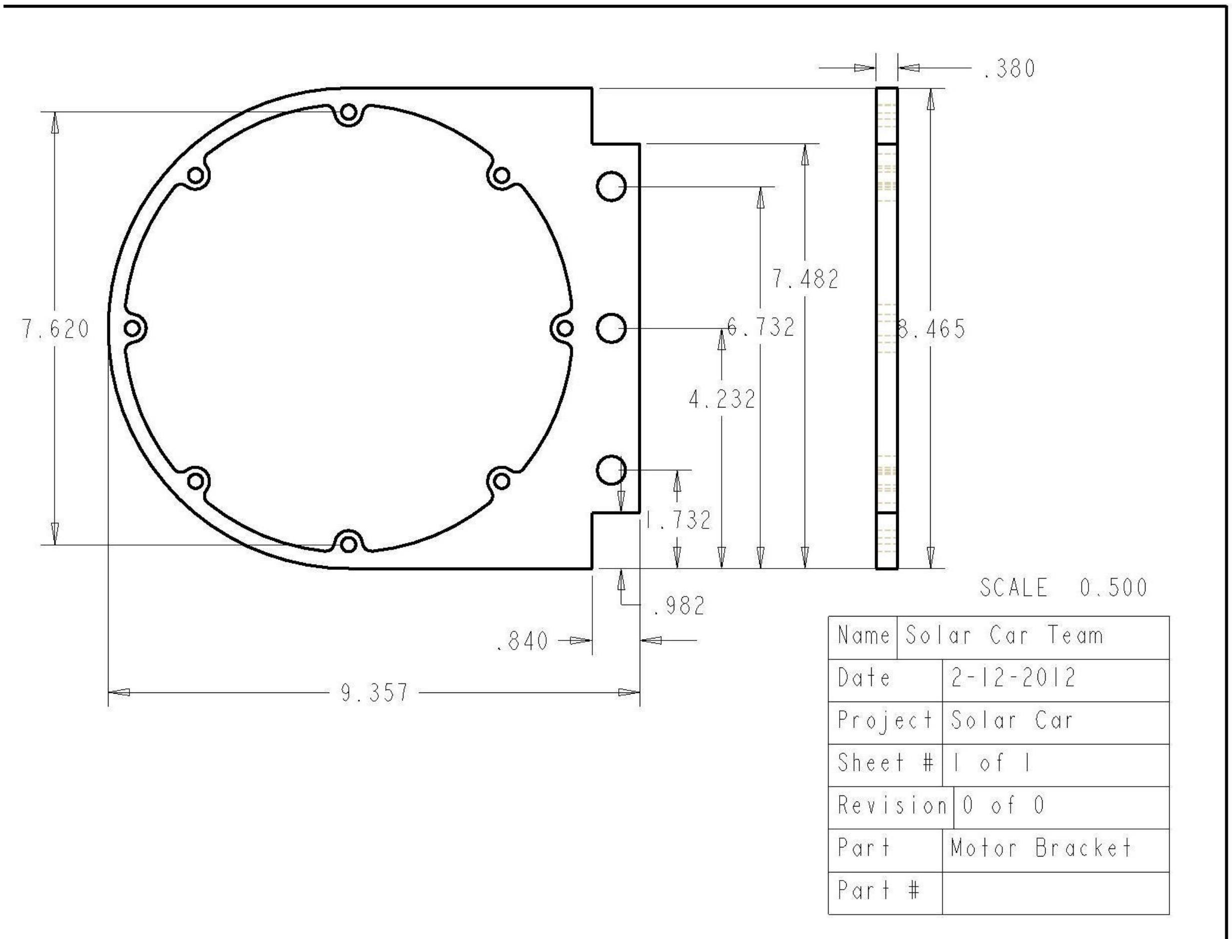
3.00
3.25
3.75
4.85
5.10
6.18
6.43
8.03
8.28
9.26
9.51
10.25
11.11
11.36
12.75
14.00
.25
SCALE 0.300
Aluminum material
All dimensions in inches
Name Solar Car Team
Date 2-6-2012
Project Solar Car
Sheet # 1 of 1
Revision 0 of 0
Part Back plate
Part # SC_003



