



SOLAR EAGLE II TECHNICAL REPORT

January, 1995

School of Engineering and Technology
California State University, Los Angeles





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**SOLAR EAGLE II PROJECT
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FINAL TECHNICAL REPORT

September 15, 1992 to November 15, 1993

Richard D. Roberto
Principal Investigator

California State University Los Angeles
5151 State University Drive
Los Angeles, CA 90032

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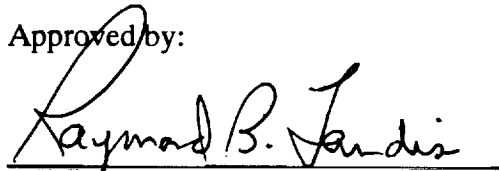
SOLAR EAGLE II TECHNICAL REPORT

Prepared by:



Richard Roberto, Professor
Mechanical Engineering

Approved by:



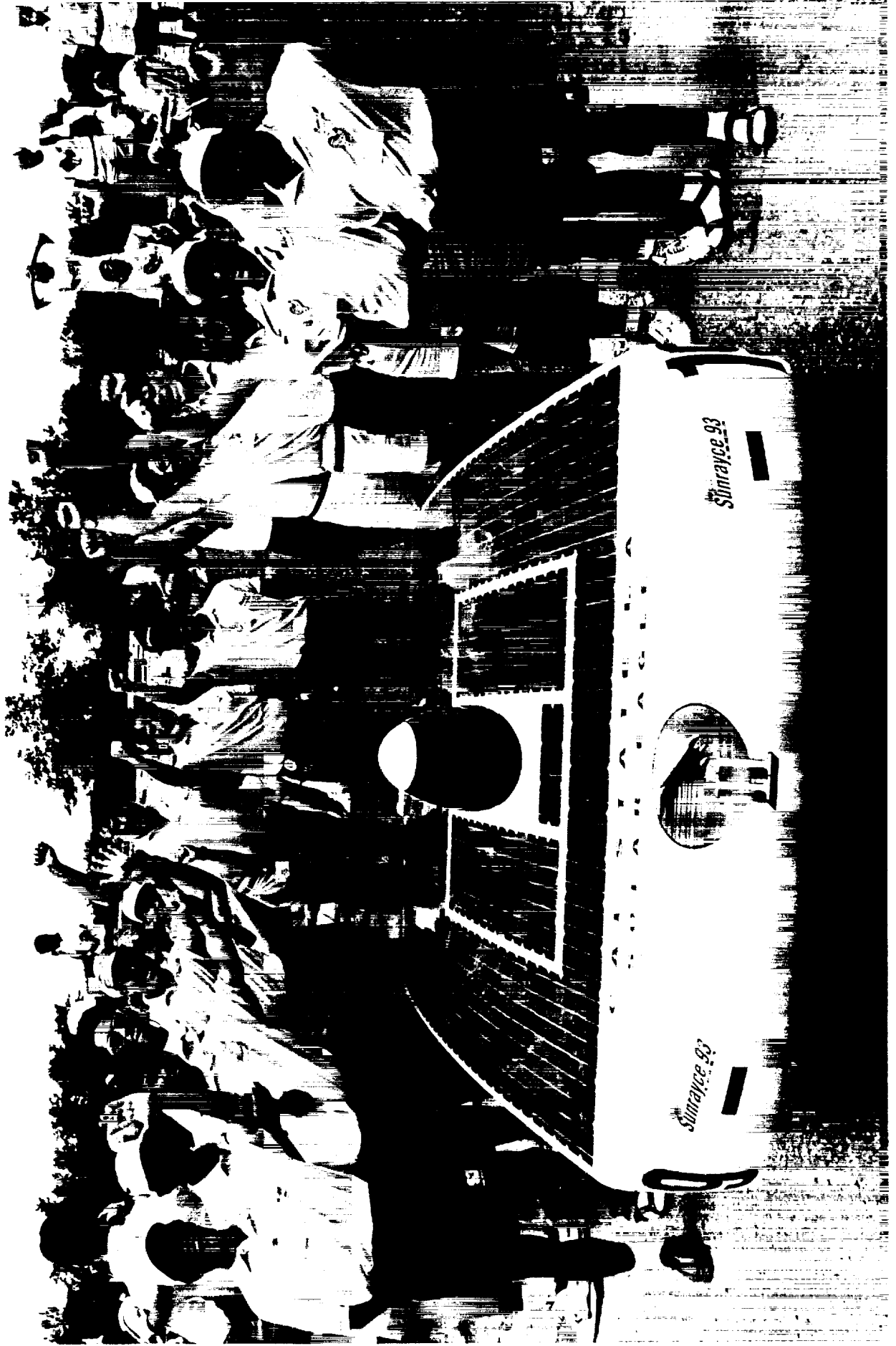
Raymond B. Landis, Dean
School of Engineering and Technology

School of Engineering and Technology
California State University, Los Angeles



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SOLAR EAGLE II VEHICLE AND TEAM

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SUMMARY

During a 22-month period from February 1991 to December 1993, a dedicated group of students, faculty, and staff at California State University, Los Angeles completed a project to design, build, and race their second world class solar-powered electric vehicle, the **Solar Eagle II**. This is the final report of that project.

As a continuation of the momentum created by the success of the GM-sponsored Sunrayce USA in 1990, the U.S. Department of Energy (DOE) picked up the banner from General Motors as sponsors of Sunrayce 93. In February 1991, the DOE sent a request for proposals to all universities in North America inviting them to submit a proposal outlining how they would design, build, and test a solar-powered electric vehicle for a seven-day race from Arlington, Texas to Minneapolis, Minnesota, to be held in June 1993. Some 70 universities responded. At the end of a proposal evaluation process, 36 universities including CSLA were chosen to compete.

By April 1993, CSLA had assembled a team, raised \$ 78,000 from the University and \$164,401 from corporate and state and federal agency sponsors, designed and fabricated an all new vehicle, and passed the qualifying trials with flying colors by winning the pole position for the upcoming race. CSLA took a third position in Sunrayce 93, and thirteenth position in the World Solar Challenge in Australia later in the year. Again, the Solar Eagle Project brought great recognition to CSLA and generated unprecedented pride and spirit throughout the campus community.

This report documents the **Solar Eagle II** project--the approaches taken, what was learned, and how our experience from the first Solar Eagle was incorporated into **Solar Eagle II**. The intent is to provide a document that would assist those who may wish to take up the challenge to build **Solar Eagle III**.

There were also major differences in the race conditions between the Sunrayce 93 and the World Solar Challenge. For the World Solar Challenge, racing was from 8:00 am to 5:00 pm with charging allowed from 5:00 pm to sunset and from sunrise to 8:00 a.m. The entries stopped wherever they were on the road at 5:00 pm and set up camp for the night. For the Sunrayce 93, racing began at 9:00 am and ended when a specific distance was covered. If the day's course was not completed by 5:30 pm, the car was trailered in and a two-minute per mile time penalty was added to a nine-and-one-half hour full day's time. Charging was permitted from 7:00 am to 9:00 am and after the car arrived at the destination point for that day until 8:00 pm. At the end of seven days, the car with the lowest cumulative time was the winner. Designing a car that would be competitive for both race conditions was an extra challenge for the U.S. teams who chose to go to Australia.

Cal State L.A.'s Response

Because of our successes with the first Solar Eagle project, there was considerable interest on the part of students for continuing forth with a second vehicle. Members of our School Industry Advisory Board encouraged us to do so. The CSLA campus community, which had given the Solar Eagle Project so much support in the past, also seemed enthusiastic that we should continue. There was also a sense that the Solar Eagle Team had learned so much with the first car that it would be a waste if all of that knowledge were not put to use in building a second car. So, when the Department of Energy announced that they would sponsor Sunrayce 93, all of the signs were pointing towards continuing our efforts in solar car racing.

