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

**Solar Car Needs Analysis and Requirements**

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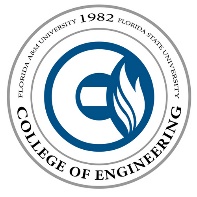


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1. **Overview of Design Team**

Project Leader **–** Fritz Jeanty manages the team as whole, develops a plan and timeline for the project, and delegates tasks among group members according to their skills. He finalizes all documents and provides input on other positions when needed. He organizes and plans all meetings and also keeps a record of the correspondence of the team. He is responsible for overall planning and progress of the project.

Lead Mechanical Engineer- James Croasmun leads all mechanical engineering design aspects of the project. He keeps a line of communication with the lead ECE and project leader. He is responsible for knowing the details of the design and presenting the options for each aspect of the design process. He keeps a record of all design documentation and is responsible for the gathering of design documentation for all reports.

Lead Electrical Engineer- Zachary Barr is responsible for all ECE design for the project. He maintains a line of communication with the lead mechanical engineer as well as the project leader. He keeps a record of all ECE design documentation for the project.

Financial Advisors- Jose Cardenal and Francois Wolmarans together manage the budget and maintain a record of all transactions made for the project. They will present any product or expenditure requests to the advisor who is then responsible for reviewing the analysis of equivalent/alternative solutions. They relay information to the team and if the request is granted they order it. They will keep a record of the analysis and budget adjustments.

Secretary/Web Master- Julia Clarke is responsible for recording all meeting minutes. She manages the posting of materials and documents to the website.

Rules Requirements Advisor/PRO-E Manager- David Jolicoeur is responsible for making sure the project is in compliance of the rules for the Shell-Eco Marathon competition. He will inform the team if we do not meet the requirements for the competition. He is also responsible for all designs that will be drawn using PRO-E and will then show the rest of the team the designs.

Installations Manager- Wael Nabulsi is responsible for component installation for the car. He will inform the team when a component needs to be installed and with the team approval will install the component. He is also responsible for making sure the chassis is not affected by the installation of different components.

* The roles of the design team might change slightly once we meet with the project advisor.

1. **Needs Analysis**
   1. **Overview of the Solar Car Project**

The 2012-2013 Solar Car Team provided the 2013-2014 team with a body, chassis, and solar panels. Due to limited time, last year’s team was unable to construct a fully functional car. This year’s team is completing the car and making sure it complies with the “2014 Shell Eco- Marathon Challenge’s” requirements.

* 1. **Statement of the Problem**

The 2013-2014 FAMU-FSU Solar Car team aims to build a solar car that adheres to the rules and regulations of the “2014 Shell Eco-Marathon Challenge” competition. The goal of this project is to complete construction of last year’s design.

Using mechanical, electrical, and ergonomic design the group will build, test, and improve last year’s design for a finalized product that’s competition ready. Additionally, the group will add the necessary components that will get the car up to par with the requirements for the “Shell Eco-Marathon Challenge”.

In order to determine the 2014 Solar Car’s required and desired capabilities the team created a house of quality (HOQ) shown in *Figure 1-1*. The house of quality allowed the team to identify critical manufacturing, and quality control measures which need to be implemented in order to satisfy the customer’s (Shell) needs and create a course of action for the team.

The group began by comparing the required dual breaking system to each of the thirteen quality characteristics. After careful analysis the following relationships were established:

* Strong relationship with safety, because having dual breaking systems adds extra safety measures to the car.
* Weak relationship with weight, because adding a secondary breaking system will slightly increase the cars weight.
* Moderate relationship with cost, because the dual breaking system will moderately increase the cars cost.
* Strong relationship with regenerative breaking system, because the breaking systems will be directly related to regenerative breaking.

The required safety features were then compared to each of the thirteen quality characteristics. A roll bar, 5 point seat belt, rear view mirrors, turning radius requirements, and bulk heads were considered when establishing the following relationships:

* Weak relationship with ventilation, because having a ventilation system will increase the operational safety when operating in extreme environments.
* Moderate relationship with speed, because adding these safety features moderately increases the vehicles weight which ultimately decreases the vehicles speed.
* Strong relationship with safety, because each of these safety features adds an extra level of operational safety.
* Moderate relationship with turning radius, because increased turning radius increases the cars maneuverability which affects the overall safety of the driver.
* Strong relationship with weight, because adding these safety features will significantly increase the cars weight.
* Strong relationship with visibility, because safety features such as the rear view mirrors will directly affect the driver’s visibility.
* Weak relationship with economic aspects of the car because implementing all of the safety features will make it more difficult to design the car in an ergonomic manner due to space restrictions.
* Strong relationship with cost, because implementing each safety feature will significantly increase the cost of the project.
* Weak relationship with a super capacitor, since the addition of a super capacitor increases the probability of an overload.

