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THE *SOL OF NEW ORLEANS*: AN UNDERGRADUATE DESIGN EXPERIENCE

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ABSTRACT

This paper presents the incorporation of the design, construction, and testing of a solar-powered car into the undergraduate curriculum of the Electrical Engineering Department of the University of New Orleans. All work on the vehicle is entirely performed by students who earn design credits in our Senior EE Design Project and/or Special Problems in EE courses.

Keywords: *Design, undergraduate engineering curriculum, solar power, solar-powered automobiles.*

INTRODUCTION

In recent years, the undergraduate Electrical Engineering (EE) curriculum at the University of New Orleans (UNO) has been revised to emphasize open-ended engineering design throughout the course of study. A capstone course, Senior Electrical Engineering Design, has been added to the courses required for graduation. Other courses, such as Special Problem in EE and Special Topics in EE also emphasize engineering design.

One of the options offered to our students is to participate in the *Sol of New Orleans* project to earn credit for the Senior Design or Special Problems courses. The *Sol of New Orleans* is the name of UNO's solar-powered car for Sunrayce 97. The vehicle was entirely designed, funded, built, and tested by students who have enthusiastically participated in this endeavor. The project is managed by Senior students with the aid of a faculty advisor and support from the administration and faculty of the College of Engineering.

Today's engineering graduate will be entering a world of collaborative enterprises. Since each team is solely responsible for the design, marketing, construction, and racing of their car, Sunrayce is an excellent preparation for the transition from the university environment to the work force.

This paper presents various aspects of the *Sol of New Orleans* and Sunrayce, including curriculum integration, fund-raising, project management, technical issues, and student response to this novel project.

ABET REQUIREMENTS

In order for an engineering project to contain "true design", the specification of the problems must be open ended. There must be many possible solutions and the student must know the criteria used to chose among them [1]. Since a single design course cannot provide the required design experience to the students, a design thread now runs throughout the entire curriculum, culminating in the capstone design course, Senior EE Design. Several courses have been modified to incorporate design material and especially design projects. Other issues, such as safety, esthetics, and ethics are also considered in various courses and laboratories.

Another important aspect of ABET requirements is also addressed in this design course: the issue of improving communication skills. Individually-written reports and oral presentations are required from all students, and some component of the grading is based on these written and oral reports.

Clearly, the design of a road-worthy, safe, solar-powered car meets the open-ended requirement for a design project. All systems, mechanical and electrical, must be proposed, designed, built, tested, and documented by the students. The project emphasizes creativity, innovation, resourcefulness, and management proficiency.

SUNRAYCE

Electric vehicles are often considered to be tomorrow's replacement for today's internal combustion engine automobiles. While automobile manufacturers have experimented with solar and electric vehicles, the public always viewed them more as novelty items than feasible alternatives to non-renewable fossil fuel burning engines.

In 1987 this perception of solar power began to change. It was then that the Australian adventurer Hans Tholstrup created an international race for solar powered cars: the World Solar Challenge. Twenty-five teams from eight countries raced solar vehicles over 3000 kilometers between Darwin and Adelaide, Australia. The General Motors entry, *Sunraycer*, won this inaugural event and became the focal point of a far-reaching public awareness campaign which ultimately reached millions of people.

Following their victory, GM donated their car to the Smithsonian and, along with the Department of Energy, decided to sponsor Sunrayce USA, a biennial solar-powered car race. The first competition was held in 1990. Sunrayce 97 was held between June 14 and 29, 1997. The course stretched from Indianapolis, Indiana to Colorado Springs, Colorado, a distance of 1980 Km.

The University of New Orleans entering Sunrayce 97 with the *Sol of New Orleans*. This is not only the first time a Louisiana university was represented, but the *Sol of New Orleans* was also the only university from the entire Gulf Coast area. Students from about 70 colleges and universities expressed their desire to participate this year, with about 55 of them going through Scrutineering, the mechanical, electrical, static and dynamic tests and inpections. Thirty-six solar vehicles qualified for the 97 race and 34 vehicles crossed the finish line the last day of the race.

COURSE STRUCTURCE

Students choosing to take this project for credit select what car subsystem (see below) they wish to work on; each group has 4 to 6 students. The faculty advisor for the project is the professor for the class. One or two students are assigned as Managers, and all others share non-technical responsibilities such as public relations, fund raising and logistics. The class usually meets formally twice a week and each team meets quite often to perform work on their subsystem. Each team is required to first submit a proposal for their subsystem, then a timeline with milestones, followed by a detailed system diagram once the design is almost complete. All students must independently write reports at the end of the semester and give an oral presentation and system demonstration.

FUND-RAISING AND MANAGEMENT

The main goal of the project is to teach the design process and allow the students to get hands-on experience in system design and integration. The nature and magnitude of the *Sol of New Orleans* project is such that it requires much more than design, construction, and testing.

Fund raising events which include among others "adopt-a-cell", corporate sponsorship, various sales, and search for grants [3], have been a priority from the beginning of the project. About $28,000.00 were received in Corporate sponsorships and individual donations. Financial support was also received from UNO's College of Engineering and the Electrical Engineering Department.

