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Challenges Faced by the Undergraduate Solar Car Team at Middle Tennessee State University

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Abstract

Our solar car team at MTSU comprises mainly of Engineering Technology students. The Solaraider III (MTSU's third solar car) is a 19-ft-long, 6-ft-wide and 4-ft-high vehicle. The project provided many challenges to the team in several areas including design and analysis, fabrication, assembly and testing. electricity and electronics, and fund raising. Faculty advisors for the solar car team were faced with difficult tasks such as recruitment and retention of students, curriculum integration of the project, and fund raising. We built the Solaraider II in 1997 and participated in the Sunrayce 97 qualifier in Indianapolis. Our car did not pass the braking test because it weighed 1250 lb and the braking system was not adequate. The overweight of the solar car was mainly because of the fiberglass body, array and nose. The Solaraider III team was faced with the task of reducing the weight, installing new brakes and reducing the friction at all joints. Unlike many big schools, we do not have resources to build the car using carbon fiber and titanium. However, we have several industry sponsors whose facilities and service we utilized to make necessary changes. We fabricated the frame for the array using aluminum tubing. The frame was covered with thin, perforated aluminum sheet clad with aircraft-grade Dacron. In this process, we worked with the faculty and students from the aerospace department. We mounted the solar panels on the 91-square-foot array and rewired them. We fabricated the body and nose with light PVC tubing and Dacron. We machined new large size rotors and installed motor cycle master cylinders and calipers. We replaced all steel bushings of the front suspension with Teflon bushings. This author recruited several team members through announcements in faculty and student chapter meetings, and by posting flyers and brochures on campus. The author worked with the team members closely in many areas, helped in the design of new parts and structural analysis of the car. Many of the team members received credit in related Engineering Technology courses such as CADD, Dynamics, and Senior Project taught by this author. We raised funds from industry sponsors and professional societies. We reduced the weight by 250 lb and tested the car at the Nissan's test track for speed and endurance. The Solaraider III project has been a good learning experience for all of us. Currently, we are preparing for a solar car race to be held in June 2000.

I. Introduction

Middle Tennessee State University (MTSU) is located in Murfreesboro, about 30 miles to the southeast of Nashville. MTSU was founded in 1911 and is the fastest growing university in the state of Tennessee. Currently, the student enrollment is approximately 19,000 and we have 750 full-time faculty members. The university has five colleges; Basic and Applied Sciences, Business, Education, Liberal Arts, and Mass Communication. Engineering Technology and Industrial Studies is one of the 10 Departments under the college of Basic and Applied Sciences. We offer Engineering Technology, Industrial Technology, Pre-engineering, and Pre-architecture programs. Our Department has an enrollment of 600 students, of which 200 are majors in Computer, Design, Electro-Mechanical, and Manufacturing Engineering Technology concentrations. The solar car project is an on going undergraduate student activity at MTSU since 1995 and this author has been serving as chief faculty advisor for the team. The students design, fabricate and test a solar car according to Sunrayce regulations. Sunrayce is a biennial solar car race nationally sponsored by General Motors (GM), the U.S. Department of Energy (DOE) and Electronic Data Systems (EDS). The race is held in June of every odd year and open to all four-year colleges and universities on the North American continent. In this article, we address the challenges faced by our undergraduate team while building MTSU's third solar car, the Solaraider III.

II. The Challenges

We competed in the Sunrayce 97 qualifier that was held in June, 97 in Indianapolis. Our solar car, the Solaraider II failed the braking test and because of that we could not compete in the ten-day race from Indianapolis to Denver. In our follow-up meeting we analyzed the situation and identified the problems with the Solaraider II. Our car weighed 1250 lb. and we had used two independent go-cart hydraulic brakes. These factors and friction at the A-arm joints (due to the steel inserts) contributed significantly to our failure in the braking test. Most of the additional weight came from the array and body made of fiberglass and the extra large canopy made of Plexiglas. Using these materials to build our solar car was not the team's preference. MTSU does not have a budget for supporting the solar car project. The solar team raised funds working with the Development office, the dean and the department chair to carryout the project. Although we are located in an industrialized area and we have many sponsors we could not raise sufficient cash to buy items such as carbon fiber for the array and body, titanium alloy tubing to build the main frame, and lightweight bubble for the canopy. The array and body of the Solaraider II were fabricated at our sponsor's boat manufacturing facility. Initially, they had agreed to use mostly carbon fiber in these parts but could only use fiberglass because of their budget cuts. The canopy was built at another sponsor's facility with available materials and facility. The team also had to raise funds to cover logistical and travel expenses. Another major reason for failing the braking test in Indianapolis was that we could not test the car thoroughly before the qualifier.