Required emergency procedures were compared to each of the thirteen quality characteristics. The addition of a ten second escape plan, and an electrical shutdown switch were considered when establishing the following relationships:

* Strong relationship with safety, including a ten second escape plan and having emergency shutdown switches will significantly increase the operational safety.
* Weak relationship with weight, because including these emergency procedures will slightly increase the cars weight due to extra parts.
* Strong relationship with ergonomic aspects, because including these emergency procedures will directly affect the ergonomic design of the car.
* Weak relationship with radio communication because having radio communication will make following emergency procedures easier at the time of an emergency.
* Moderate relationship with cost, because adding the extra parts necessary to incorporate these emergency procedures will moderately increase the cost of the project.

Required visibility was compared to each of the thirteen quality characteristics. The addition of rear view mirrors and a 180 degree field of vision were considered when establishing the following relationships:

* Strong relationship with safety because having the required visibility specs met significantly increases the operational safety of the vehicle.
* Strong relationship with visibility because having the required visibility specs met significantly increases the driver’s visibility.
* Weak relationship with radio communication because radio communication will allow the pit crew to help the driver with their surroundings.
* Weak relationship with cost because having the required visibility specs met will slightly increase the project’s cost. For example rear view mirrors will need to be purchased.

Required vehicle dimensions were compared to each of the thirteen quality characteristics. After careful analysis the following relationships were established:

* Weak relationship with ventilation, because the constricted size of the car limits the types of ventilation which can be used.
* Strong relationship with speed, because the vehicles dimensions directly affect the vehicles speed. The larger the vehicle, the slower it will run due to the limited engine size and energy capabilities.
* Strong relationship with safety, because the larger the car the more safe it will be. Inversely the smaller the car the less safe it will be.
* Strong relationship with turning radius because the turning radius is directly affected by the vehicle dimensions.
* Strong relationship with weight because the larger the car the more it will weigh, and vice versa, the smaller the car the less it will weigh.
* Strong relationship with visibility because the dimensions of the car will directly affect the drivers visibility. The shape and dimensions can also add blind spots in the driver’s field of vision.
* Strong relationship with ergonomic aspects of the car dimension limits will directly affect the ergonomic design capabilities. The smaller the car the more difficult it will be to implement an ergonomic design.
* Strong relationship with cost because the larger the car the more material is used which increases the cost of the project, and vice versa the smaller the car the less material that is used, and the cheaper the cost of the project.

Separated fire proof compartments were compared to each of the thirteen quality characteristics. The fire retardant bulk heads were also considered when making these correlations. After careful analysis the following relationships were established:

* Weak relationship with ventilation, because the separate fire proof compartments make it more difficult to add ventilation to the car. Furthermore, the separated fire proof compartments take up a considerable amount of space which also decreases the ventilation possibilities.
* Strong relationship with safety, because having the separate fire proof compartments will directly increase the operational safety of the vehicle.
* Moderate relationship with weight, because adding the materials necessary to implement the separate fire proof compartments and the bulkheads will moderately increase the weight of the vehicle.
* Moderate relationship with cost, because adding the materials necessary to implement the separate fire proof compartments and the bulkheads will moderately increase the cost of the project.

Required indicators and switches were compared to each of the thirteen quality characteristics. The escape latch indicators and red arrows, the system shutdown switch, and the system shut down indicators were considered when establishing the following relationships:

* Strong relationship with safety, because the switches and indicators considered directly increase the operational safety during an emergency.
* Strong relationship with ergonomic design, because the location of the switches must be easily accessible to the driver of the car.
* Weak relationship with cost, because the switches and indicators considered should be fairly inexpensive to implement.
* Strong relationship with the odometer, because it is an indicator that is highly desired.
* Strong relationship with the accessory battery, because the accessory battery will power the additional indicators and switches.

The electric horn was compared to each of the thirteen quality characteristics. After careful analysis the following correlations were made:

* Strong relationship with safety, because having an electric horn will allow the driver to safely pass other vehicles on the track.
* Weak relationship with cost because the electric horn will be fairly inexpensive to implement.
* Strong relationship with the accessory battery, because the electric horn will be powered by the accessory battery.