As soon as DOE sent out a request for proposals, work on the Solar Eagle II began. As required by the request for proposals, the proposal included sections on team organization, selection of the vehicle concept, undertaking the engineering tasks, obtaining components, fabricating the vehicle, performing evaluation testing, achieving reliability, selecting and training drivers, planning race logistics, devising race strategies, and raising funds and other support. Most of these topics to be addressed were also required for the proposals for the 1990 race. This allowed us to revisit the proposal we wrote for the GM Sunrayce USA and update it to incorporate what we had learned. A proposal was written and submitted, and by the end of February, 1991, we were informed that we were again selected as one of 36 universities that would participate in Sunrayce 1993.

In the introduction to the proposal, the objectives of Cal State L.A.'s participation in building a solar-powered car were delineated.

1. To broaden the vision of our previous efforts and stimulate the creativity of faculty and students on the project, given cross-disciplinary combination of technologies involved.
2. To enable team members to apply theory to solve a variety of practical problems, apply the knowledge that was gained on the first Solar Eagle Project.

INTRODUCTION

Background

Solar car racing for the U.S. began with General Motor's decision to participate in the 1987 World Solar Challenge in Australia. The car that was built for that race was called the Sunraycer. The design and fabrication of the vehicle was a collective effort on the part of GM, Hughes, Delco Remy, and the genius of Aerovironment President Paul MacCready and his staff. The Sunraycer scored an overwhelming victory in that race, captured the imagination of the world, and brought great visibility and recognition to General Motors.

Rather than build a Sunraycer II for the 1990 World Solar Challenge, GM decided to sponsor a race among the universities of North America to be held in the Summer of 1990. Thirty-two universities from the U.S. and Canada were chosen to participate in an eleven-day, 1,643-mile race from Lake Buena Vista, Florida to Warren, Michigan. The design specifications for the vehicles to race in GM Sunrayce USA were the same as for the Australian race. This was done so that GM could award as a prize sponsorship of the three top teams in the Sunrayce to participate in the 1990 World Solar Challenge later that year.

GM Sunrayce USA was indeed a success in many ways. It provided enormous recognition for the schools that participated, it provided a public view of what engineering students could accomplish, and it captured and stimulated the imagination of the thousands of spectators who came to see the race. It was certainly a media event. But more importantly, it provided a wonderful, once-in-a-lifetime learning and life experience for the engineering students who participated. Despite the success of GM Sunrayce USA, General Motors decided not to sponsor future races. Fortunately, the U.S. Department of Energy stepped in and assumed sponsorship for the next race. They were given permission by GM to continue the use of "Sunrayce" for the designation of future races.

Since the World Solar Challenge was scheduled to be held every three years, it was originally thought that the Sunrayce would follow that schedule and that the overall design specifications for the vehicles would conform to the rules for the world race. Therefore, the next Sunrayce was planned for the Summer of 1993 and was called Sunrayce 93. A new route was chosen, from Arlington, Texas to Minneapolis, Minnesota, and the length of the race was shortened to seven days to cover some 1000 miles. However, Sunrayce 93 officials did make rule changes in order to diminish the expense of building an entry. The Sunrayce entries now had to use terrestrial grade solar cells and lead-acid batteries. The rule changes that were made did not prohibit Sunrayce entries from participating in the World Solar Challenge, but did limit the potential to design a high performance vehicle. Also, both the Sunrayce and the World Solar Challenge instituted a rule change that now allowed the use of auxiliary charging panels during the beginning and the end of the day charging periods so long that these extra panels fit within a prescribed volume. In general, however, the race regulations for the Sunrayce were far more restrictive than those of the World Solar Challenge.

3. To enrich the educational experience by simulating conditions that students will encounter after graduation as they use a team approach to focus on a practical goal within a tight schedule.
4. To sensitize students to environmental issues by exposing them to a new technology based on a non-fossil fuel.
5. To build team spirit and dedication among a remarkably diverse student body and faculty.
6. To draw attention to the accomplishments of our School and the University, fostering pride among the alumni and the members of the campus and surrounding community.
7. To draw attention to the recognition gained by the University at large for the School's participation and success in the first Sunrayce and the World Solar Challenge.

The proposal was submitted by early February 1991 and by the end of that month we were notified that we were again chosen to participate in Sunrayce 93. By then, a group of interested students had been assembled and preliminary discussions were taking place as to the concept of the second vehicle. Dick Roberto was again chosen to act as the technical director of the project, Ricardo Espinosa, a driver from the first team was chosen as student team leader, and Ray Landis, the Dean, would be overall project manager.

Development of Team Solar Eagle

Many of the original team members of the first Solar Eagle Project had graduated, leaving only four original Solar Eagle team members to help guide the new students. The early meetings of the new team focused on teaching the new members what was done in the past and the lessons learned. The emphasis was on incorporating all that we had learned into the designing and building of a more competitive vehicle. It was also decided that this new project would be designated Solar Eagle II.

By the summer of 1991, a core team began to emerge. The following is a list of student team members:

Ken Ahn -- Electronic assembly and repair

John Aventino -- Body fabrication

Juan Argueta -- Mechanical systems and body fabrication

Luis Bravo -- Electronic assembly

Richard Benavides -- Solar panel assembly and repair

Robert Diefenbach-- Batteries/Race strategy

Thu Doung -- Body fabrication

Ricardo Espinosa -- Team leader and driver

Armando Garcia -- Solar panel assembly/Structural analysis

Erick Juarez -- Body construction/Driver

Fang Liang -- Electronic assembly

Jonathan Lam -- Body construction

Carlos Moran -- Tires, wheels, body fabrication

Tai Nuyen -- Mechanical systems/Solar panel assembly

Filipe Rojas -- Body fabrication

Gwan The' -- Driver/Body fabrication

Suchon Tsaowimonsiri -- Solar panel assembly

Roman Vasquez -- Public relations

Jesse Villegas -- Race strategy and weather

Silvia Villasenor -- Public relations

In addition, the following members of the School of Engineering and Technology faculty and staff were key members of the Solar Eagle II team:

Dick Roberto -- Faculty advisor and chief engineer

Ray Landis -- Fund raiser, public relations, race strategy and project manager

Chivey Wu -- Aerodynamics

Steve Felszeghy -- Structural analysis, race strategy

Dan Roberto -- Mechanical systems fabrication

Mike Obermeyer -- Power electronics and instrumentation

Kathy Lex -- Fiscal management

Don Maurizio -- Logistic support

Laura Carlson -- Public relations/fund raising

Finally, significant media and public relations support was received from the following Cal State L.A. personnel

Stan Cartensen -- Photography

Dave McNutt -- Creative media, artistic design and photography

Bill Stellmacher -- Video support

Carol Selkin -- Manager, Cal State L.A. Office of Public Affairs

Those listed above are only a partial list of the many individuals that made significant contributions to the Solar Eagle II project.

Design Overview

The design of Solar Eagle II began in earnest following notification by the U.S. Department of Energy that CSULA had been selected as one of 36 universities to participate in Sunrayce 93. We began by assessing the strengths and weaknesses of the first car and reviewing the specs of the other competitors and their strengths and weaknesses. With all the changes in the regulations and the race route, and from what we had learned with the first vehicle, we anticipated from the outset that an all new design would be necessary. Some of the major rule changes we had to comply with were as follows:

1. We were required to use terrestrial grade solar cells as opposed to space quality cells.
2. We were required to use lead-acid batteries as opposed to silver-zinc batteries.
3. The race route was shortened from 1643 to 1000 miles, and the race was shortened from 11 to 7 days.
4. We were allowed to begin charging as soon as we reached our destination for the day as opposed to waiting until 5:00 pm.

Regardless of the changes in the race rules and regulations, the problem of designing Solar Eagle II still focused on the same design parameters that guided the design of Solar Eagle (I). These design parameters are:

1. Solar panel power
2. Vehicle weight
3. Aerodynamic drag
4. Power system efficiency
5. Vehicle reliability and durability
6. Manufacturability
7. Cost.

The conflicting requirements of high solar panel power, low vehicle weight, low drag, high power system efficiency, high reliability, ease of manufacturability, and low cost, presented challenging design tradeoffs typical of many engineering projects.

