FAMU-FSU College of Engineering
Sustainable Engineered Solutions

Solar Car Design:

Needs Analysis and Requirements

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1 Overview of Design Team

Project Leader \Lead EE–MATTHEW BOSWORTH Manages group as a whole and develops project plan and timeline. Relegates work load across team and delegates tasks according to skill sets. Establishes milestones and finalizes all documents. Updates team every 24-48 hours of current group standing. Makes final decision when agreement cannot be made. Responsible for all aspects of electrical and computer simulation design.
TECHNICAL RESPONSIBILITES: DSP programming, Energy System, overall design

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

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

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

Secretary–THIERRY KAYIRANGA Records meeting minutes, monitor and update online directory, including reference list.
TECHINICAL RESPONSIBILITES: Power Electronics, Energy System

2 Needs Analysis

2.1 Overview of the Solar Car Project

This document establishes the need analysis and requirement specifications for the 2012-2013 FAMU-FSU Solar Car. The design goal is to redesign the car from the ground up, using many lessons learned from the past years senior design teams, for entry into the "Shell-Eco Marathon Solar-Battery Electric Class" in 2014. The solar car should be able to run entirely on batteries, a super capacitor and solar power in time for the competition in 2014. This year's efforts focus on a novel energy system and redesign and build of the body of the car.

2.2 Statement of the Problem

Due to the relevant and challenging current automotive and energy trends, a need has been established for the use of sustainable and renewable energy sources. Although there are numerous other methods of generating electricity, solar power has a number of advantages for both the consumer, the producer and the environment.

The FAMU-FSU Solar Car Team of 2011-2012 provided the first fully functional Solar Car. After showcasing the design and model, the car was procured by a FSU student organization called Sustainable Engineered Solutions (SES).

The Solar Car Design this year relies upon three main focuses: a redesigned body and chassis, a solar panel-battery-super capacitor hybrid energy system, and a microprocessor controller. Selection of the focuses was made based on the Shell Eco-Marathon's design requirements and limitations. The solar car this year will not be fully functional, yet a redesigned body with necessary safety requirements will be built and a newly designed energy system using solar panels, batteries and a super capacitor will be prototyped. Due to limited time, this year's group won't be able to complete the entire car, however the design and all the purchased parts will be in line with the "Shell Eco-marathon

Challenge" rules and requirements.
The following year's plan is included in this document. The overall goal for these two years is to take the final designed car to competition in Houston, TX. The new design team in 2013 with focus on energy system integration with motor and chassis, install brakes and regenerative braking as outlined in 2011, and finish all necessary safety requirements and communications related to the "Shell Eco-Marathon" in 2014.

NOTE:
To delineate between the first and second year's requirements a notation of 1.xxx and 2.xxx respectively is used. If this notation is not used, each year's team must consider these requirements. The requirements and guidelines for the "Shell Eco-Marathon" competition are subject to change per year to year basis.

Required Capabilities:

RCAP-1.001: The vehicle's body must be designed and built to the Shell Eco-Marathon specifications described for the "Prototype Division".
RCAP-1.002: Permanent fire retardent barriers must completely separate the vehicle's proplulsion and energy storage systems from the driver's compartment.
RCAP-1.003: The driver must be able to vacate the vehicle at any time without assistance in less than 10 seconds.
RCAP-2.004: The vehicle's energy system must be designed and prototyped to fit the Shell Eco-Marathon's "Solar-Battery Electric Class".
RCAP-2.005: The vehicle must conform to all saftey standards outlined by the Shell Eco-Marathon guidelines.

Desirable Capabilities: (in order of highest to lowest priority)

DCAP-1.001: Design and build vehicle body, chassis and suspension.
DCAP-1.002: Design and build roll cage to meet saftey requirements.
DCAP-1.003: With no motor load the solar cells must charge the batteries and super capacitor.
DCAP-1.004: The energy system must optimally control three energy sources or storage devices: solar panels, batteries, and a super capacitor.
DCAP-1.005: The energy system must be monitored by microprocesser.
DCAP-1.006: The energy system must be protected from overload and short circuit conditions.
DCAP-2.001: Integrate energy system with motor and drive train onto chassis and suspension.
DCAP-2.002: Integrate regenerative braking system as in 2011.
DCAP-2.003: With a motor load the solar cells and super capacitor should act as a parallel source along with the batteries to run the motor.
DCAP-2.004: Integrate and control regenerative braking system with mechanical braking system.
DCAP-2.005: Integrate energy system with drive train.
DCAP-2.006: Complete installation of a necessary components: meters, safety materials, wiring, etc.

2.3 Operational Description

Upon entering the "cockpit," the driver should execute a start up 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 and mechanical systems. All other systems are automated after startup, but should report their state to the driver where applicable.

3 Requirements Specifications

3.1 Functional Requirements

REQF-001: The vehicles must be able to travel greater than 6 miles.
REQF-002: The vehicles must operate in all kinds of weather.
REQF-003: The vehicle must hold one driver.
REQF-004: The vehicle must have the ability to turn.
REQF-005: The vehicle must be able to move at an average speed of 15 mph.