The Li-Ion battery and the battery management system were compared to each of the thirteen quality characteristics. After careful analysis the following relationships were established:

* Strong relationship with speed, because the power which the battery produces, directly affects the vehicles speed.
* Strong relationship with safety, because implementing the battery and battery management system means having specialized safety precautions such as fire retardant bulk heads.
* Moderate relationship with weight because the battery weighs approximately 10lbs.
* Strong relationship with cost, because the Li-Ion Battery is one of the most expensive components in the vehicle.
* Strong relationship with a super capacitor, because the super capacitor will help charge the battery.
* Strong relationship with the regenerative breaking, because the regenerative breaking will help charge the battery.

The vehicles efficiency was compared to each of the thirteen quality characteristics. In terms of the competition the vehicles efficiency will be measured in km/kWh. After careful analysis the following relationships were established:

* Weak relationship with speed, because the speed at which the vehicle travels will affect the vehicles overall efficiency.
* Strong relationship with weight, because the vehicles weight will directly affect the efficiency. The lighter the vehicle the more efficient it will be.
* Strong relationship with a super capacitor, because the super capacitor will help charge the battery, thus increasing the distance traveled.
* Strong relationship with the regenerative breaking, because the regenerative breaking will help charge the battery, thus increasing the distance traveled.

Next it was determined that each functional requirement had to be ranked according to the HOQ optimization criteria. The direction of improvement for each variable was ranked as requiring minimization/maximization; in the case of a binary variable, each characteristic was simply marked to indicate that the requirement has been fulfilled. The results were as follows:

* Ventilation: Maximize
* Speed: Maximize
* Safety: Maximize
* Turning Radius: Maximize
* Weight: Minimize
* Visibility: Maximize
* Ergonomics: Maximize
* Radio Communication: On target
* Cost: Minimize
* Accessory Battery: On target
* Super capacitor: On target
* Odometer: On target
* Regenerative Braking: On target

The correlation between each quality characteristics was assessed based on the optimization criteria in order to determine the nature and strength of their relationship.

The ventilation variable shared the following correlations:

* A weak positive relationship with safety, because proper ventilation will help to ensure that the driver can operate the vehicle with full awareness of their surroundings.
* A strong positive relationship with ergonomics, because it ensures the comfort of the driver.
* A weak negative relationship with cost, because creating proper ventilation will require additional tool work and possibly procurement.
* A strong positive relationship with the accessory battery, because the ventilation may run off of the accessory battery.

The speed variable shared the following correlations:

* A strong negative relationship with the safety, because increasing the speed requires a reduction of materials used for the chassis, thereby reducing the overall safety of the driver in case of an accident.
* A strong positive relationship with the weight, because decreasing the weight will lead to a faster top speed.
* A weak negative relationship with ergonomics, because improving the ergonomics will require additional material which increases the weight.
* A strong positive relationship with the accessory battery, because the ventilation will run on the accessory battery.
* A strong negative relationship with cost, because increasing the speed will require additional mechanical and electrical parts.
* A weak positive relationship with the super capacitor, because the super capacitor will help to store additional power for the motor.
* A weak positive relationship with the regenerative braking, because it will help to generate additional power for the motor.

The safety variable shared the following correlations:

* A weak positive relationship with the turning radius, because the car needs to be able to safely navigate turns.
* A strong negative relationship with the weight, because the additional safety features will add additional weight to the car.
* A strong positive relationship with visibility, because the driver needs to be able to see everything within a 180 degree field of vision.
* A strong positive relationship with ergonomics, because it is directly related to all indicators and gauges that provide the operator with necessary information.
* A weak positive relationship with radio communication, because it will allow the pit crew to keep in contact with the operator in case of an emergency.
* A strong negative relationship with cost, because each additional safety consideration requires additional purchasing or modification.
* A weak positive relationship with the accessory battery, because the additional battery will power all of the safety components.
* A weak positive relationship with the super capacitor, because the super capacitor increases the risk of fire hazard.
* A weak positive relationship with the regenerative braking, because adding the additional components would increase the probability for mechanical error.

The turning radius variable shared the following correlations:

* A weak negative relationship with the weight, because adding the additional mechanical parts would cause a small increase in weight.
* A weak negative relationship with the cost, because procuring the additional parts would also increase the cost.

The weight variable shared the following correlations:

* A weak negative relationship with visibility, because adding the additional Plexiglas cover would increase the weight.
* A weak negative relationship with ergonomics, because adding additional material to increase the ergonomics would increase the weight.
* A strong positive relationship with cost, because reducing the weight would require much more expensive materials (i.e. Al honeycomb).
* A strong negative relationship with the accessory battery, because the additional battery adds significant weight to the vehicle.
* A weak negative relationship with the super capacitor, because it will add additional weight to the vehicle.
* A weak negative relationship with the odometer, because installing it will require additional parts which will add to the weight.
* A weak negative relationship with the regenerative braking, because the additional parts will increase the weight.