Project management, with a student project manager, student co-manager, team leaders for each subsystem, and faculty advisor, is also extremely important and incorporated into the course. Myriad tasks such as vehicle registration, insurance, and logistic matters were handled by the managers.

SYSTEMS AND TEAMS

The students participating in the *Sol of New Orleans* work in teams specializing in a given system of the car and then integrate their designs into the solar vehicle. The systems designed were: solar array, battery system, motor and motor controller, telemetry (sensors and computer communications), chassis, brakes, suspension, steering, and body. Efficiency, safety, and minimization of cost are the main goals for all the systems.

Battery Array: The objective of the battery array is to deliver power to the vehicle's motor/controller when the solar array's output power is insufficient, and to store the energy which the solar array absorbs from the sun. The U.S. Battery's 22NF-HC lead-acid battery was chosen due to its outstanding theoretical performance and its reasonable price and advertised delivery time. We tried to maximize power to cost ratio and minimize weight to cost ratio. The battery array of the *Sol of New Orleans* produces a nominal bus voltage of 108 V and is configured as nine 12-V batteries in series. Of all the batteries we researched, the 22NF-HC had the greatest current output at 62 Amp-Hours at a 20 Amp/Hour rating. The batteries were cycled (charged and discharged) to increase the output power. Proper fusing and main disconnect capabilities, as required by Sunrayce regulations [2], were ensured.

Solar Array: The solar vehicle can only be powered by the array and the charge stored in the batteries through the solar array. The solar array consists of substrate, solar cells, wire ribbons, diodes, encapsulation, bus bars, and maximum power-point trackers. The *Sol of New Orleans* uses ASE America's high performance solar cells which have the highest power to area ratio of all those we studied. Our solar array consists of four panels in series, at about 27 V each, with a peak measured current of 9 A. Each panel contains 162 solar cells, has an area of 1 m by 2 m., and is configured as follows: Six strings of 9 cells are connected in series to obtain the desired voltage, and three of these are connected in parallel to reach the desired current. To optimize for maximum power delivered to the batteries and/or motor, a maximum power point tracker is necessary. Our array also contains 6 auxiliary small panels of 9 cells each, used to boost the voltage if necessary. The cells are mounted on a honeycomb substrate from Wescor Composites and then encapsulated with a Dow-Corning Toluene solution.

Motor and Motor Controller: We decided to use a DC brushless permanent magnet motor, the most efficient class of motors available for electric vehicles. We selected and purchased a Solectria BRLS8 motor with a 90 % efficiency rating and a power output of 8 hp, but optimized for 2 hp. In order to ensure the motor and controller could efficiently operate together we decided to purchase Solectria's UMOC225 universal motor controller which comes with a variety of extras: an ignition box, pot box, forward-neutral-reverse switch, and soft start to prevent sparks when the UMOC is connected to the battery pack during installation.

Telemetry: The vehicle's telemetry system accurately captures, processes, and displays real-time data for the following: Battery voltage for each of the three sets of three batteries, total battery current, speed of the car, motor temperature, motor controller temperature, voltage for each of the four solar panels, and current into and out of the power trackers. Data read by the appropriate sensors are sent to and processed by a Fluke wireless data logger. These data are then transmitted to a computer in the support vehicle for analysis and storage. The telemetry system allows the team to have access to the performance and status of each aspect of the vehicle's subsystems during operation so that they can determine which course of action to take as problems develop in a particular subsystem, to receive alarms alerting the team of potential or actual problems, and to make the best possible decisions regarding adjustments needed due to road, weather, or other racing conditions

Mechanical systems: Large amounts of time were spent in the design and fabrication of each individual piece that make up the various components of the mechanical subsystems. The description of several main components is given below.

Chassis: Tubular space frame design made with AISI 4130 steel. This steel, while difficult to weld, provides high strength characteristics necessary to overcome the large stress.

Suspension: The front end suspension was made by using a dual A-Arm, common on most full-size automobiles. This suspension required extensive calculations and time for fabrication, but paid off when the University of New Orleans proved to have an extremely strong and reliable front suspension system. The shocks used were originally designed for motorcycles. Since the design of the solar car is low to the ground, the shocks and springs had to be carefully calculated. The system chosen allowed for the car to have smooth ride, great handling, and ease of control. The rear suspension is made to resemble a swing arm suspension, a popular automobile design which provides stability and strength. The rear suspension was constructed out of 6061-T6 aluminum.

Steering: The steering consists of a rack and pinion design. This special steering rack provided for good handling and control of the vehicle, with absolutely no play or looseness in the steering.

Wheels and Tires: The wheels and tires of the solar car were the only part on the car specifically built for solar cars. The wheels were purchased from New Generation Motors and the tires were donated by Bridgestone.