In the spring of 1998, we decided to compete in Sunrayce 99 and submitted our proposal in January of 1998. In this proposal,[1] the author discussed different aspects of the project including Design and Engineering (driver safety, design and analysis, and material selection) in accordance with Sunrayce 99 regulations.[2] Topics such as Organization and Project Planning, Curriculum

Integration, Fund Raising and Team Support, Vehicle Testing and Driver Training, and Logistics were also discussed. In February, the Sunrayce Headquarters informed us that we have been selected as one of the 58 teams to compete in Sunrayce 99. We had to recruit new team members because only two of those who worked on the Solariader II were available. The others had either graduated or were enrolled in the coop and internship programs. We had approximately a year to modify the existing car or build a new car and test it thoroughly. But there were many problems and challenges. This author was faced with the task of recruiting new members who will have continued interest in the project. Many of our Engineering Technology majors are nontraditional students; they work full/part time in industry, have good hand-on experience and can contribute significantly to the project. However, many of them are married, have families and take a full load of courses. Previously, we worked on the solar car in our department's woodshop and used the machine shop and welding facilities. Because of a new program that was scheduled to begin in the fall of 1998, we had to move the solar car facility to a building located 10 miles from the university campus. This posed other problems because previously team members worked on the car as and when they found time and now they have to plan ahead, and some of them had to depend on others for transportation. Also, in our first meeting with the MTSU Development office, we found out that fund raising for Sunrayce 99 would be solely the team's responsibility.

III. Solutions and the Solaraider III

In order to recruit new team members, we posted fliers and brochures at various locations on our campus. This author made announcements in classes and faculty meetings. We recruited 10 team members some of them with experience in machining, hydraulics, fabrication, electricity and electronics, and design and analysis and the others with an aptitude to learn these skills. This author identified many problems of the solar car with courses such as CADD, Senior Project, and Dynamics so that the team members may receive credit for their work. He also worked with the team on weekends and in the evenings on weekdays. We decided to keep several components of the Solaraider II including the main frame made of 1.25-inch square aluminum tubing, the electric motor and control unit, solar panels, the hydraulic power steering unit, solid aluminum wheels and the rear wheel drive mechanism. The other parts would be either modified or replaced.

One major task was to reduce the weight of the car and we discarded the fiberglass belly and nose, and the Plexiglas canopy of the Solaraider II. We removed the solar panels from the array, cut the fiberglass and retained the supporting aluminum frame. The team decided to use thin aluminum sheet on this frame to support the solar panels. One of our team members worked for an aluminum sheet metal fabrication shop and through his efforts we obtained 0.025-inch thick aluminum panels as a gift-in-kind. This team member punched a large number of 2-inch-diameter holes in these 4 ft x 1.25 ft panels to make them light. We strengthened the array frame with 1-inch aluminum angles and square tubes, and riveted the aluminum panels to the frame. We did not want to glue the solar panels directly on the aluminum panels to avoid short-circuiting. One of our team members suggested the use of aircraft grade Dacron on the array as an insulating layer between the solar and aluminum panels. This author contacted a faculty member at MTSU's Aerospace department who agreed to provide his expertise and necessary tools and materials. We covered the aluminum panels with Dacron by gluing them along the edges. The fabric was made taut by applying heat on the surface with an electric iron (Fig. 1). The specialty of Dacron is that it can be glued, peeled and patched easily. The amount of heat applied determines how taut the fabric would be and when the fabric is peeled off the surface it will return to its original shape and size. This was a good learning experience for all of us. Two team members mounted the solar panels to the Dacron-covered array using a special type of silicone glue manufactured by General Electric. Each panel consists of twenty 4 in. x 4 in. solar cells connected in series, and the solar array of our car is made of 42 such panels. Two team members wired these solar panels, with 210 cells connected in series forming one bank, and four such banks were connected in parallel. Diodes were soldered across each panel to ensure continuity in the event of short-circuiting. Each solar bank was wired to a linear current booster.

The braking system of the Solaraider II was inadequate and difficult to prime because of the small nylon brake lines. One team member worked for a company that manufactured hydraulic tubes and fittings for various applications. He contacted a motorcycle parts dealer and obtained three Harley Davidson master cylinders and matching calipers as a gift-in-kind. He worked with his supervisor and got necessary steel tubing and fittings as a donation. He designed a 10-inch-diameter rotor for our new braking system and e-mailed the drawing file to our another sponsor. Four 0.2-inch-thick rotors were machined out of SAE 4130 steel at their facility. Two independent braking systems, one for the two front wheels and the other for the rear wheel, were assembled and mounted on the car. After spending several hours, the systems were primed and tuned.