The visibility variable shared the following correlations:

* A strong positive relationship with ergonomics, because it allows for clear vision of the race track which is essential to human factors design.
* A weak negative relationship with the cost, because the Plexiglas cover and machining will cost additional money.

The ergonomics variable shared the following correlations:

* A strong negative relationship with cost, because increasing the comfort of use for the operator will increase costs.
* A weak positive relationship with the accessory battery, because some components (such as ventilation) will operate off of the additional battery.
* A weak positive relationship with odometer, because the odometer is an indicator which increases the safety of use for the operator.

The radio communication variable shared the following correlations:

* A weak negative relationship with the cost, because procuring the equipment will add to the costs.

The cost variable shared the following correlations:

* A weak negative relationship with the accessory battery, because the additional battery will add to the cost.
* A weak negative relationship with the super capacitor, because the additional electrical parts will add to the cost.
* A weak negative relationship with the odometer, because the additional equipment will add to the cost.
* A weak negative relationship with the regenerative braking, because the additional mechanical equipment will add to the cost.

The accessory battery variable shared the following correlations:

* A strong positive relationship with the odometer, because the odometer will be powered using the additional battery.

Lastly, a competitor analysis was done using the FAMU-FSU 2011 solar car as a competitor. Using the requirements for participation in the 2014 Shell Eco-Solar challenge, we ranked both designs side by side. The 2014 solar car design scored a 5 in each category, and showed great improvement over the previous design.

**Required Capabilities**

RCAP-1.001: Vehicles must be equipped with two independent breaking systems.

RCAP-1.002: The vehicle must conform to all required safety features outlined by the Shell Eco-Marathon guidelines.

RCAP-1.003: The driver must be able to vacate the vehicle at any time without assistance in less than 10 seconds.

RCAP-1.004: The vehicle must conform to all visibility requirements outlined by the Shell Eco-Marathon guidelines.

RCAP-1.005: The vehicle must conform to all prototype dimensions and specifications outlined by the Shell Eco-Marathon guidelines.

RCAP-1.006: The vehicle must contain fire retardant barriers which completely isolate the driver’s compartment and all other compartments (i.e. energy storage system).

RCAP-1.007: The vehicle must contain a permanently installed emergency shutdown mechanism that is well positioned and clearly visible on the vehicle body.

RCAP-1.008: The vehicle must be equipped with an electrical horn emitting a sound greater than 85dB.

RCAP-1.009: The vehicle must contain a Lithium-Ion battery with an installed Battery Management System.

RCAP-1.010: The vehicle must be able to operate at a high efficiency level (km/kWh).

**Desired Capabilities (Highest to Lowest Priority)**

DCAP-1.001: Integrate a full safety system that meets all required safety capabilities.

DCAP-1.002: Attain all required capabilities while keeping the total cost below $6000.

DCAP-1.003: Keep the overall weight of the vehicle under 140kg.

DCAP-1.004: Meet all requirements of the Shell Eco-Marathon guidelines while maintaining a comfortable environment for the driver.

DCAP-1.005: Maintain a 180 degree field of vision for the driver.

DCAP-1.006: Integrate a regenerative breaking system.

DCAP-1.007: Attain a vehicle average speed of 15mph.

DCAP-1.008: Integrate a super capacitor for energy storage.

DCAP-1.009: Integrate an accessory battery.

DCAP-1.010: Maintain a turning radius of 8 meters.

DCAP-1.011: Integrate an odometer.

DCAP-1.012: Integrate ventilation system.

DCAP-1.013: Integrate radio communication.

* 1. **Operational Description**

Upon entering the vehicle, the designated driver must sit in the seat and adjust the rear and side mirrors to maximize the viewing capacity of the driver. Once the mirrors have been adjusted the driver must securely harness themselves to the driver’s seat using the required five point harness. Once strapped into the driving compartment the steering must be checked by turning the steering wheel left and right to ensure proper operating conditions. An assistant must be utilized on the outside of the vehicle that can ensure the breaking calipers are engaged when the break petals are compressed by the driver. There will be three pedals in the chassis; one for the throttle, one for the front wheels, and the last one for the rear wheel. Once all the mechanical systems have been tested the electrical systems can be engaged using the master switch which is located in the driver compartment. The states of the electrical systems are displayed in the driver’s console which contains the joule meter and battery charge meter. In case of and emergency the master electrical switch can be switched off which will cut off all electric systems and the driver can escape the cockpit through the drivers hatch.

