**Solar Car Team – Specifications and Requirements**

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**1 Overview of the Design Team**

EE Team:

* Shawn Ryster – Project Manager
* Greg Proctor- Co-Treasurer
* Patrick Breslend-Co-Treasurer
* Jordan Eldridge-ECE technical lead

ME Team:

* Brad Burke – ME team Leader
* Valerie Pezzullo- Secretary
* Tyler Holes- Media Coordinator

**2 NEEDS ANALYSYS**

***2.1 Overview of the Solar Car Project***

The solar car project is a three year project with the end goal of competing in the American Solar Challenge (ASC). This year is the final phase of the solar car project where the existing systems are integrated with the solar cells and max power point tracker. The solar car should be able to run entirely on solar power by the end of the year. The solar car should be capable of competing in cross-country voyages for future events.

***2.2 Statement of the Problem***

This year’s project started where last year's project left off. The current car was left in the following condition: To our knowledge the major mechanical and electrical components are in working order however the car itself does not run. This could be simple as a lack of charge in the batteries or could be as major as a fundamental component of the car not working. We have not had a chance to test the car. However that being said, these are the electrical and mechanical problems that the group is aware of.

There are several mechanical and electrical issues that need to be resolved, as well as issues that are desirable to resolve. 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 handling. Therefore, a latching system needs to be implemented to stabilize the lid and so that the lid would be able to be removed from the inside and outside of the car. The solar panels need to be integrated so that they work in amalgamation with the hinging of the top. In the case of brake failure, a parking or emergency brake system needs to be implemented. Furthermore, a braking issue that needs to be resolved is to integrate and control the regenerative braking with the mechanical braking system. The breaking system needs to be analyzed from both a mechanical and electrical standpoint. Solar panels vary output current and voltage to the battery. Implementing a max power point tracker (MPPT) between the battery and the solar array can solve this problem. The next requirement is to redesign an aerodynamic bubble to encase the driver. Finally, the driver cockpit needs to be equipped with an outside air circulation and ventilation system that will additionally cool the rest of the car including the solar panels.

There are some issues that are not necessarily required but are desired to be resolved. The current rack and pinion used for steering is shorter than optimally desired. An extension of the length of the rack will allow for a wider steering range. The height of the steering column should be increased as well as the supporting rod; the benefit of raising the steering column is that it would allow the driver to move more freely inside the vehicle. Currently, the supporting rod is a safety hazard for the driver as well as an inconvenience when operating the vehicle. The driver also would benefit greatly from having a control cluster. As an additional safety measure and to the convenience of the driver, the top of the cars body needs to be attached to the bottom of the car with hinges. This would be ideal to tilt and lift the lid for quick entrance and exit as well as a benefit for the car’s solar efficiency during stationary charging. The rear wheel attachment may need to be redesigned to stabilize the wheel as well as securing it in place. Tires with tread are desired for traction control and stability because in earlier testing traction was an issue. Also, the tires could be encased to protect the electronics existing near the tires. A rear-viewing system could be added to aid the driver in maneuvering the vehicle. The final mechanical problem that is desired is a roll-cage design that follows safety regulations for future competitions.

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: Implement parking brake
* RCAP-007: Integrate and control regenerative braking with mechanical brake system
* RCAP-008: Design bubble for driver encasement
* RCAP-009: Driver cockpit equipped with an outside air circulation and ventilation system
* RCAP-010: Rear wheel bolt attachment to be redesigned

Desirable Capabilities (in order of highest to lowest priority)

* DCAP-011: the driver should be able to lift the top of the car or the enclosure and exit the vehicle without outside assistance.
* DCAP-012: 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-013: the vehicle should conform to as many safety standards as possible (brake lights, turn signaling, rear view mirrors)
* DCAP-014: Extend height of steering column and stabilizing rod
* DCAP-015: Extend length of rack & pinion in steering mechanism
* DCAP-016: Design roll cage to meet safety requirements
* DCAP-017: the controller in the car should record the state of the vehicle to be analyzed later.

***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 systems. All other systems are automated, but should report their state to the driver where applicable.

**3 Requirements Specifications**

***3.1 Functional Requirements***

These specify specific behaviors of a system. They define the internal workings of the system:

that is, the calculations, technical details, sizes, data manipulation and processing, and other

specific functionality. Examples include:

* FREQ-001: Power generated by the solar array must exceed the power consumed by control systems.
* FREQ-002: Cooling system shall maintain a temperature between 40 and 95 F
* FREQ-003: Latching system for the lid (CAP-005) will fit inside the lid and will be able to be operated from the inside or outside of the lid.
* FREQ-004: Implemented parking brake (CAP-006) will bypass the hydraulic brake system and the regenerative brake system to stop the car in emergency situations. The brake will be able to keep the car in a static position on an incline of 15̊.
* FREQ-005: Integration and control of the regenerative braking with mechanical brake system (CAP-007) will allow the regenerative braking to be applied up to a certain point after which the mechanical brake system will be applied.
* FREQ-006: Resign of the bubble for encasing the driver in the car (CAP-008) will be based on the desired drag coefficient to ensure minimum drag on the vehicle so that it can be operated efficiently.

***3.2 Non-functional Requirements***

* NFREQ-001: Fuses or breakers should be used to prevent over-currents within the subsystems.
* NFREQ-002: Current should be prevented from flowing back into the solar array.
* NFREQ-003: The driver’s enclosure shall be designed with aerodynamic efficiency as the primary concern.
* NFREQ-004: The driver cockpit is to be equipped with an outside air circulation and ventilation system (CAP-009) keeping the inside of the vehicle between 40 ̊F and 95 ̊F. This will allow the driver to be more comfortable when operating the vehicle and allow for a safe range of temperature for running electronics.