Hubs, axles and wheel mountings on the Solaraider II made the change of wheels difficult and time consuming. One team member modified these components (Fig. 2) so that the wheels can be changed as quickly as in our gasoline engine cars. Some of this work was done in our machine shop and the rest was done at one of our sponsor's facility. Each of the two front suspension units has twelve joints because of two A-arms and a vertical spindle. We decided to replace the steel inserts at these joints with Teflon bushings. One of our sponsors provided the materials and the bushings were machined at the State Technology Center in Murfreesboro. The instructor and students from the Center visited the solar car facility to study the car and collect relevant information. One team member coordinated this activity and fitted the new bushings.

We noticed the twisting of rear suspension about the longitudinal axis of the car when it was loaded. Also, it was difficult to access the rear brake and the drive wheel. One team member modified the rear axle assembly and solved the problem to a great extent. But we decided to design and build a new rear suspension and replace the old one when necessary. Two team members designed and built a new sturdy and easy-to-access rear suspension. One of our sponsors donated aluminum tubing and the unit was fabricated at another sponsor's facility.

Two members worked on the canopy, belly and nose of the solar car. The canopy was built using 0.5-inch-diameter PVC tubing, Dacron fabric and 0.1-inch Lexan sheets. Leon sheets were used only where visibility for the driver was essential. The other two parts were fabricated using frames made of 1-inch-diameter PVC tubing and Dacron was stretched around the frame. We made all of these modifications and tested our solar car, the Solaraider III.

IV Curriculum Integration

Engineering was done for almost all components of the solar car in the term, final and senior projects in courses such as CADD I (ET 231), CADD II (ET 336), and Senior Project in Engineering Technology (ET 480). Trial and error technique was used while tuning the braking system to achieve the required braking distance and time. This technique was also used to prevent the relative motion between the steering control arm and wheels when the brakes were applied suddenly. Before covering the aluminum panels of the array with Dacron, we wanted to conduct some tests. Two students built a 1.25 ft x 1.25 ft frame, tested it and received credit towards their final project in ET 231. Another student designed the array and received credit towards his term project in ET 336. One team member received credit towards his ET 480 for designing and building the new rear suspension. Two other students received credit towards their Senior Project for working on the array. This author gave solar car related problems in ET 384 as a project. These problems were based on Sunrayce regulations and involved acceleration, deceleration, stopping time and distance traveled during the braking test of the Solaraider III. One student received credit in the capstone course for designing and fabricating the canopy. This author performed a detailed analysis of all moving parts of the Solaraider III considering different theories of failure.[3] The frontal, rear, side, and roll over impacts were also considered in the analysis. Some team members participated in this task. Another faculty member in the department helped us with the inspection and analysis of weld joints of the main frame.[4] Projects in ET 231, 336 and 384 contributed 10-25% towards the final grade. The Senior Project contributed 100% towards the final grade. In all courses, the students were required to submit a written report and their projects were evaluated based on visual inspection and the report.

V. Tests

We drove the solar car around the facility a few times and drove it to the campus and it ran well and the brakes functioned properly. But we had not tested it under the Sunrayce qualifier conditions. We drove the car in a big parking lot on campus, brought its speed to 30 mph and applied the brakes suddenly to bring the car to a complete stop in 3 seconds. We passed this test but noticed that the front two wheels were moving outwards when the car stopped. After several runs we realized that it was due to the relative motion between the vertical spindle that houses the hub and axle assembly and the control arm of the steering mechanism. We solved this problem by fastening two components by keys and socket head screws. Another requirement of the qualifier was that the solar car should complete 50 miles in 2 hours. We wanted to conduct this test at Nissan's test track located 6 miles from our university. One of our team members contacted Nissan and on a Saturday we tested the Solaraider III (Figs. 3 and 4) by driving it continuously. Although the average speed of the car was 30 mph in the first hour, it dropped to 18 mph in the second hour. We identified this problem with the electrical charging system and worn out Teflon bushings. We are in the process of replacing the Teflon bushings with graphite-impregnated bronze bushings. We are also testing the charging system. We weighed the solar car at Nissan's weighing bridge and found out that we have reduced its weight by 250 lb.

VI. Conclusions

We did not have sufficient time to solve the two problems before Sunrayce 99. We raised nearly $5000 from local sponsors, professional societies and with the help of our department chairman. These funds were sufficient to buy the silicone glue, spare parts and fasteners. Logistical and travel expenses would have cost us approximately $8000. Therefore, we decided not to compete in Sunrayce 99 and instead, prepare for a short race to be held June 2000 in Kansas. The Solaraider III project has been a good learning experience for all of us. This project promoted teamwork, and helped students work with local industries and participate in fund raising and public relations activities. They learned the practical significance of strength-to-weight ratio, thermal expansion, drag, and friction as related to the performance of the solar car. The team members learned new fabrication techniques besides priming and tuning of a hydraulic braking system. The team members also had a lot of fun as their spouse, children or girlfriend visited the solar car facility and many a time participated in our activities. The author wishes to thank all those who helped us with the Solaraider III project.