1. **Requirements Specifications**
   1. **Functional Requirements**

FR-1.001: The vehicle must be able to travel greater than 6 miles.

FR-1.002: The vehicle must be able to operate in all kinds of weather.

FR-1.003: The vehicle must hold one driver safely.

FR-1.004: The vehicle must meet required steering capabilities.

FR-1.005: The vehicle must be able to move at an average velocity of 15 mph.

* 1. **Structural Requirements**
     1. **Chassis Requirements**

SCR-1.001: The vehicle chassis must support the full load of the driver and structural components without deforming.

SCR-1.002: The roll bar must be at least 5 cm above the helmet of the rider when fully seated and fastened with the seatbelts.

SCR-1.003: The roll bar will also have to extend in width above the drivers shoulders when seated in a normal position.

SCR-1.004: The roll bar must withstand a static load of 700 N applied on a vertical, horizontal, or perpendicular direction without deformation.

SCR-1.005: The vehicles body must retain its shape during gusts of winds, rain, and any environmental effects that may occur.

SCR-1.006: The upper part of the body will be manufactured out of a custom plastic dome for visibility that will not shatter into pieces during impact which could be a hazard to the driver.

SCR-1.007: The vehicle’s body must be designed with a drag coefficient less than or equal to 0.15. Reducing the coefficient of drag will increase the overall efficiency and performance.

SCR-1.008: Wight distribution is essential for stability and will decrease the chances of roll overs.

* + 1. **Wheel Requirements**

SWR-1.001: All types of wheels and tires are allowed.

SWR-1.002: Wheels located inside the vehicle body must be isolated from the driver by a fire-retardant bulkhead.

SWR-1.003: All handling readjustments and manipulations are prohibited during the race.

SWR-1.004: All components of the vehicle must be secured away from the wheels so they do not interfere with the steering.

SWR-1.005: The three wheels must support the full load of the car and driver and remain in contact with the ground at all times.

* + 1. **Braking Requirements**

SBR-1.001: Vehicle must be equipped with two independently activated braking systems; one for the front wheels and one for the back wheels.

SBR-1.002: The right and left wheels on the front of the chassis must be properly balanced and functioning together with a single command.

SBR-1.003: The two braking systems must be able to be engaged without removing either hand from the steering wheel.

SBR-1.004: Each braking system must keep the vehicle immobilized when engaged on a 20 degree incline.

* + 1. **Steering Requirements**

SSR-1.001: The turning radius for the competition is 8 meters.

SSR-1.002: The turning mechanism must be properly installed and implemented in order to ensure safety when completing maneuvers on the track.

* + 1. **Visibility Requirements**

SVR-1.001: The driver must have a full visibility of 90 degrees on each side of the longitudinal axis.

SVR-1.002: The driver must be able to pass the visibility test while remaining strapped into the vehicle with the top of the helmet located 5 cm below the roll bar at all times.

SVR-1.003: Vehicle must be equipped with rear view and side mirrors with a minimum surface area of 5 X 5 cm.

* + 1. **Propulsion and Energy Storage**

SPER-1.001: A permanent fire retardant bulkhead must completely separate all propulsion and wiring systems from the driver compartment.

SPER-1.002: Holes made in the bulkhead to connect wires and cables must be well insulated and filled to pass safety inspection.

SPER-1.003: The battery and engine compartments must be easily accessed by race technicians.

* 1. **Electrical Requirements**
     1. **Solar Requirements**

ESR-1.001: Limit allowable amount of solar energy to 20% of total propulsion energy consumed.

ESR-1.002: A third diode will be used to serve as protection from unwanted current flow into the modules.

ESR-1.003: Monocrystalline solar cells will be used to provide higher electrical efficiency.

ESR-1.004: The total combined surface area of solar cells will be less than 0.17m^2 (10 cells of 5X5 inches).

* + 1. **Battery Requirements**

EBR-1.001: The vehicle will use one Lithium-Ion battery.

EBR-1.002: A Battery Management System must be installed to control and protect against risk of fire.

EBR-1.003: The battery must be in a separate compartment from the chassis.

EBR-1.004: An accessory battery will be used to power the horn, odometer and ventilation system.

EBR-1.005: The accessory battery must be electrically isolated from propulsion battery and super capacitor.

EBR-1.006: Only one propulsion battery and one accessory battery must be used.

* + 1. **Misc. Requirements**

EMR-1.001: The vehicle will have an external location for the joule meters.

EMR-1.002: The maximum voltage on board of the vehicle at any point must not exceed 48V nominal.