The first major tradeoff to be made is between panel power and aerodynamic drag. Large panels that enhance solar energy collection often produce more drag which offsets the gain in solar energy. In our first car, we opted for good aerodynamics which was achieved, but at the cost of panel power. This time we decided to look at the possibility of a less aerodynamic shape which would collect more energy. In order to diminish the weight of the vehicle, the new design was shorter with a canopy protruding from the solar panel itself. The new design also incorporated flat vertical sides to provide space for additional solar cells. These cells were to collect energy when the sun was low or in times of diffuse sunlight. The main panel was a one-dimensional curve so that large terrestrial-grade solar cells could be easily mounted.

With the exterior shape of the vehicle fixed, the internal frame could now be configured. It was decided to make an aluminum tubular frame as was done with the first car, rather than a monocoque structure of composite materials. The design of the frame was facilitated by the use of finite element analysis. While the frame was being designed, the design of the power train was proceeding on parallel effort. Once the configuration of the frame was established and positioned within the body shell, the location of the power electronic components could be established.

The design of the power electronics and instrumentation system also paralleled the design of the body shape and frame. The design of the power electronics system included the selection of the solar panel voltage thereby requiring integration with the solar power system design. The solar panel design was constrained by the size and structural design of the panel, selection of the operating voltage for the system, design of the solar cell size and circuitry, and the selection of peak power trackers to ensure solar panel operation at maximum power. Battery selection was determined by the operating voltage of the system and the maximum battery capacity allowed by the race regulations. A minor consideration at this point in the design process was the design of the instrumentation and telemetry system.

One of the primary lessons learned from the design and construction of the original Solar Eagle vehicle was that to maximize the efficiency of the design and performance of the vehicle, the engineering of the entire vehicle must be completed before the construction begins. While this idea appears to be obvious, it is very difficult in practice when there are so many details about the car that are unknown in the beginning, or when experience is lacking. This was certainly the case with the first car. With Solar Eagle II, however, we were far more aware of the process of building a solar car and of what to expect. This allowed us to complete much more of the design of the car before the construction stage began. With the experience from the first car, we were able to integrate the sub-systems of the vehicle, and practice systemic design in a more technically correct manner. As a result of better systemic design, we were able to improve the operating efficiency of Solar Eagle II over Solar Eagle (I) by some 15%. In short, we knew better what we were doing the second time around. It should be pointed out, however, that knowing what to do the second time around did not make the job easier as we first had thought. Our experience base led us to explore many more issues and to explore each one of them in much more depth.

Summary of Vehicle Fabrication

By January 1992, the fabrication of Solar Eagle II was well underway. Since the frame and body design proceeded along parallel paths, the frame and body fabrication also proceeded simultaneously. The frame was completed first allowing us to test the running gear of the vehicle before the completion of the entire car. This is the advantage of building a separate tubular frame instead of an integrated monocoque structure.

The running gear was tested by the end of 1992 and by April 13, 1993, the day of the roll-out ceremony, the car was complete. The only sub-system where real difficulties were experienced and where major delays occurred was the solar panel. This occurred because the manufacturer of the cells did not deliver on schedule and the poor quality of the solar cells made them difficult to work with. Qualifying trials at the Phoenix International Raceway were held during the last week in April. The last sub-system of the vehicle to be completed was the telemetry system.

The roll-out ceremony on April 13 included both solar vehicles. The program depicted the retirement of Solar Eagle (I) and the "birth" of Solar Eagle II. Later that month, qualifying trials were held at the Phoenix International Raceway for those universities on or near the west coast. The universities in the eastern part of the U.S. were qualified at the Indianapolis Speedway one week before the qualifying trials in Phoenix. Solar Eagle II won the pole position for the Sunrayce 93 with the fastest qualifying time, an average speed of 50.4 MPH over fifty laps (50 miles).

Final Vehicle Specifications

The following is a summary of the technical specifications of Solar Eagle II:

Dimensions:

Length:	4.8 meters
Width:	1.85 meters
Height:	1.0 meters
Wheelbase:	2.43 meters
Wheel tread:	1.47 meters
Solar panel length:	4.32 meters

Weight:

Vehicle weight without batteries and driver: 360 lbs
Battery pack, Sunrayce 93: 262 lbs
Battery pack, World Solar Challenge: 90 lbs
Driver and ballast: 175 lbs

Frame:

The frame is welded of 6061-T6 aluminum alloy tubing. Most of the tubing is 1.0" diameter with a .058" wall thickness. Some of the smaller load bearing members are 1/2", 5/8", 3/4, and 7/8 diameter tube with the same wall thickness. The structural part of the frame weighed 19.9 lbs.

Suspension:

The suspension is a double A-arm, coil-over shock arrangement. The shocks are light weight aluminum units purchased from Works Performance in Chatsworth, California.

Steering:

The steering is rack and pinion with a 1/2 turn lock-to-lock.
The turning radius is approximately 17 feet.

Brakes:

The front brakes are hydraulic, and the rear brake is regenerative, capable of using the motor as a generator. The front brakes operate from a foot pedal and the rear brake operates from a switch and potentiometer mounted on the steering wheel. Also, a hand brake was required for the Sunrayce. This is a simple friction element that rubbed on the rear wheel.

Motor and Controller:

The motor and controller package is a DC brushless system produced by Solectria. The output of the systems used in the Sunrayce 93 could produce about 7 HP continuously and over 12 HP intermittently. The motor used in the 1993 World Solar Challenge was

a specially wound series motor that produced 2.5 HP continuously, and 6 HP intermittently. The overall efficiency of all these systems is at least 90%.

Solar Cells:

The top panel of the vehicle carried 754 terrestrial grade (97 mm x 94mm) cells, and the sides of the vehicle carried 410 cells (100 mm x 21 mm) each. The cells were manufactured by BP Solar in Madrid, Spain. The top panel had two strings of cells and each side had one string. The rear string on the top panel had 360 cells and the front string on the top had 394 cells. The cells were covered with .006 thick cover glass with an anti-reflecting coating. The cover glass is glued to the solar cell with optically clear silicon adhesive. The cover glass was donated by the Optical Coating Labs Inc. The power from each string is routed through a peak power tracker called the "Maximizer" made by the Australia Energy Research Labs (AERL).

Batteries:

For Sunrayce 93, ten 12-volt lead acid batteries were used. These batteries, made by U.S. Battery, are a deep-discharge U-1 type designed for wheelchairs. The batteries used in the World Solar Challenge were silver-zinc made by Eagle Picher. This pack was comprised of 82, 1.5, 40 amp-hr cells. Both the lead-acid and the silver-zinc pack produced 5000 watt-hrs of energy, the maximum allowable by race rules.

Throttle:

The throttle is a hand-operated potentiometer mounted on the steering wheel. The throttle has a positive return torsion spring. Engagement of the brakes disables the throttle.

Instrumentation:

The instrumentation for the vehicle is a computer-controlled system that reads and displays all of the vehicle functions including battery voltage and current, motor current, and panel power. The system also computes and displays amp-hrs, watt-hrs, and watt-hrs/mile. For battery charging, the system will monitor all the individual cells in the pack. A digital display mounted to the forward end of the canopy provides the driver with all the measured and computed information.

Telemetry:

An on board telemetry system purchased from Monicor is an RF modem that transmits all of the measured and computed information from the vehicle to a lap top PC located in a chase vehicle.

Body:

The materials used to fabricate the body include carbon fiber, light weight foam, honey comb, and epoxy. The body consists of three major parts, the under pan attached to the frame, the underside of the body shell, and the top side of the body shell. The process for fabricating the body was a wet lay-up of materials with the use of vacuum bagging. The canopy is tinted acrylic plastic.

Tires and Wheels:

The front tires are 20-inch Avocet BMX slicks (freestyle), and the rear tire is a 20 inch ACS BMX tire with shallow treads. All tires are mounted on a 48 spoke rim, laced to a specially designed splined hub. For racing, all tires were inflated to 100 psi - 110 psi.

Drivetrain:

The major difference between Solar Eagle (I) and Solar Eagle II is the change from a four to a three wheel design. On Solar Eagle II, the drive wheel is a rear wheel in the center of the car. Both the motor and wheel are mounted to a swing arm allowing 2.5 inches of vertical travel for the wheel. This arrangement does not require the addition of any more bearings in the drive train other than those in the motor and wheel. The resulting improvement in mechanical efficiency is significant. The motor power is transmitted through a Poly Chain, Kevlar gear belt by Gates. Gear ratios ranging from about 6:1 to 4:1 are possible with this design.