SCALE 0.500

Name	Solar Car Team
Date	1-20-2012
Project	Solar Car
Sheet #	1 of 1
Revision	0 of 0
Part	Wheel Hub
Part #	SC_002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7.482
6.732
7.620
8.465
4.232
1.732
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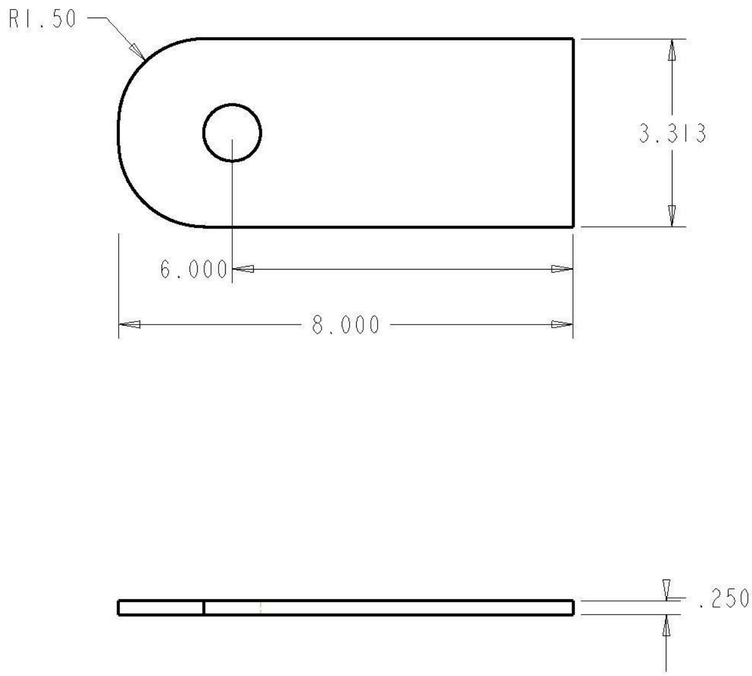
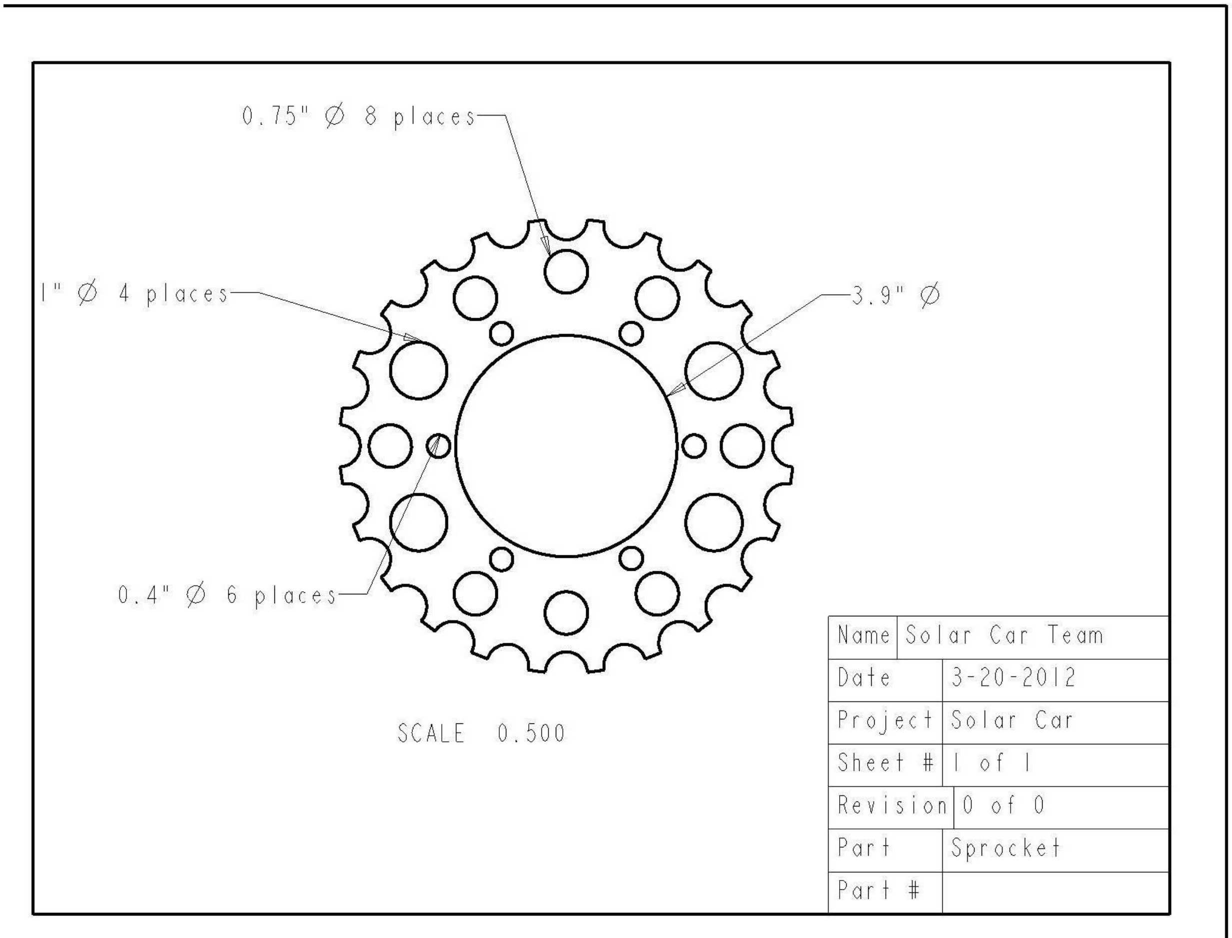
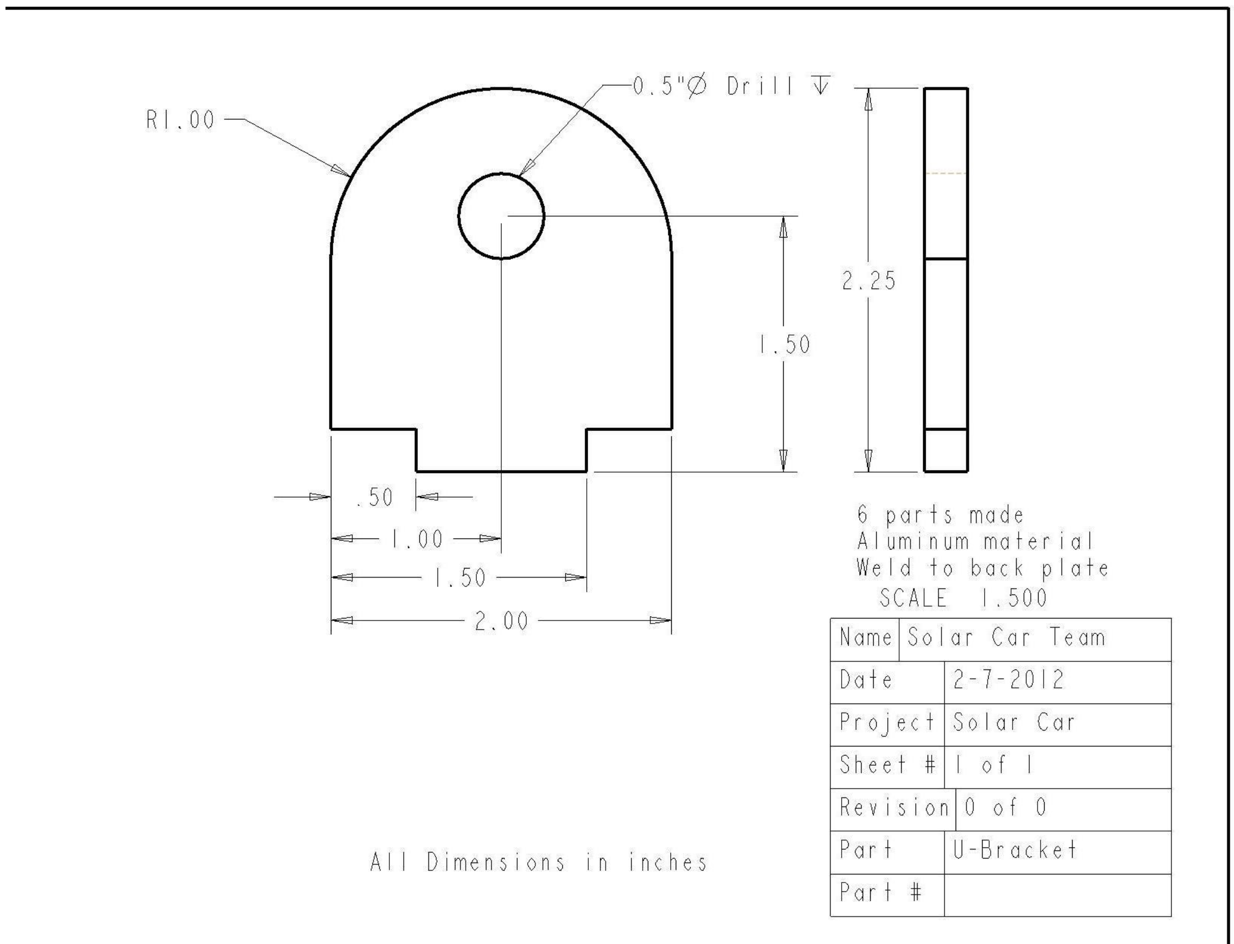
.840
9.357
SCALE 0.500
Name Solar Car Team
Date 2-12-2012
Project Solar Car
Sheet # 1 of 1
Revision 0 of 0
Part Motor Bracket
Part #