EMR-1.003: Change resistors to allow battery to operate at 26V once passed through the DC-DC converter

* 1. **Safety Requirements**

SR-2.001: A permanent ﬁre retardant Bulkhead must completely separate and effectively seal the vehicle’s propulsion and energy storage systems for the driver’s compartment.

SR-2.002: Fully harnessed drivers must be able to vacate their vehicle at any time without assistance in less than 10 seconds.

SR-2.003: The safety harness for the driver must be propriety, i.e. speciﬁcally manufactured for motorsport use, and withstand a force of at least 1.5 times the driver’s weight.

SR-2.004: Vehicle must be ﬁtted with a ﬁre extinguisher (ABS or BC type) with minimum extinguishant capacity of 2lb.

* 1. **Non- Functional Requirements**

NFR-1.001: Driver and reserve driver must be designated for competition.

NFR-1.002: Official Logos must be present on the vehicle to compete.

NFR-1.003: Driver and backup driver required to pass driving knowledge test.

NFR-1.004: At no point on the race track are drivers allowed to push their vehicle.

NFR-1.005: Minimum driver weight is 50 kg.

NFR-1.006: For practice and competition a motorcycle style helmet must be worn.

NFR-1.007: Drivers must wear a racing suit as the outermost layer of clothing.

NFR-1.008: Safety glasses are required for all team members.

NFR-1.009: Hearing protection is required for all team members.

NFR-1.010: Gloves for fuel, motor oil, and general work are required.

* 1. **Constraints**

CRC-1.001: Vehicle must adhere to required dimensions.

CRC-1.002: A maximum of 60 volts are allowed on the vehicle.

CRC-1.003: Solar arrays must not protrude from the surface of the vehicle.

CRC-1.004: Total cost of project must remain below $6000.00.

CRC-1.005: Technical documentation must be submitted to Shell by December to qualify for competition.

CRC-1.006: Vehicle must pass safety inspection on arrival at competition.

1. **Test Plan**

**4.1 Capabilities Test**

RCAP-1.005: The vehicle must conform to all prototype dimensions and specifications outlined by the Shell Eco-Marathon guidelines.

Location: COE Portable

Tester: All team members

Steps:

1. With the wheels, and seat installed the driver will be strapped into the driver’s seat.
2. Using a tape measurer all dimensions will be taken and compared to the required specifics supplied by the competition.

RCAP-1.008: The vehicle must be equipped with an electrical horn emitting a sound greater than 85 dB.

Location: COE parking lot

Tester: All team members

Steps:

1. The driver will enter the vehicle and turn on the accessory electrical system.
2. One team member will stand 4 feet from the front of the car with an audio measuring device.
3. When ready the driver will sound the horn and the other team member will record the reading given by the device
4. This result will be compared to the requirements given by the competition.

DCAP-1.003: Keep the overall weight of the vehicle under 140kg.

Location: COE parking lot

Tester: All members

Steps:

1. The team must obtain three bathroom scales.
2. The team will lift the car and slide a scale under each wheel and then set it back down.
3. The weight can be taken from each scale and added together to give us the total weight.

DCAP-1.007: Attain a vehicle average speed of 15mph.

Location: COE parking lot

Tester: All team members

Steps:

1. This test will need to be run early morning on a weekend when the parking lot is empty.
2. The team will use one of their cars to get the distance of one lap around the parking lot.
3. The driver will enter the vehicle, strap in, and turn on the electric systems.
4. When the driver starts to lap around the parking lot one member will use a stop watch to determine how long it takes.
5. With the distance and the amount of time taken to travel said distance the velocity can be calculated.

DCAP-1.011: Integrate an odometer.

Location: COE parking lot

Tester: All team members

Steps:

1. The driver will enter the vehicle and strap into the driver’s seat.
2. The electrical system will then be turned on.
3. Two team members will get into that team members car.
4. The two vehicles will line up side by side and the driver of the solar car will shout out the reading on the odometer as they are driving and those results will be compared to the reading taken at the same time in the team members’ car.

**4.2 Functionality Test**

FR-1.001: The vehicles must be able to travel greater than 6 miles.

     Location: COE parking lot

     Tester: All team members

     Steps:

1. The team driver, Julia Clarke will drive the vehicle continuously for 6 miles.

FR-1.002: The vehicles must operate in all kinds of weather.

Location: COE parking lot

     Tester: All team members

     Steps:

1. The team driver, Julia Clarke will drive the vehicle on a sunny day, rainy day, and overcast day, and test for the following capabilities.
   1. Can the vehicle reach a top speed of 15 miles per hour?
   2. Can the vehicle come to a full stop within 8-10 feet?