Cooling:

Driver cooling is provided by a muffin fan drawing air from the wheel well. Additional fans are used to ventilate the battery box and cool the peak power trackers.

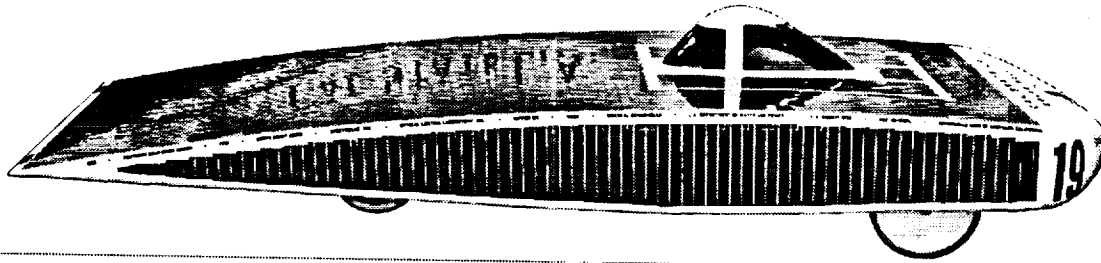
DESIGN AND FABRICATION OF SOLAR EAGLE II

The following sections discuss the design and fabrication of the major subsections of Solar Eagle II. These subsections include:

1. Aerodynamic design/Selection of the external shape
2. Mechanical systems
3. Electrical systems
4. Body fabrication including the solar panel
5. Solar power system

Aerodynamic Design/Selection of the External Shape

With a solar panel of 8 m² in the horizontal plane and the type of solar cells as allowed by the rules, the input power available to power the vehicle is relatively low, less than 1.5 HP under ideal conditions. To achieve the vehicle speeds that would make a car competitive, aerodynamic drag becomes very important, particularly at speeds greater than 25 MPH. Aerodynamics is the design parameter that was brought to the forefront in the design of the GM Sunraycer. Also, the design team of the GM Sunraycer as well as those teams that followed, became very much aware of the conflict between shapes that are very good aerodynamically and shapes which are good at enhancing solar energy collection. A case in point would be a design that employs a flat panel that can be tilted to track the sun as the vehicle is in motion.



While a moveable flat-panel design will maximize the collection of solar energy, it will produce considerable drag that would cancel the advantage of the extra power collected by the tilting panel. The objective as defined by the GM Sunracer designers is to maximize the power per unit drag of the vehicle. This is not an easy task. There are many considerations to be made: the size and type of solar cells to be used; the direction of the race route; the expected weather conditions; and the design speeds.

The design of the original Solar Eagle vehicle provided us with considerable experience with ground vehicle aerodynamics. Several models were built and tested in our wind tunnel. The largest model we could test was 1/6 scale. From that effort, a concept was chosen based on what we thought at the time was the best in terms building a competitive car. As was mentioned earlier, the criteria established for Solar Eagle II was to compromise the aerodynamic quality of the vehicle for a shape that would enhance the power input.

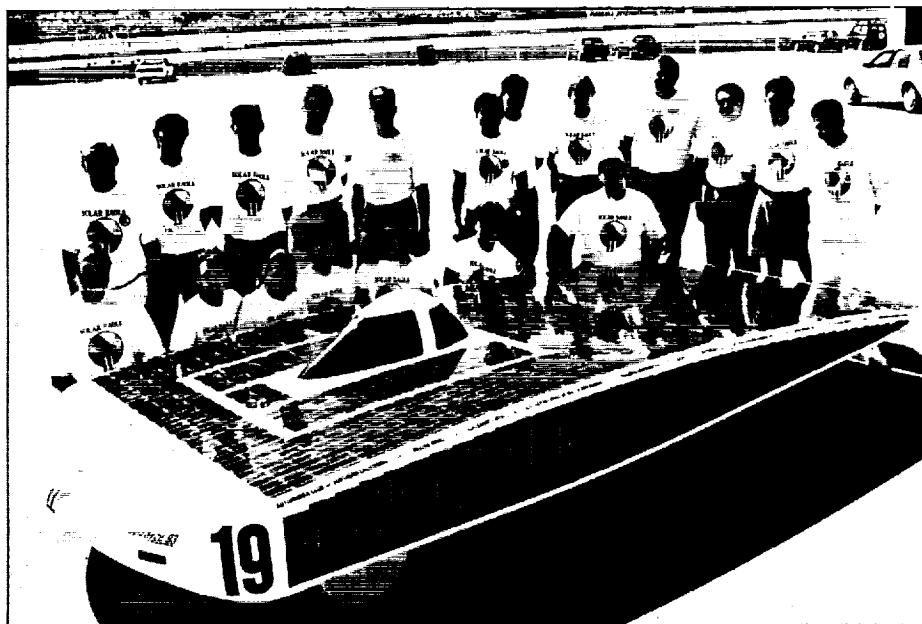
The criteria we were trying to satisfy were:

1. A drag coefficient of less than 0.15 with the smallest possible frontal area. Solar Eagle (I) had a drag coefficient of 0.12 with a frontal area of 1.1 square meters.
2. A relatively flat surface with a one dimensional curve that would be simple to build and would allow for the mounting of large solar cells that could flex in one direction. (Small solar cells would permit a two dimensional curve.)
3. Stability in the presence of side winds and gusts.
4. A shape that is neutral in terms of lift, and with zero moment about the pitch axis.
5. Sufficient interior space for the driver, frame, batteries, suspension, and electronic equipment.

The new rules allowed for a narrower car down to 1.6 meters wide with a solar panel up to 4.4 meters long so that 8 square meters in the horizontal plane could be achieved. A narrower car was desirable for placement into a trailer that would fit into a shipping container for transport to Australia. A shorter car was desirable in order to decrease the overall volume and weight of the vehicle. To accomplish both, a design with a canopy within the boundaries of the top solar panel was selected. This allowed for a vehicle that was not much longer than the solar panel. Since the canopy took up space for solar cells on the top panel, it was calculated that vertical sides with solar cells would more than make up for the lost cells on the top panel.

During Summer 1991, one of the team members undertook an independent study project to build a wind tunnel model with a larger solar panel. A model was built that would allow different sections of the body to be changed out quickly so that effects of the changes could be measured. The study showed that a vehicle with large panels on the side that would make use of the permitted height (1.6 meters) produced considerable drag and was very bad in cross winds.

After this study was completed, another model was built that was a compromise between a car with just a flat top panel and one that included tall side panels. After several changes to the underside of this model, we achieved a shape that had zero lift and pitch moment, was fairly stable in side winds up to 20 degrees, and had a drag coefficient of 0.14 with a frontal area of less than 1.0 square meters full scale. The only drawback to the shape was that its vertical sides created corners as seen from the front, which are not good aerodynamically. The corners were softened with a radius. Although the radius represented wasted space in terms of the total solar cell coverage on the top panel, the shape is a compromise with the overall design criteria in terms of increasing the solar collection area over that of Solar Eagle (I), and building a smaller car. Except for the rounded surfaces on the nose, the flat surfaces on the sides and bottom sides, and the one dimensional curve on the top made the shape relatively easy to build.