3.2 Structural Requirements

3.2.1 Chassis Requirements

StREQc-1.001: There will be no aerodynamic appendages which adjust their position or are prone to changing shape due to wind.
StREQc-1.002: The vehicle body must not be prone to changing shape due to wind; sharp points must have a radius of 5cm or greater.
StREQc-1.003: Windows must not be made of any material which may shatter into sharp shards.
StREQc-1.004: The vehicles chassis or monocoque must be solid.
StREQc-1.005: The vehicle chassis must be equipped with a roll bar that extends 5cm around the driver's helmet and extend in width beyond the driver's shoulders when seated in normal driving position with the saftey belts fastened.
StREQc-1.006: For prototype vehicles the said opening may be enclosed wholly or partly by means of hinged, detachable and/or folding doors, provided that a release mechanism is easily operable from inside and that the method of opening from the outside is clearly marked by a red arrow.
StREQc-1.007: The maximum height of the vehicle must be less than 100cm.
StREQc-1.008: The maximum height measured at the top of the driver's compartment must be less than 1.25 times the maximum track width between the two outermost wheels.
StREQc-1.009: The maximum total vehicle width must not exceed 130 cm.
StREQc-1.010: The maximum total length must not exceed 350cm.
StREQc-1.011: The vehicle's body shape must be designed for peak aerodynamic performnce.
StREQc-1.012: The vehicle's interior must be large enough to support all necessary electronics, mechanics, and driver.
StREQc-1.013: The vehicle's body must be designed with a drag coefficient less than or equal to 0.15.
StREQc-2.001: The maximum vehicle weight, without the driver is 140kg (310lbs).
StREQc-2.002: Both propulsion and accessory batteries must be installed outside of the driver's compartment behind a bulkhead.
StREQc-2.003: The vehicle's mass must be as light as possible for reduced energy consumption.
StREQc-2.004: The vehicle's mass distribution must be such that the car maintains stability.

3.2.2 Wheel Requirements

StREQw-1.001: Prototype vehicles must have three or four running wheels, which under normal running conditions must be all in continuous contact with the road.
StREQw-1.002: The wheels of the vehicle must be able to support moving.
StREQw-1.003: The track width must be at least 50cm, measured between the midpoints where the tires touch the ground.
StREQw-1.004: The wheelbase must be at least 100cm.
StREQw-2.001: Wheels must be located inside the vehicle body and be isolated from the driver using a bulkhead.
StREQw-2.002: Any handling or manipulation of wheels by the driver is forbidden from the moment the vehicle is at the starting line until it crosses the finish line.

StREQw-2.003: The suspension must be developed well-tuned for the vehicle on a relatively flat surface.

3.2.3 Steering Requirements

StREQs-2.001: The turning radius must be sufficient to enable safe overtaking as well as negotiating the turns of the track.
StREQs-2.002: The required turning radius is 6m.

3.2.4 Braking Requirements

StREQb-2.001: Vehicle must be equipped with two independently activated brakes or braking systems; each comprising of a single command control, command transmission, and activators.
StREQb-2.002: One system has to act on all front wheel(s), the other on all rear wheel(s).
StREQb-2.003: The braking system must hold the car in place on a 20 degree incline.

3.2.5 Visibility Requirements

StREQv-1.001: The driver must have access to a direct arc of visibility ahead and to 90 deg on each side of the longitudinal axis of the vehicle.(DCAP-003)
StREQv-2.001: The vehicle must be equipped with a rear-view mirror on each side of the vehicle.

3.2.6 Misc

StREQm-2.001: The vehicle's seat must support driver safely with seat belts prescribed by "Shell Eco-Marathon" guidelines.
StREQm-2.002: The vehicle's pedals must be installed in the correct position.

3.3 Electrical Requirements

3.3.1 Solar

eREQs-1.001: By-pass and protection diodes must be designed to solve partial shading and loss of delivered power.
eREQs-1.002: The vehicle will use a third diode to serve as a protection diode for the unwanted flow of current back into the modules.
eREQs-1.003: The vehicle will utilize monocrystalline solar cells to provide higher electrical efficiency.
eREQs-2.001: The solar cells must be positioned at an angle to provide maximum exposure to sun.

3.3.2 Batteries

eREQb-1.001: The vehicle will utilize super capacitors and/or lithium batteries only.
eREQb-2.001: A battery management system (BMS) must be installed while using lithium based batteries.
eREQb-2.002: The batteries will be housed in a completely separate compartment from the chassis.
eREQb-2.003: The batteries and/or super capacitor must be electronically isolated from the vehicle frame and the accessory battery circuit.
eREQb-2.004: An auxiliary battery system will be used to power horn, lights, accessories, data acuisition, etc.
eREQb-2.005: Only one propulsion battery system and one accessory battery system permitted.

3.3.3 Misc

eREQm-1.001: The vehilce will have a location for joulemeters that can be positioned so that their display can be easily read from outside the vehicle.
eREQm-1.002: The maximum voltage on board of the vehicle at any point must not exceed 48V nominal and 60V max.
eREQm-2.001: Joulemeter placement must be inaccessible to driver.