FR-1.003: The vehicle must hold one driver.

Location: COE parking lot

    Tester: All team members

    Steps:

1. The team driver, Julia Clarke will enter the vehicle.
2. The team driver, Julia Clarke will drive the vehicle continuously for 0.5 miles.

FR-1.004: The vehicle must meet required steering capabilities.

    Location: COE parking lot

     Tester: All team members

    Steps:

1. The team driver, Julia Clarke will enter the vehicle.
2. The team driver, Julia Clarke will turn the steering wheel to the right 100 percent and the vehicles turning radius will be measured (must be at least 8 meters).
3. The team driver, Julia Clarke will turn the steering wheel 100 percent to the left and the vehicles turning radius will be measured (must be at least 8 meters).

**4.3 Structural Test**

SCR-1.001: The vehicle chassis must support the full load of the driver and structural components without deforming.

Location: COE parking lot

Tester: ME team members and driver

Steps:

1. The team driver, Julia Clarke enters the vehicle.
2. The ME team members check chassis for any bending or deforming from added weight of driver

SCR-1.002: The roll bar must be at least 5 cm above the helmet of the rider when fully seated and fastened with the seatbelts.

Location: COE parking lot

Tester: ME team members and driver

Steps:

1. The driver enters the vehicle with helmet on and straps themselves into the driver’s seat
2. ME team measures the clearance between the top of the helmet on the roll bar to ensure requirements are met.

SCR-1.003: The roll bar will also have to extend in width above the drivers shoulders when seated in a normal position.

Location: COE parking lot

Tester: ME team members and driver

Steps:

1. The driver enters the vehicle and straps themselves into the driver’s seat.
2. ME team measures clearance between the driver’s shoulders and roll bar to ensure requirements are met.

SCR-1.004: Roll bar must withstand a static load of 700 N applied on a vertical, horizontal, or perpendicular direction without deformation.

Location: COE computer lab

Tester: ME team

Steps:

1. ME team builds the roll bar using Pro Engineer.
2. The CAD files are then uploaded into Adams and a virtual simulation can be run to ensure it will withstand the required forces.

SWR-1.004: All components of the vehicle must be secured away from the wheels so they do not interfere with the steering.

Location: COE parking lot

Tester: ME team

Steps:

1. ME team member sits in vehicle and straps themselves into the driver’s seat.
2. With the top removed from the chassis the team member will turn the wheel all the way from the left to the right.
3. Other team members need to inspect that no rubbing or wires interfere with the steering.
4. The rear wheel will also be examined to ensure connecting wires are properly stored and there are no interferences with the wheel.

SWR-1.005: The three wheels must support the full load of the car and driver and remain in contact with the ground at all times.

Location: COE parking lot

Tester: ME team and driver

Steps:

1. The driver enters the vehicle and straps themselves into the driver’s seat.
2. The driver engages the battery and begins to accelerate the vehicle.
3. Once in motion the driver will begin to complete several turning maneuvers in front of the other team members to ensure that all wheels stay in constant contact with the ground and there are no visual signs of the chassis deforming.
4. The driver stops the vehicle and shuts off the electrical system and steps out of the vehicle.
5. The ME team will go over the entire chassis inside and outside to ensure no damage or deforming occurred during operational maneuvers.

SBR-1.001: Vehicle must be equipped with two independently activated braking systems; one for the front wheels and one for the back wheels.

Location: COE parking lot

Tester: ME team

Steps:

1. A team member enters the car and straps themselves into the driver’s seat.
2. A team member stands at each wheel and ensures that the brakes activate when the petal is compressed by the driver.

SBR-1.002: The right and left wheels on the front of the chassis must be properly balanced and functioning with a single command.

Location: COE parking lot

Tester: ME team

Steps:

1. A team member enters the vehicle and straps themselves into the driver’s seat.
2. A team member stands at each of the front wheels.
3. When the driver presses the petal the other team members need to assure that the breaks clamp down on the calipers.
4. Once the breaks are functioning properly their compressive forces will need to be measured.
5. A force meter will be utilized and the breaks reapplied and compressive forces of left and right front wheel will be measured.
6. Once the team knows the compressive force for each break the team can balance them by adjusting the hydraulic fluid contained in the break lines.
7. The above procedure is repeated until a balance of approximately ±1 N is reached.

SBR-1.004: Each breaking system must keep the vehicle immobilized when engaged on a 20 degree incline.