Mechanical Systems

The mechanical design and fabrication of Solar Eagle II can be divided into the following components:

1. Frame
2. Suspension
3. Wheels
4. Steering
5. Brakes
6. Drive train

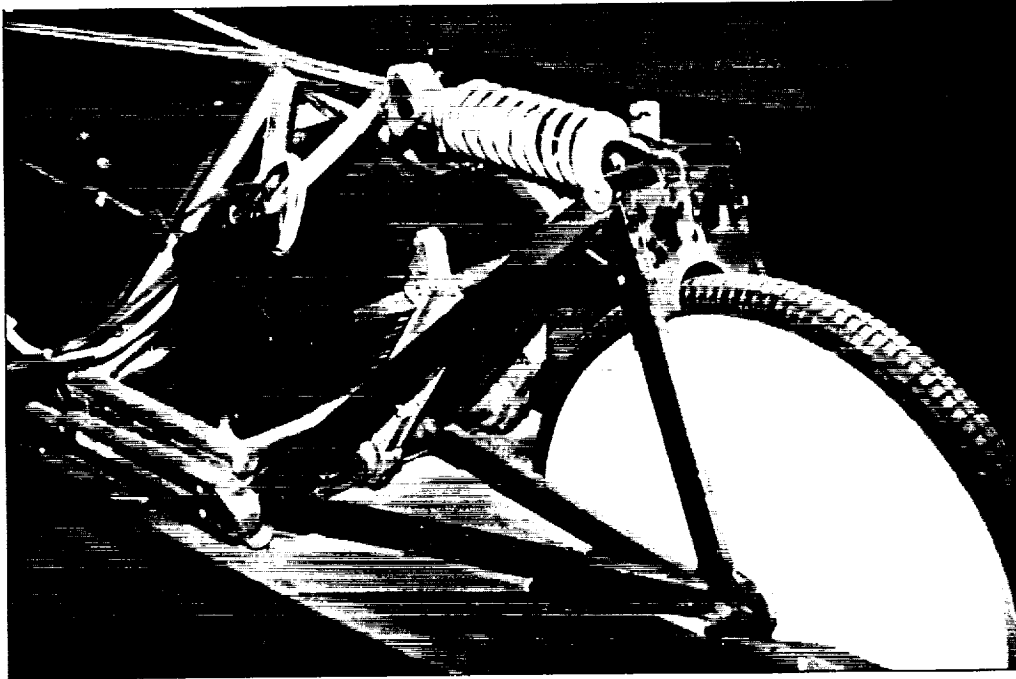
The following sections describe key aspects of the mechanical design and fabrication of each of these components:

Frame The frame on both Solar Eagle vehicles built at CSLA are made of welded 6061-T6 aluminum alloy tubing. The basic frame on the Solar Eagle (I) is a triangulated space frame that proved to be incredibly rigid and efficient, weighing only 23 lbs. While this type of frame performed perfectly, it did not easily facilitate the design and mounting of the suspension system, the driver ergonomics, the mounting the body shell, and the support of the battery pack. To eliminate these problems, it was decided to build a more rectangular frame for Solar Eagle II. A rectangular frame is not as efficient as a triangular space frame. However to make the Solar Eagle II frame as efficient as possible, other components of the vehicle doubled as structural components that would provide structural rigidity while eliminating the need for tubular members in the frame. The bottom shell of the body when fastened to the under side of the frame doubled as a shear panel, eliminating the need for cross bracing on the bottom horizontal plane of the frame. The battery box when attached to the tube frame behind the driver provided the torsional rigidity of the frame between the driver compartment and the rear wheel. The seat doubled as support for the driver and acts as an inclined shear panel for the frame. In short, the structural frame of Solar Eagle II was a hybrid.

A structural analysis of the frame was carried out using MacNeal-Schwendler's PAL2. The frame and suspension system was designed for the following maneuver loading conditions: 1g braking, 1g cornering, and a 3g vertical load. The design criteria for these loading conditions taken one at a time and in combination was a post welding stress limit of 8000 psi at any point. Later, a crash analysis was done for the following criteria: 4.5 g nose collision, 4.5 g side collision, and a 6g rollover.

Suspension Solar Eagle II incorporates a double A-arm suspension in the front and a trailing arm for the rear. The double A-arm suspension provides the designer with the best control of wheel geometry with the ground. Both solar vehicles built by CSLA utilized a computer program written in Mathcad that located the attachment point of the upper A-arm that would minimize the transverse "scrubbing" of the tire on the ground as the wheel moves through it vertical travel.

The same program also helped locate the vertical placement of the rack and pinion steering system to minimize bump steer.



The trailing arm for the rear wheel was fabricated from thin wall 1/2" x 1.0" chrome moly tubing. The mono-shock configuration on the trailing arm proved to be the most compact design. The trailing arm pivots from both sides of the frame in sealed and permanently lubed spherical bearings. The unit is designed so that a rear wheel change is possible without opening up the vehicle. A belt tensioning link was designed that it would fold near its midpoint and loosen the belt tension enough to allow the removal of the belt from the wheel pulley. Removing the belt from the pulley and loosening two nuts clamping the axle to the trailing arm assembly allows the wheel to be removed from out the bottom of the vehicle.

The shock absorbers, front and rear, are coil-over, gas-charged hydraulic units. The shock bodies are high strength, aircraft quality aluminum, and the coil springs are steel. The front shocks allow for 2.5 inches of vertical wheel movement, and the rear shock allows for 2 inches of vertical movement. The units are produced by Works Performance Products in Chatsworth, California. Works Performance uses a computer program to select the spring and damping rate based upon the suspension configuration and the wheel loads.

Steering A steering wheel was selected as the preferred interface between the driver and the vehicle because all drivers are accustomed to it and would react predictably in an emergency. However, the driver compartment in Solar Eagle II is more confined than in than in Solar Eagle (I). The Solar Eagle II frame is narrower and the low solar panel restricts driver from above. All this made the space available for a steering wheel very limited. Consequently, the steering system design was very difficult. The steering wheel, as it turned out, was the only feasible method for steering. In order to accommodate the limited space, the steering wheel was made rather small so the driver's hands would not strike the underneath of the solar panel as he/she turned corners. A small steering wheel along with the decision to limit the rotation of the steering wheel to only plus and minus 90 degrees lock-to-lock, makes the steering a bit stiff. But the small rotation of the steering wheel is necessary in order to incorporate a finger operated throttle. This type of throttle provides much better motor control, and is only a feasible if the driver does not have to move his/her hands on the steering wheel to accomplish lock-to-lock maneuver. To compound the problem of the steering wheel design, the decision was made to mount the electric brake control and all the switches for the radio and instrumentation on the steering wheel as well. The intent was that the driver could carry out all functions most critical to the control of the vehicle, and communication with the outside world, without taking his/her hands off the wheel. Except for the horn, this was achieved. As it turned out the steering wheel became a very compact and sophisticated instrument in itself.

The steering wheel mounts directly to a rack and pinion box, where the rack connects to tie rods above the drivers knees. Both the rack and pinion are made of steel and trimmed for minimum weight. The housing for the unit consists of two major pieces, and is designed so that an adjustment is possible that eliminates the backlash between the gears.

The steering linkage system was modeled on a computer using software called ME Workbench by Iconnex. The computer model focuses on the determination of tie rod lengths, the steering arm lengths and angles, and the relative position of these components in the plan view of the vehicle that would best duplicate the theoretical Ackerman turning angles for the wheels. The design effort yielded a system configuration that achieves a 0.2 degree error for a turning radius of 17 feet.

As explained earlier, a computer program was written for the suspension system to minimize the wheel scrub as the wheel moved vertical in a bump. A modification of this program allowed us to study the bump steer characteristics. This modification allowed us to locate the vertical position of the steering box relative to the steering arms that would minimize bump steer. However, in Solar Eagle II, the constraints presented by other aspects of the overall design did not allow a steering box location that would produce the minimum amount of bump steer.

Brakes The Sunrayce 93 regulations required that the vehicle employ two independent braking systems outside of motor regeneration. A hydraulic disk brake system was designed for the front wheels and a mechanical friction brake was designed for the rear wheel. The design of a hydraulic system posed a difficult problem since it is essential that the brakes do not create any

frictional drag when they are not in use. A hydraulic disk system was designed to include a spring loaded caliper arm and a spring loaded disk pad on the piston side of the caliper. When the brake is not in use, both the pad on the piston side and the dead side of the caliper will pull away from the disk plate. The front brakes are operated by a foot pedal. The activation of this brake will turn off all power to the motor, and make the throttle inoperative.

The rear brake incorporates a plate that simply rubs against the top of the wheel. This brake is activated by a hand lever in the driver compartment which pulls on a shielded cable attached to a lever mechanism that applies pressure to a shoe that rubs on top of the wheel. This brake was removed for the 1993 World Solar Challenge, because it was not required by the rules for that race.