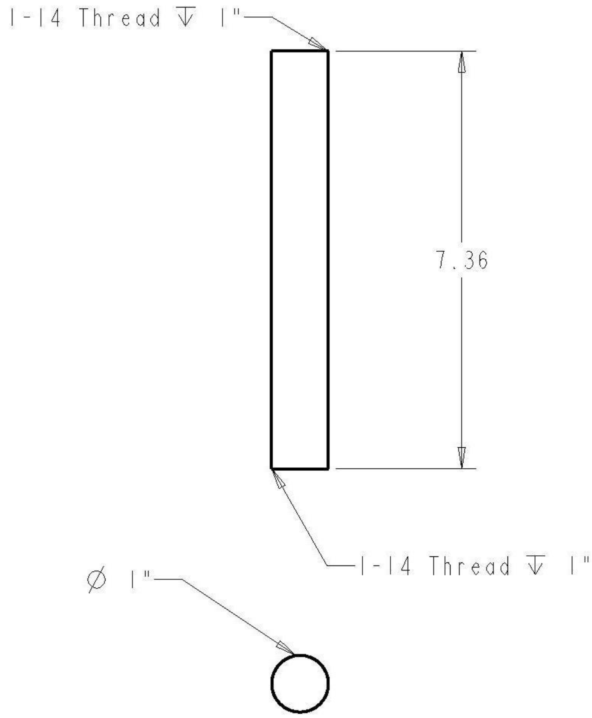


SCALE 0.500

Name	Solar Car Team
Date	2-6-2012
Project	Solar Car
Sheet #	1 of 1
Revision	0 of 0
Part	Rear Arm insert
Part #	SC_04


0.75" ∅ 8 places
1" ∅ 4 places
3.9" ∅
0.4" ∅ 6 places
SCALE 0.500
Name Solar Car Team
Date 3-20-2012
Project Solar Car
Sheet # 1 of 1
Revision 0 of 0
Part Sprocket
Part #