***3.3 Constraints***

These limit the development in some way, such as defining an operating system that the project

must run on, which programming language must be used to implement the system, what drawing

tools must be used, or specific vendors which must be used for manufacture. Constraints may

also include regulatory constraints, environmental impact constraints, physical constraints,

constraints for safety reasons, cost limits, time limits, etc.

* CONS-001: The solar array surface area is limited to the surface area of the existing body (6m­­2 or 64ft2) which equals 70 solar modules.
* CONS-002: The solar panels purchased should match the previously purchased solar panels (PT15-300).
* CONS-003: The existing frame, chassis, suspension, motor, 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 $10,000.
* CONS-005: The solar array and MPPT/converter system must operate at the voltage levels of the existing batteries and solar modules (converter must go from 107.8 V down to 99 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 existing 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 1.6 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 ft2 and no smaller than 5.42 ft2. 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 we would like to have the friction due to drag as low as possible, with the coefficient of drag below 0.2. The roll cage to encompass the driver will be able to withstand at least 800 lbf in compression.

**4 Preliminary Test Plan**

During Phase 2, testing was proposed for the various mechanical and electrical components based on the requirements and constraints presented to the team. The team created a table of the each test to be performed on the vehicle. For Phase 3, there will be changes made to many of the major components and additions made to the mechanical and electrical systems. Therefore, all of the tests that were performed in the previous phase must be repeated and new tests need to be performed on the new components. All of the old and new tests are listed in Table 1 below.

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| Table 1 – Preliminary Test Plan |
|  Test | Test Case # | Result |
| Rack and pinion steering test | SS-001 | TBA |
| Brake rotor | BS-001 | TBA |
| Master cylinder | BS-002 | TBA |
| Brake Caliper | BS-004 | TBA |
| Upper Control Arm Structural Testing | SP-001 | TBA |
| Lower control Arm Structural Testing | SP-002 | TBA |
| Upright structural Testing | SP-002 | TBA |
| Front Suspension | SP-004 | TBA |
| Rear Suspension | SP-005 | TBA |
| Test Regenerative Breaking signal when the regenerative breaking handle is asserted | PGS-001 | TBA |
| Test regenerative breaking system charges the battery | PGS-002 | TBA |
| MCU power test | SCS-001 | TBA |
| SW-192 relays test | CS-002 | TBA |
| 12 Volt to 9 Volt DC-DC converter test  | CS-003 | TBA |
| Fuse Box Test | CS-004 | TBA |
| Potentiometer Test | CS-005 | TBA |
| Motor Controller power Test | CS-006 | TBA |
| BMS Power Test | CS-007 | TBA |
| MCU/12 V to 9 V DC-DC Integration Test | CS-008 | TBA |
| MCU/Relay/Fuse Box Integration Test | CS-009 | TBA |
| Breakout Board Test | CS-010 | TBA |
| Speedometer Test | CS-011 | TBA |
| 100 V to 12 V/ Fuse Box Integration Test | CS-012 | TBA |
| Full Control Integration Test | CS-013 | TBA |
| Dashboard Control Integration Test | CS-014 | TBA |
| Battery Charger Integration Test | CS-015 | TBA |
| State of Charge Meter Power Test | MS-001 | TBA |
| State of Charge Meter Shunt Current | MS-002 | TBA |
| Latching System for Lid | MS-003 | TBA |
| Parking Brake Test | MS-004 | TBA |
| Regenerative/Mechanical Braking Integration | MS-005 | TBA |
| Bubble Aerodynamic Test | MS-006 | TBA |
| Air Circulation Test | MS-007 | TBA |
| Solar Integration Test | EE-001 | TBA |
| Solar Module Test | EE-002 | TBA |
| Solar Array Test | EE-003 | TBA |
| Max Power Point Tracker Test | EE-004 | TBA |
| Stationary S.A. Charge Test | EE-005 | TBA |
| Dual Source Battery/ S.A. Charge Test | EE-006 | TBA |
| Dual Source Battery/Regen Charge Test | EE-007 | TBA |

**5 References**

Solar Car final report spring 2011
Solar Car Design Review & Test plan, Spring 2010
Dragon12-plus-usb Trainer user manual for rev G board
EV power LPF Battery balancing system Datasheet
BMS master control unit (BMS-MCU-4C)
Albright sw180andsw190 series of dc contactors
PT15-300 Flexible Solar Panel 15.4V @ 200mA
PT15-300 I-V curve for 100% and 25% efficiency
New Generation Motors company corp. NGM-EV-C200-TB test box operation manual version 1.0
New Generation Motors company corp. NGM-EV-C200 series controller Operating manual Version 1.1D
SCM150-XXX Axial Flux, Brushless PM Motor
tbs electronics e-xpert pro high precision battery monitor
Thunder Sky Operation Manual
KPL Charger Instruction Manual
NMB 3610KL 04W-B10 Fan Data Sheet:
NuGen Mobility Inc., Ashburn, Virginia 2007
Mechanical Spot Caliper

**6 Definitions**

MPPT - Maximum Power Point Tracker

MCU- Motor Control Unit

Bubble - The Driver Enclosure Unit

RCAP-xxx - Required Capabilities

DCAP-xxx - Desired Capabilities

FREQ-xxx - Functional Requirements

NFREQ-xxx - Non-Functional Requirements

CONS-xxx - Constraints

MS-xxx - Mechanical System

EE-xxx - Electrical System

CS-xxx - Control System

**7 Appendix**

Preliminary Block Diagram