Drive Train One of the major changes made in the design of Solar Eagle II was the decision to make it a three wheel vehicle. This choice eliminates much of the running gear that was part of original Solar Eagle vehicle. The decision was based on a desire to make a more efficient drive train. The only similarities in the drive train for the two cars is the size of the drive wheel and the type of gear belt used. The Solar Eagle II drive train is simply a motor with a drive pulley transmitting power to the drive wheel via a Poly-Chain gear belt. The motor pulley is a stock, purchased unit made of steel, and the driven pulley attached to the drive wheel is a custom, light weight, anodized aluminum unit. The belt tensioner can be adjusted to accommodate different pulley sizes with center distances ranging between 14.5 and 15.0 inches.

With four different motor pulleys and three different wheel pulleys, five different ratios can be achieved ranging from 6:1 to 3.76:1.

The decision to go to a three wheel design proved to be a good one. The overall efficiency of Solar Eagle II, which includes the electrical and mechanical efficiency, is about 15 % better than the Solar Eagle (I). A large part of the increase is due to the three wheel design. It should be noted that the vast majority of the solar vehicles that competed against us were also three wheel designs. Of the top five cars in the 1993 World Solar Challenge, only one was a four wheel design. The downsides of a three wheel design is that there is more load per wheel and it is less stable on the road.

Electrical Systems

The electrical systems design and fabrication involves the following components:

1. Motor and motor controller
2. Power electronic systems
3. Batteries
4. Auxiliary power systems
5. Controls and instrumentation
6. Onboard telemetry

The following sections present key elements of the design and fabrication of each of these components.

Motor and Motor Controller In September 1991, the School of Engineering and Technology received a grant from the Southern California Edison Company for electric motor testing. With money from that grant, equipment was purchased and a motor test lab was built. The lab equipment included; a three phase analyzer, Eddy Current Dynamometer, dynamometer controls and a battery pack. During that same period, we purchased a brushless motor and controller system from Solectria with the hope that it would be a better system than the Unique Mobility system that powered Solar Eagle (I).

After some difficulty in attaining accurate input current measurements to the motor and controller system to be tested, the lab was operational and yielding good results by the end of November 1991. To become more knowledgeable in the design of Solar Eagle II, we tested both Unique Mobility motor systems that were purchased for Solar Eagle (I). The purpose of this effort was to explain the performance characteristics of Solar Eagle (I). The tests were very revealing. Both motor systems tested to have efficiencies in the low 80% region, dropping to as low as 60% at low power and speed settings typical of race conditions. This validated some our suspicions as to why Solar Eagle (I) did not perform as expected.

We then tested the first Solectria system that had arrived as the motor testing lab was being finished. It tested in the slightly below 90% region and promised to be a significant improvement over the Unique Mobility systems. The Solectria system was at least 20 lbs heavier, but the improved efficiency overshadowed that disadvantage. A second Solectria system was purchased, and proved to be a little better. The first Solectria system experienced an unexpected burnout during the testing and was returned to Solectria for repair.

The Sunrayce 93 race route passed through cities and towns with a fair amount of hills. To provide a wide range of performance characteristics, the Solar Eagle II drive system was configured so that the motor could be switched from a series to a parallel wound configuration to achieve a high torque, low speed, and a low torque, high speed mode of operation. This proved to be a very workable and beneficial design. The switching of windings, however, was not needed for the 1993 World Solar Challenge. That race required only the series wound configuration--high torque with low speed--because the race route was generally flat with almost no traffic. Therefore, the series-parallel switch was removed for the 1993 World Solar Challenge.

The two Solectria systems proved worthy, as we thought, throughout the testing phase both on the bench and in the vehicle. We used the second system during qualifying and during most of the testing phase. At the qualifying event at the Phoenix International Raceway in April 1993, we won the pole position at a speed of just over 50 MPH. During the testing and team preparation phase of the project just prior to the Sunrayce, the vehicle was test driven some 1,200 miles. There was a hint of some trouble with the motor during this testing phase but it seemed to pass.

Real trouble occurred, as luck would have it, during the first day of Sunrayce 93. We were two hours from the start line with a 20 minute lead on the second place car, when a major system failure occurred. In the process of trying to exchange controllers, the backup system was blown. With nothing left to race with, we were rescued by James Warden, the president of Solectria. He installed a new controller, and after three and a half hours, we were back on the road, falling in line in 27th place. We continued to experience problems for the next two days. By the end of day three, we were in seventh place. That evening we received a totally new system, motor and controller, from James Warden. He also insisted that we change out the throttle control pot and cable, which was suspect. At that time, we also found stray voltage from the panel on the frame of the vehicle. All these changes were made on the evening of the third day of the race and from that point on, we did not experience any more problems.

To this day we are not sure what caused the motor failure on the first day of the race. The driver described the event as the motor trying to switch into reverse. The noise generated by this event could be heard in the chase vehicle as a loud bang. Even after we were back on the road with a new controller, the symptoms continued. To prevent burning the controller each time the symptom occurred, the driver would simply come off the throttle, coast to a stop, and allow the controller to reset itself into the forward mode, and then continue on. Needless to say that having to stop every so often to reset the controller made it difficult to regain our position in the race.

Many theories were put forth to explain the problem. Some thought that the problem was with the motor and the Hall effect switches that establish the shaft position for the controller logic. Others suspected the D-connector that passed the throttle control signals to the controller. James Warden thought that the pot we were using for the throttle was not the correct type. Another theory was that the panel voltage leaking to the frame may have sent signals to the controller and contaminated the controller logic. All of these issues were addressed at the same time, the evening of the third day of the race. Since we did not have the opportunity to isolate the effect of each change that was made, we will never know what really happened. However, the performance on the Solectria systems in terms of efficiency was certainly better than the Unique Mobility systems that powered Solar Eagle (I). We were very pleased with the last system that James Warden installed in our vehicle on the third day of the race, and we purchased that system after the race.

The 1993 World Solar Challenge in Australia is a much different race. The race period every day is nine hours long. To do well requires a vehicle that can travel fast on sunlight alone with very little input from the batteries. Efficiency and panel power are crucial to success. Solar Eagle II could run at 40 MPH on 1,000 watts. Therefore, a small motor would be appropriate since we were not going to experience the hills and traffic conditions that we experienced in Sunrayce 93. A small motor running close to its maximum output would be more efficient.

To prepare for the Australian race, we made two purchases that would make us a bit more competitive and reliable. We arranged with Industrial Drives to build a special brush type motor for us. This motor design is a remake of a motor that was used by Crowder College in the GM Sunrayce USA in 1990 and in the 1990 World Solar Challenge later that year. The controller for this motor, also used by Crowder, is a unit purchased from the Australian Energy Research Labs (AERL) a year before. The system can produce 2,000 watts of continuous power but proved to be less efficient (86%) than the Solectria systems (90% +) we had acquired earlier. Being a brush motor with very simple electronics, and being identical to a system successfully used by a competitor in a previous race, the Industrial Drive/AERL system was considered to be a good backup system should all else fail. The second system we prepared for the 1993 World Solar Challenge consisted of a new motor from Solectria (new purchase) and the controller from the third system purchased after Sunrayce 93. The new motor, motor #4, from Solectria was a custom series wound brushless motor designed specifically for the expected conditions of the 1993 World Solar Challenge. It produced 2,500 watts of continuous power with a top speed of 3,000 RPM. The gear ratio was set up so that the top motor speed would produce a vehicle speed of a little more than 45 MPH. At the design cruising speed of 40 MPH, we could capture the system's best efficiency which tested out to be 91%. The new Solectria system became our front line system for the race. However, we did experience one problem during a trial run of the vehicle four days before the race. It was an event similar to what happened in the Sunrayce, but it only happened once. For a quick fix, we changed the throttle control pot and control line bypassing the D-connector again as we did in the Sunrayce. We now suspected that the problem all along had to do with humidity causing the control signals passing though the D-connector to become corrupted. High humidity was a common factor during the first two or three days of the Sunrayce 93 and in Darwin, Australia. After the change was made, no more problems occurred and the Solectria system performed well.

Power Electronic System The power electronic system refers to the circuits that connect the solar panel, the batteries, and the motor so that the solar energy is efficiently utilized to power the vehicle. The system brings electrical energy in from the panel through peak power trackers and feeds the energy onto a battery bus. The peak power trackers adjust the current-voltage characteristics of the solar panel to ensure that the panel produces its maximum power. The energy from the solar panel can either be used to charge the batteries or power the motor through the motor controller.