3.4 Safety Requirements

SaREQ-1.001: The roll bar must be capable of withstanding a static load of 700N applied in any direction without deformation.
SaREQ-1.002: A permanent fire retardent Bulkhead must completely separate and effectively seal the vehicle's propulsion and energy storage systems for the driver's compartment.
SaREQ-1.003: Fully harnessed drivers must be able to vacate their vehicle at any time without assistance in less than 10 seconds.
SaREQ-1.004: The vehicle design must ensure safety for driver, bystanders, and other motor vehicles.
SaREQ-2.001: 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.
SaREQ-2.002: All batteries and super capacitors must be protected from short circuits with either fuses, fusable links, or circuit breakers.
SaREQ-2.003: Vehicle must be fitted with a fire extinguisher (ABS or BC type) with minimum extinguishant capacity of 2lb.
SaREQ-2.004: All vehicle electrical circuits must be protected against electrical overload.
SaREQ-2.005: Only full-face or three quarter helmets are permitted and they must comply with safety standards.

3.5 Non-Functional Requirements

REQN-001: All electrical/electronic cases must be made of transparent material or at least have a transparent top.
REQN-002: Vehicle must be equipped with an >420Hz electric horn that is effectively audible volume >110dB.
REQN-003: Vehicle design, manufacturing and testing will utilize the help of Sustainable Engineered Solutions which will also provide help with the location and acquisition of funding sources.
REQN-004: All documents for the 2012-2013 year will be documented using LaTeX.
REQN-005: Drivers of prototype vehicles must weigh at least 50kg in full driving gear.
REQN-006: A precise technical description of the vehicle's fuel system and electrical circuitry is required prior to event.
REQN-007: A point to point vehicle wiring diagram showing the location of all major relevant electrical components is required prior to event.
REQN-008: Component voltage, current and power ratings of major components are required prior to event.
REQN-009: Location and ratings of all circuit protection devices are required prior to event.
REQN-010: Illustration of how the emergency stop system works, and presence of both external and internal emergency switches is required prior to event.
REQN-011: A detailed description of all storage devices being used is required prior to event.
REQN-012: A printed up to date copy of detailed documents described above required at event.
REQN-013: With use of a Lithium based battery, documentation of BMS system required at event.
REQN-014: Solar panel and MPPT datasheets required at event.

3.6 Sponsor Requirements

SpREQ-2.001: Pace number must be on front and sides of prototype vehicle and a size of 200mm x 170mm.
SpREQ-2.002: Shell Pecten must be on front and sides of prototype vehicle and a size of 205mm x 205mm with a mandatory space of 100mm must be left free on all four sides.
SpREQ-2.003: All sponsors logo can be positioned together along the side of the vehicle. Dimensions will vary, but must be smaller that the Shell Pecten and must fit within a surface of 400 squared cm.

3.7 Constraints

CON-001: The solar array surface area is limited to the surface area of the chassis.
CON-002: The cost of materials and components.
CON-003: Limited time to finish total project in one year, thus pushing project to a two year mark.

4 Preliminary Test Plan

Table 4.1: Solar Car Test Plan

Test Name	Test Case #	Result
YEAR 1		
Solar Module Single	SM-1.001	TBD
Solar Module Combined	SM-1.002	TBD
Solar Module Protection	SM-1.003	TBD
Boost Converter	BC-1.001	TBD
Buck-Boost Converter	BC-1.002	TBD
Super-Capacitor alone	BC-1.003	TBD
Energy System Combined w/o load	ES-1.001	TBD
Energy System Combined w/ load	ES-1.002	TBD
Motor Load Test	ML-1.001	TBD
Aerodynamic Prototype Testing	AP-1.001	TBD
Roll Bar Test	AP-1.002	TBD
Stress-Strain Tests	AP-1.003	TBD
Cockpit Escape Test	AP-1.004	TBD
Suspension Vibration Test	SS-1.001	TBD
Wheel Deflection Test	WT-1.001	TBD
YEAR 2		
Energy System Combined w/ regenerative braking	ES-2.003	TBD
Test regenerative breaking system	ES-2.004	TBD
MCU power test	ES-2.004	TBD
Suspension Testing	SS-2.001	TBD
Brake rotor Test 20 degree	SS-2.002	TBD
Caliper Test	SS-2.003	TBD
Turning Radius Test	SS-2.004	TBD
Motor Torque Test	MT-2.001	TBD
Mirror Test	MT-2.002	TBD
Fuse box test	FB-2.001	TBD
BMS Power Test	BC-2.004	TBD
Full Control Integration Test	IT-2.001	TBD
Dashboard Control Integration Test	IT-2.002	TBD

NOTE: ALL TESTING TYPES AND REQUIREMENTS SUBJECT TO CHANGE.

Test Plan – Solar Car Team '12

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

EXPECTED RESULTS:

ACTUAL RESULTS:

STATUS: ☐ PASSED ☐ FAILED

FAILURE CAUSE (S):

SUGGESTED SOLUTION (S):

COMMENTS:

References

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

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

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

[4] POSHARP. Solar panel database, 2012.

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

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

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

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

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

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