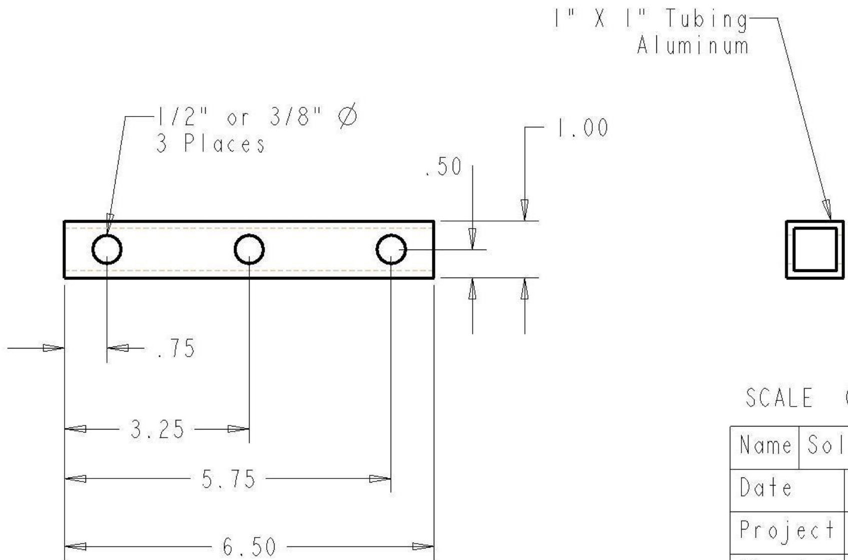

R1.00
0.5"Ø Drill ⊽
2.25
1.50
.50
1.00
1.50
2.00
6 parts made
Aluminum material
Weld to back plate
SCALE 1.500
All Dimensions in inches
Name Solar Car Team
Date 2-7-2012
Project Solar Car
Sheet # 1 of 1
Revision 0 of 0
Part U-Bracket
Part #



All dimensions in inches
12L14 Steel material

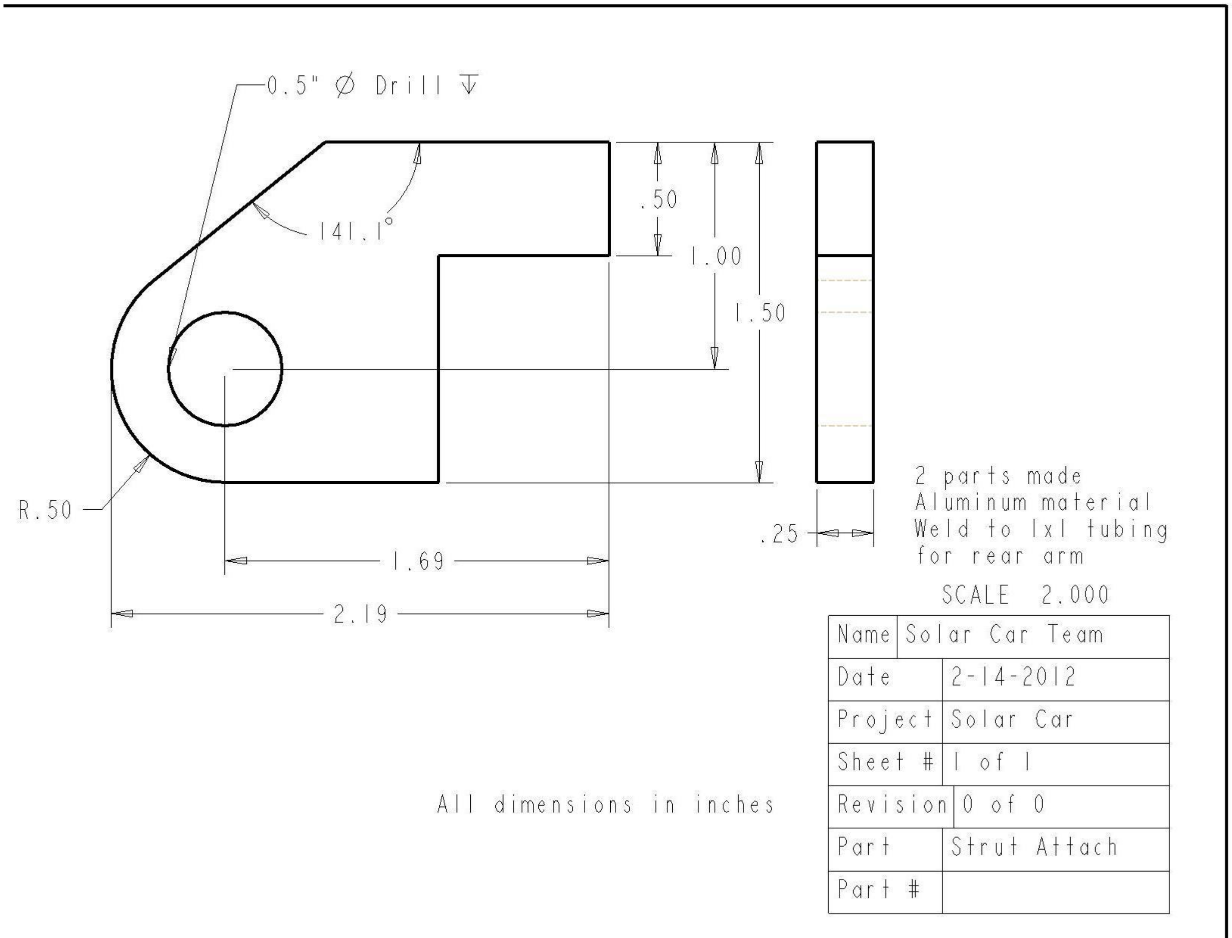
SCALE 0.500

Name	Solar Car Team
Date	2-14-2012
Project	Solar Car
Sheet #	1 of 1
Revision	0 of 0
Part	Tire Shaft
Part #	