The power system is turned on by switches on a panel on the left side of the driver compartment. The switch panel is accessible to the driver and anyone standing next to the vehicle, when the canopy section is raised. The switch panel has three switches; 1) the battery switch, 2) the motor switch, 3) the solar panel switch. All power switches in the switch panel are rotary switches made by the Electro-Switch Corporation. Semi-conductor fuses are connected in line to provide protection. The battery circuit has a 100 amp fuse and the controller circuit has a 60 amp fuse. All power cables are of 6 gage stranded wire with closed, soldered terminal ends.

The system is designed so that the battery switch is turned on before the other switches. This is necessary to prevent damage to the components of the power system. After the battery switch is turned on, either the motor or the panel circuits can be activated. The motor circuit has a precharge switch that is turned on 5 seconds before the main switch is thrown. The precharge switch charges the large capacitors in the controller with a controlled amount of current to prevent large destructive transients when the main power switch is thrown.

The system is configured such that the power from the panel can charge the batteries or power the motor directly depending on the power demand for running the vehicle. For example, if the vehicle is moving at a speed that requires less than what is being produced by the solar panel, the system will use the excess energy to charge the batteries. If the power demand from the vehicle is more than what the solar panel is producing, the power to run the vehicle will automatically be supplemented by the batteries to meet the demand.

Batteries The design parameter for the battery pack in both the Sunrayce 93 and the 1993 World Solar Challenge is that the total battery capacity must not exceed 5 kilowatt-hrs based on a 20-hour discharge rate. However, the Sunrayce 93 rules specified the use of off-the-shelf, commercially available lead acid batteries. The power system is designed around a 120 volt bus. The Sunrayce battery pack selected consisted of ten, 12-volt batteries.

Team Solar Eagle II addressed the issue of the lead acid battery pack on two fronts. First, we searched the market for an existing battery that had a good energy to weight ratio, and second, we worked with a lead acid battery manufacturers to design a "Sunrayce battery" for sale to Sunrayce entrants. The specifications for the perfect battery were established for Solar Eagle II's operating voltage of 120 volts. 5 kilowatt-hrs from a 120 volt system meant the batteries must produce just over 41 amp-hrs. An equally important issue was that the pack be as light as possible. Both fronts were attacked simultaneously with calls made to major battery manufacturers requesting technical support and literature.

Three companies were interested in designing a custom battery: Teledyne; Trojan Battery, and Concorde Battery. Meetings were established, many phone calls were made, and technical specifications were conveyed. Unfortunately, after a considerable amount of waiting for something to come forth, not a single company was able to or wanted to design a lead acid battery that was significantly better than what could be currently found in the marketplace. The efforts made on the second front were more fruitful.

Batteries that looked promising were ordered and tested for energy and power density, and cycle tested at different depths of discharge to determine their degradation against cycle life. Much of the testing was made possible by Dr. John Dunning, Manager of Delco Remy, West Coast Operations. His facilities were made available for much of the discriminating tests performed to weed out the good batteries from the mediocre ones. At this facility the "Single Channel Cycler" was used to test the 12 volt and some 24 volt batteries. The Cycler allowed a computerized cycling and monitoring of the battery under test. It was quickly learned that most batteries did not meet the manufacturer's specifications.

The following is a list of some of the batteries tested:

- Exide starter battery, H55-60, 70-50
- Teledyne 24V aircraft starter battery, G-246
- Panasonic starter battery, Miata car battery
- GNB utility battery, CS-190, HD-12
- Deka utility battery, 8TU1
- U.S. Manufacturing utility battery, U1
- Trojan utility battery, DC-9R

After testing many different classes of batteries, the utility class stood out. The clear winner was the U.S. Manufacturing Company U1 battery.

After this selection was made, many more hours of work were necessary to condition the batteries. The batteries were cycled in order to improve their capacity and power density. Approximately 30 cycles at 80% depth of discharge were run on nearly 60 batteries in the hopes of finding 12 equally matched batteries. The selection process for the best 12 was conducted at Dr. Dunning's Delco Remy battery test facility, again using the Single Channel Cycler. The final set of batteries that were selected produced 15.8 watt-hrs/lb at a usable 4-hour discharge rate, and 19.7 watt-hrs/lb at the 20-hour discharge rate. As it turned out, the battery pack in the Solar Eagle II in the Sunrayce produced nearly the maximum energy allowed and was one of the lightest packs amount the entries (262 pounds).

Since the World Solar Challenge did not restrict the battery type to any particular type, the battery of choice in terms of energy density per unit weight is silver-zinc. For the battery pack we chose a silver-zinc battery made by Eagle-Picher Industries, model SZHR 25-5, a 40 amp-hr, 1.5 volt cell. 83 cells were required to achieve the 5 kilowatt-hr capacity. These batteries required an activation procedure which included filling the cells with a pre-measured amount of battery fluid (potassium hydroxide), and applying an initial charge. This procedure was carried out in Darwin, Australia, five days before the race. The cells were clamped together in six rows with hardware that also allowed the pack to be secured into the battery box. Clamping the cells prevents the cell from expanding when they are charged or discharged with high currents.

Both the lead-acid and silver-zinc pack used in the two races, were housed in a battery box which is an integral part of the structural frame of the vehicle. For the battery box to operate as a structural member, the box must always be covered with the lid fastened in place. With the lid in place, the battery box tended to trap the heat generated by the batteries. This was an ideal environment for the lead-acid batteries but not for the silver-zincs. A ventilated cover would have been better for the silver-zinc pack. In the 1993 World Solar Challenge, the silver-zinc batteries ran very hot which diminished their performance and added some heat to the structure which may have caused the thermal protection system to shut down the peak power trackers.

Auxiliary Power Systems The auxiliary or house-keeping power system is powered by two model VI-51J CZ, DC-DC converters purchased from the Vicor Corporation. The input of the converters are across the main battery and the output of the converters produces power at 12 volts DC. One of the converters was used to power the lights, horn and cooling fans. The other is used to power the telemetry and instrumentation system.

Instrumentation

The instrumentation system is divided into three subsystems: the CPU, the multiplexer, and the display. The following is a description of each subsystem:

The CPU The CPU has two microcontrollers, the 16 Mhz 68hc11e4, and the 8 Mhz 68hc11e9. Both communicate with each other through a dual port ram chip. The 68hc11e9 has the responsibility for the speed, the driver input, the display, and the RF modem I/O. The 68hc11e4 has control over four, 12 bit A/D converters, nonvolatile ram, battery backed up date and clock, and a 84 channel multiplexer. The A/D converters measure panel current, buss current, multiplexer voltage, and buss voltage.

The Display A 4 x 40 character display is mounted just below the driver's line of vision in the canopy. It is divided into two sections: a fixed 4 x 20 character display on the left side; and a selectable 4 x 20 character display on the right side. The fixed display reads the following values: MPH, watt-hrs per mile, watt-hrs, amp-hrs, battery voltage, battery current, panel current, and motor current. The selectable right hand side of the display can page through the readings of all 84 battery voltages, buss watts, panel watts, motor watts, trip distance, and messages received from a remote computer via an RF modem. The right hand side of the display is controlled by three SPDT momentary switches located on the left hand side of the steering wheel placed so the driver can elect/deselect, increment/decrement, and page up/page down, simply by depressing the appropriate switch.

The Multiplexer For the 1993 World Solar Challenge, Solar Eagle II had a battery pack of 83, 1.5 volt cells. A multiplexer was used to monitor the voltage on each cell and display the readings on the display and on a remote computer via an RF modem. Twenty-two, 4-pole relays are used to form a multiplexer matrix capable of sampling up to 88 battery voltages. Each voltage measurement is accomplished by averaging 64 samples from a 12 bit A/D converter. A scan rate ranging from 4 seconds to 10 seconds, can be selected by the driver by depressing the appropriate switch on the steering wheel. As the pack is scanned, the new values are sent to the display and the remote computer via the RF modem.