Braking System: consists of a dual-piston master cylinder that, when the pedal is depressed, distributes the hydraulic fluid with a 60:40 front to rear ratio, easily keeping the car under control in fast braking conditions. This fluid flows through the 3/16 in. braking steel and flexible braided rubber tubing and is used to compress the calipers; there are two calipers on each of the two front wheels and two calipers on the rear axle. The brake rotor and master cylinder are manufactured by Wilwood and intended for strip racing cars, while the aluminum alloy brake pads from Paul Martin Products are designed for high speed go-carts.

BUDGET

The cost of components for the solar car is about $32,000.00. Details can be provided upon request. The major expenses are: solar cells ($4,400), motor ($2,450), motor controller ($3,670), wireless data logger ($3,230), logger base station ($1,615), power trackers ($2,000 used), metal and tubing (about $3,000), wheels ($1,530), batteries ($1,440), DC-DC converters ($660).

RESULTS

The *Sol of New Orleans* team started the design of the solar car, with emphasis on the electrical systems, during the Summer of 1996, and continued during the Fall and Spring semesters of 1997. Actual construction of the car commenced with the solar array in late October 1996 and the frame was started in late January 1997. We had a working car in mid April 1997. In late April we attended the Western Regional Qualifiers (WRQ) in Mesa, AZ and passed Scrutineering --the mechanical and electrical inspections and dynamic testing-- on April 26. We tried to qualify during the WRQ but failed to do so by completing only 88 of the required 100 miles. On June 18 we qualified to participate in the race by completing more than the required 100 miles in the Indy 500 track during the Last Chance Qualifiers.

All systems in the car worked exceptionally well. We had a minor problem with the alignment which caused excessive wear of the tires, leading to several punctures during the first 20 miles or so of the qualifying laps. The wheels were re-aligned and we had no flats or blowouts during the rest of the qualifyiers or throughout the race. Also, two of the three inspectors were somewhat concerned about the welding of the rear aluminum suspension and we had to modify it (about 10 hours of work).

The *Sol of New Orleans* average speed was about 18 mph, with peak speeds in flat terrain of about 45 mph. The car can be operated continuously for about 6 hours without recharging in poor weather conditions; under sunny conditions, and depending on the terrain, it can operate for about 10 hours. During the seventh day of Sunrayce, the *Sol of New Orleans* ran for 8 hours (166 miles) on hilly terrain.

There were several days in a row with distances in the travel route of over 140 miles; unfortunately, our car could not finish all these without recharging, but the *Sol of New Orleans* crossed the finish line on its own power on June 29 in Colorado Springs, CO.

STUDENT RESPONSE

Informal comments from the students about this project have been very positive. Several students have enthusiastically participated in the project without receiving course credit for their contributions, and spent countless hours building the vehicle and participating in the Sunrayce events. Students participating in this project were also asked to fill out an anonymous survey. A summary of the results follows (these percentages reflect activities of the spring 1997 semester only).

Eighty-one percent of students enrolled in the course because they felt it would be an exciting and challenging project, offering a opportunity to gain some practical engineering experience. Ninety percent of respondents cited teamwork, communication skills, solving both technical and interpersonal problems and the importance of fund raising as the primary lessons learned. Other responses mentioned conflict resolution, research, and organizational skills. 90 % of students felt the course met their expectations of gaining practical as opposed to theoretical engineering experience. Eighty-eight percent of students felt this course was more beneficial than the standard design elective. Several students commented that they gained valuable experience in learning how to approach and solve design problems, particularly one that starts from a basic idea in a technical area they knew very little about.

Average percent of students' time spent: 35 % on design activities, 55 % on vehicle construction and 10 % on other activities (fund raising and administrative). Most students felt this project required more time than a standard design course

CONCLUSIONS AND FURTHER WORK

While it is true there are other engineering design competitions, none are as all-encompassing as Sunrayce. Public relations, marketing, and above all, raising capital, are all important areas that engineering students are often not adequately prepared to face after graduation. Sunrayce fills this void without de-emphasizing technical knowledge and skills. In fact, our team learned a hard lesson about the trade-off between funding and designing. We realized very quickly that what makes a good design is not necessarily being technologically superior, but one that is practical to produce within your means. In this way, Sunrayce nicely compliments the core curriculum of the Electrical Engineering program and standard design requirements, teaching the student to integrate engineering principles and the reality of the business world. Overall, all students involved feel a great sense of accomplishment and pride in their work and believe it was an invaluable career preparation.

We plan to greatly enhance our vehicle in the future. The following are the main systems to be re-designed and re-built: solar array, frame, chassis, body, rear suspension.

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REFERENCES

[1] Engineering Accreditation Commission for Accreditation Board for Engineering and technology, Inc. (ABET), *Criteria for Accrediting Programs in Engineering in the United States*, 1996-1997.

[2] *Sunrayce 97 Regulations*, Sunrayce 97, Nov. 1995, 16 pp.

[3] Kaminsky Bourgeois, E. J., "*The Sol of New Orleans: A solar-powered alternative to internal combustion engine automobiles*", proposal submitted to the Department of Natural Resources, State of Louisiana, Feb. 1997.