Location: FAMU Campus

Tester: ME team

Steps:

1. A team member enters the vehicle and straps themselves into the driver’s seat.
2. Both breaking systems will then be applied and the rest of the team will stand close behind the vehicle.
3. The rear breaking system will then be disengaged and the team will see if the front brakes can hold the vehicle in place.
4. The driver will then reapply both systems
5. Now the front breaking system will be disengaged to determine if the rear brakes can hold the vehicle in place.
6. In the case the breaks do not hold they will need to be adjusted and the previous steps re-run to ensure the operating requirements are met.

SVR-1.001: The Driver must have a full visibility of 90 degrees on each side of the longitudinal axis.

Location: COE parking lot

Tester: ME team and driver

Steps:

1. Julia will enter the vehicle and strap herself into the driver’s seat.
2. A team member will move from the left side of the vehicle to the right side a full 180 degrees around where Julia is situated in the vehicle to meet the requirements specified by the competition.

**4.4 Electrical Test**

ESR-1.002: A third diode will be used to serve as protection from unwanted current flow into the modules.

Location: COE parking lot

Tester: All team members

Steps:

1.) Add a diode to the electrical system

2.) Connect an external power source, voltmeter and ammeter to the system

3) Gradually increase voltage above 48V

3) Observe the ammeter and ensure the current isn’t increasing

ESR-1.003: Monocrystalline solar cells will be used to provide higher electrical efficiency.

Location: COE Portable

Tester: ECE Members

Steps:

1. Make sure that all the proper safety precautions are met.
2. Connect the Motor load to the solar panels.
3. Connect the super capacitor the remaining load.
4. With a motor load, the solar cells and super capacitor should act as a parallel source along with the batteries to run the motor.

EBR-1.002: A Battery Management System must be installed to control and protect against risk of fire.

Location: College of engineering Lab

Tester: ECE Members

Steps:

1. Connect a voltmeter to the balancing connector and measure the voltage
2. Connect the balancing pack to the charger
3. Measure the voltage increase
4. Disconnect the balancing connector and turn on the motor for discharge
5. Measure the voltage again
6. For each measurement, each cell should be within ±1V.

EMR-1.002: The voltage on board of the vehicle at any point must not exceed 48V nominal or 60V max.

Location: College of engineering Lab

Tester: ECE Members

Steps:

1. Connect a voltmeter to the completed electrical system, including propulsion battery, accessory battery and solar panels
2. Run the electrical system with all sources in use
3. Observe voltmeter and ensure the Voltage does not exceed 60V

EMR-1.003: Change resistors to allow battery to operate at 26V once passed through the DC-DC converter

Location: College of engineering Lab

Tester: ECE Members

Steps:

1. Determine which resistors need to be replaced in order to supply correct amount of voltage (26V). Determine the new value that is needed.
2. Remove the identified resistors via micro-soldering
3. Restore board with new resistors that meet the specific requirements.

**4.5 Safety Test**

SR-2.001: A permanent ﬁre retardant Bulkhead must completely separate and effectively seal the vehicle’s propulsion and energy storage systems for the driver’s compartment.

Location: COE parking lot

Tester: All team members

Steps:

1. Use pre-certified fire-proof materials to seal the compartments.
2. Use a compressed air or liquid test to ensure that compartments are fully sealed.

SR-2.002: Fully harnessed drivers must be able to vacate their vehicle at any time without assistance in less than 10 seconds.

Location: COE parking lot

Tester: All team members

Steps:

1. Test the nominated driver with a stop watch to ensure that they are able to exit the vehicle within 10 seconds with the current design.

SR-2.003: The safety harness for the driver must be propriety, i.e. speciﬁcally manufactured for motorsport use, and withstand a force of at least 1.5 times the driver’s weight.

Location: COE parking lot

Tester: All team members

Steps:

1. Add additional material to driver while in harness to test whether it can withstand 150% of driver weight.

SR-2.004: Vehicle must be ﬁtted with a ﬁre extinguisher (ABS or BC type) with minimum extinguishant capacity of 2lb.

Location: COE parking lot

Tester: All team members

Steps:

1. Ensure that fire extinguisher has an extinguishing capacity of at least 2 lb.
2. Make sure that the extinguisher is included in the chassis while maximizing ergonomics.

**References**

[1] "Rules and Regulations." *- Shell Global*. N.p., n.d. Web. 17 Sept. 2013.

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[3] Hyman, Barry I. "Chapter 2." *Fundamentals of Engineering Design*. 2nd ed. Upper Saddle River, NJ: Prentice Hall/Pearson Education, 2002. 62-69. Print.

**Appendix**