SCALE 0.500

Name	Solar Car Team
Date	3-20-2012
Project	Soalr Car
Sheet #	1 of 1
Revision	0 of 0
Part	Motor Tubing
Part #	



XI. References

Holes, Tyler. "Solar Car Team 2011-2012." *Solar Car Team*. FAMU-FSU College of Engineering, 30 Sept. 2011. Web. 05 Apr. 2012. <http://eng.fsu.edu/me/senior_design/2012/team20/>.

McMaster-Carr. Web. 05 Apr. 2012. <http://www.mcmaster-carr.com>.

XII. Biographical Sketch

Patrick Breslend

Patrick Breslend is expected to complete his B.S. in electrical engineering in May of 2012 from Florida State University, Tallahassee, Fl. He is now pursuing an M.S.E.E. degree from Florida State University under Dr. Mischa Steurer and Dr. Chris Edrington. He has worked at Florida State University's Center for Advanced Power Systems since 2009. His research includes power electronic based distribution systems and solid-state circuit breakers. Mr. Breslend is a student member of IEEE and looks forward to starting graduate school in Fall 2012.

Bradford Burke

Bradford Burke is a Florida State University student that transferred to the school in 2009 after receiving his Associates of Arts in Engineering from Broward College in the fall of 2008. He is a Mechanical Engineering major with a concentration in Mechanics and Materials. He is from Miami Gardens, FL and enjoys working out, playing basketball, and spending time with his family. In the future he plans to start his own business performing custom home theater installations. Currently he is looking forward to graduating and start working for an engineering company creating CAD models and simulating reactions and occurrences in systems, utilizing his strengths in those areas.

Jordan Eldridge

Jordan Eldridge is a Florida State University Electrical Engineering student whom is expected to graduate in the spring of 2012. He is also currently enlisted in the United States Air Force, and is set to go to Officer Training School in July of 2012. Jordan is also a founding member and current Executive Vice President of the Sustainable Engineer Solutions (SES) as well as been an active member in IEEE since 2010. Jordan plans on pursuing a Master Degree in Electrical Engineering/Systems Engineering.

Tyler Holes

Tyler Holes will be graduating with a bachelor's degree in mechanical engineering in spring 2012. After graduation, Tyler will be moving back to his hometown of Naples, Florida.

Here he will begin working as a test driver for Roush at a vehicle prototype warehouse. He plans on continuing his education after gaining work experience and wants to pursue a career in the automotive performance or aerospace fields.

Valerie Pezzullo

Valerie Pezzullo is a Mechanical Engineering student at Florida State University and will be graduating in April 2012. At the FAMU-FSU College of Engineering, she is a research assistant in the Scansorial and Terrestrial Robotics and Integrated Design Laboratory (STRIDe) and is interested in biologically inspired robotics. She is a member and the historian of both the FAMU-FSU College of Engineering chapter of the American Society of Mechanical Engineers (ASME) and the American Institute of Aeronautics and Astronautics (AIAA). She is also a member of the Society of Women Engineers (SWE), Women in Math, Science, and Engineering (WIMSE), and Pi Tau Sigma, the Mechanical Engineering honor society. She is planning attending graduate school in the fall of 2012 at Clemson University in South Carolina to study mechatronics and automation in design and manufacturing.

Greg Proctor

Greg Proctor is an electrical senior engineering major. After graduation, Greg plans to attend the University of New Hampshire College of Law specializing in Intellectual Property. He is currently studying for the patent bar and will be taking it this summer.

Shawn Ryster

Shawn Ryster is expected to complete his B.S. in electrical engineering in the spring of 2012 from Florida State University, Tallahassee, Fl. He also worked at Florida State University's Center for Advanced Power Systems in Tallahassee, Fl. as an Undergraduate Research Assistant from January 2011 to December 2011. Mr. Ryster is a student member of IEEE and is also a member of HKN, the Electrical Engineering Honor Society.