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Figures.

Figure 1. A solar car team member heating the Dacron fabric with an electric iron.

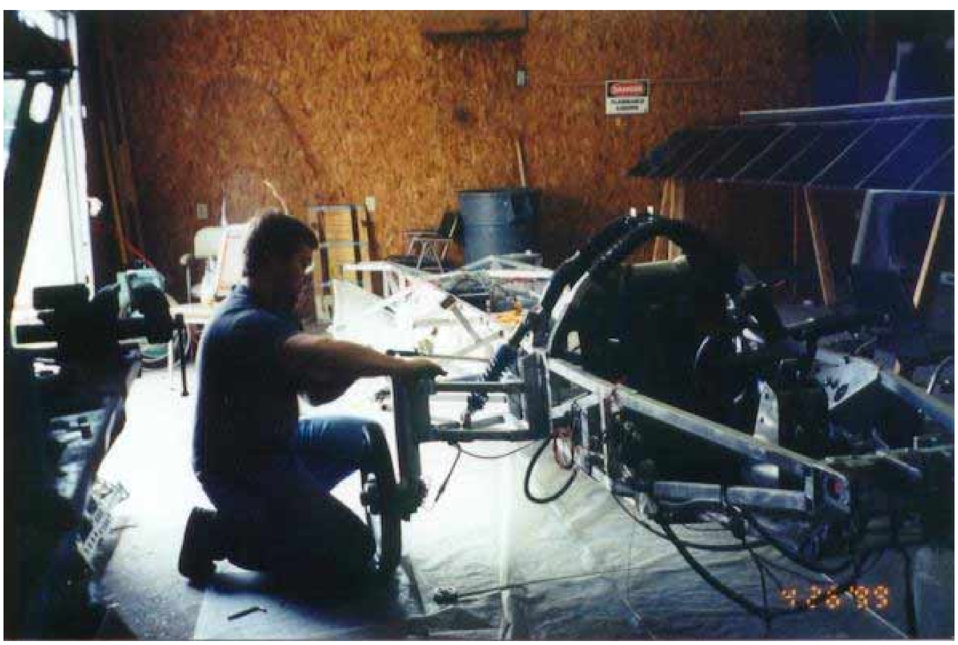

Figure 2. A solar car team member working on the front wheel of the solar car.

Figure 3. The Solaraider III at Nissan's test track.

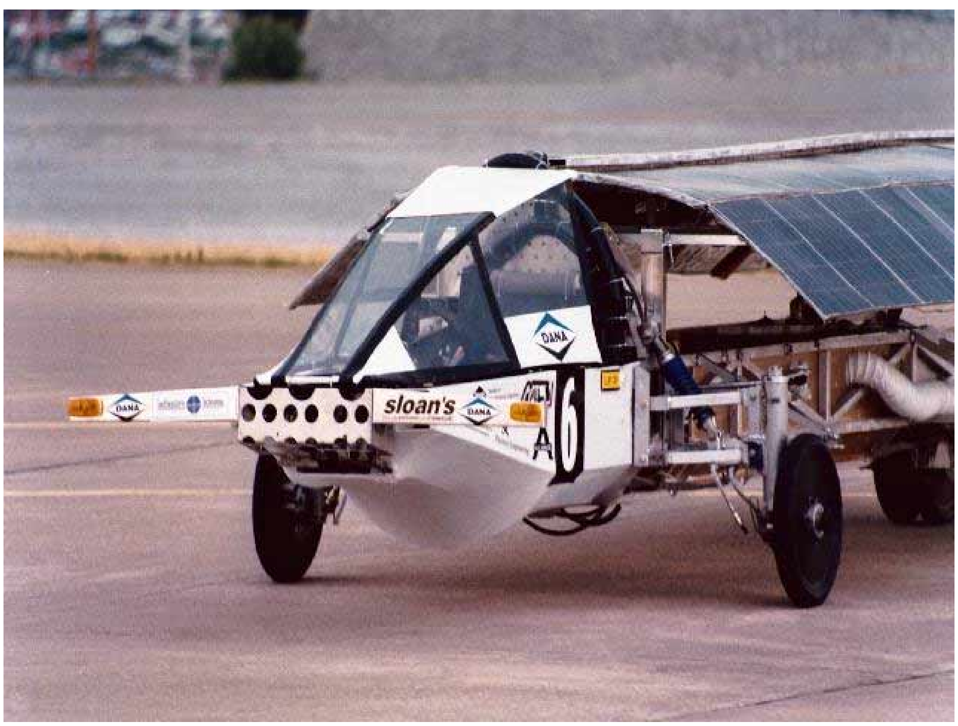

Figure 4. A close-up view of the Solaraider III.