Solar Power System

The solar power system consists of the following components:

1. Peak power trackers
2. Solar Panel

Peak Power Trackers The energy for the solar panel is fed through the peak power trackers to the batteries. The peak power trackers are Maximizers made by the Australian Energy Research Labs (AERL). The purpose of the Maximizers is to adjust the impedance load of the solar panel so that the panel will operate at its peak power point to insure maximum power from the panel. The output of the Maximizers float at a differential voltage above the battery bus voltage so that all the panel power will flow onto the battery bus. As explained earlier, the power from the maximizers can be used to either charge the batteries or be used to power the motor directly, depending on the power demands for running the vehicle. The Maximizers purchased for Solar Eagle II are different from those in Solar Eagle (I). The newer units are stripped of their power supply and are powered directly from the panel, making them much lighter.

The Maximizers have always worked very well. Their performance in Sunrayce 93 was as expected. However, their performance in the 1993 World Solar Challenge fell short of their specifications. They were unable to produce the panel power that was produced in the Sunrayce. We believe this was caused by a thermal problem. At a time in the day when the panel had produced 950 watts of power in the Sunrayce, the panel was producing 850 watts in Australia. During the race itself when the problem was finally traced to the Maximizers, extra cooling was applied to the Maximizers to correct the problem. These attempts worked to some degree but did not solve the problem entirely. Consequently, we ran the entire race with less power than was anticipated. At the end of the race, we spoke to Stuart Watkinson, the builder of the Maximizer, and he informed us that the units we purchased had a design flaw that was discovered later and he had failed to inform us of the flaw. A metal screw was used to hold an inductor to the circuit board and the screw created a heat path to the board causing the Maximizer to cut back on its power output. After the flaw had been discovered, the metal screw was replaced with a nylon screw in the later units that were sold to our competitors. It was the penalty we incurred for having started building our car early in the game and purchasing the new Maximizers before all the bugs were eliminated. Also, had we been notified of the problem we could have returned the units to AERL for correction.

Solar Panel The regulations regarding the solar cells for Sunrayce 93 were that we must use a terrestrial grade cell that cost less than \$10 per watt. At the time, all terrestrial grade cells made in the U.S. were at best 14% efficient. The most efficient terrestrial grade cell to be found was a laser etched cell made by British Petroleum Solar. The laser etching process was developed by the Australians some years ago and BP Solar had acquired the license to apply the process to terrestrial grade cells. The BP Solar cells boasted of a 17% efficiency. CSLA was one of the first schools in line for the purchase of BP cells. In December 1991 we began a correspondence with BP Solar which turned out to be the beginning of nine month struggle to

acquire their cells. We first paid for a sample group of one dozen cells with connecting tabs already attached. In three weeks they arrived mostly broken and unusable. The packing of the cells was poorly done. Of the cells that were whole, the tests showed they were far below their stated efficiency. A second group of sample cells were requested with the promise from BP Solar that better packing methods be used. The second group of cells arrived in tack and tested better than the first sample group, but were not the 17% that were advertised. Their efficiency was about 16%, but were still better than any other cell that we could buy.

By April 1992, BP Solar was advertizing cells in categories of efficiency ratings. The top category cells with a minimum efficiency of 17.5%. The second grouping had efficiencies between 17% and 17.5% and the third group was less than 17%. We opted to buy the first grouping which was still less than \$10 per watt. We placed an order for 1000 cells. Within a month of that order, Sunrayce officials declared that the 17.5% efficient cells would not be accepted by race officials since those cells were very rare and could not be supplied to all teams if they so wanted them. Legal cells are those that could be available to all 36 teams in lot sizes of 2 kilowatts per team. The initial order we placed was then changed to 1200 cells from the cheaper second group of cells (17%) which were legal.

Between January 1992 to June 1992, BP Solar changed the standard size of their terrestrial cell three times. This caused delays in delivery which continued through to the middle of Summer, 1992. The delays were beginning to create serious problems with finishing the design of the vehicle since the cell size effects the dimensions of the solar panel and these dimensions impact other aspects of the design. Each time BP Solar changed the cell size, a new panel was designed. To end the frustration caused by months of delays, we accepted the final standard cell size for delivery with the expectation that we would trim the cells to whatever size we required after delivery. Some of the cells in the order were to be cut into smaller cells for the side panels. Delivery of our cells was finally made in August, 1992.

The final design of the panel included two strings of solar cells on the top panel with a single string of cells on each side of the vehicle. The cells on top were trimmed to 97 mm wide by 94 mm long. The cells on the side were cut to 100 mm wide by 21 mm long. The forward panel on the top of the car surrounded the canopy and had 394 cells. The rear panel on the top of the car had 360 cells. Each side panel had 412 cells. The cell count in each string is limited by the open circuit voltage limit of the peak power trackers which was 250 volts. The lower limit of each string was determined by what the string voltage would produce in 50% sunlight. This condition produces at least 150 volts. Each string had its own peak power tracker to ensure independent operation of each string.

The first task upon receiving the cells from BP Solar was to test each cell individually and grade them according to current output at a specified voltage. This task was accomplished at Hughes Spectrolab in Sylmar, California. From our experience with the sample cells we had received months earlier, we knew that working with these cells would be extremely difficult and problematic. The soldering of the interconnects to the tops of the cells required a skill that was lacking within the team, and the metal laminations on the back of the cells was delicate and

would come off easily. In an attempt to eliminate the difficulties we knew existed in working with these cells we contracted with Photocomm Inc. in Scottsdale, Arizona to interconnect the cells into panels and laminate the panels between layers of plastic. The intent here was to have experienced people do the soldering, and have a laminated panel which would providing good protection for the cells and make them easy to install on the car. This did not work out, however, because a sample panel made by Photocomm proved to be extremely heavy.

By the time having the panels made by an outside vendor proved unworkable, it was the end of November, 1992. The only option at that time was to build the panel entirely by ourselves using coverglass to protect the cells. Cover glass was a option that would protect the cell, maybe improve its performance, and was light weight. As with Solar Eagle (I) we solicited and received a donation of cover glass for the cells from the Optical Coating Laboratory, Inc. (OCLI). The cover glass is bora silicate glass with an infrared and anti-reflecting coating. The infrared coating restricts certain wave lengths of light from passing through, and the anti-reflecting coating reflects undesirable wave lengths so as to reduce the surface temperature of the cell.

We also arranged with TRW to use their resistance welding equipment to attach the interconnects to the tops of the cells. This task was completed in three days. In January, 1993, the cover glass was bonded to the cells using optically clear silicon adhesive from Dow Corning, Sylgar 184. The cells were then soldered together in strings and tested in the light room facilities at TRW. This step in the process was to check if there were cells that had gone bad in the process up to that point. Changing out cells at this stage in the process would be far easier than changing them out once they were attached to the car. Since the light room was available only at night and on weekends, we had to work around TRW's schedules. After several, tedious all-night sessions at TRW, the task was completed.

With the strings of cells tested, the attachment of the cells to the vehicle began in the first week of April. Double-sided tape made by 3M was used to attach the cells to the vehicle. The process proceeded with great concern since this method of attaching cells to the car had never been done before. There was also concern regarding the degree to which the cells would remain attached to the car since the backs of some of the cells would delaminate easily. To make matters worse, the job was being rushed in order to have the car completed by the time of the roll-out ceremony and the qualifying trials at the Phoenix International Raceway. As it turned out, the panel was attached but not functioning when we arrived in Phoenix. It was, however, finished shortly thereafter.

The panel was completed by connecting up the rows of cells at the end of each row. Wires for the bypass diodes are passed through the panel substrate through drilled holes lined with epoxy tubes to provide insulation. The diodes are installed so that they bypassed 20 cells or so. Around the canopy, where shading was expected, more bypass diodes were used to minimize the losses due to shading. An umbilical cord from the frame connected the panel to the peak power trackers mounted next to the frame.

The panel produced nearly a 1,000 watts on clear days during the Sunrayce. With the sun reflecting off the clouds, a condition experienced during the last two days of the race, the panel power reached 1,300 watts and more for brief periods.

Body

The Solar Eagle II body consisted of:

1. The belly pan
2. The main body
3. The canopy section

The following section discuss the design and fabrication of each section of the Solar Eagle II body.

Belly pan Before any of the body parts could be made, the first task was to build a body plug. The plug, made from plywood, foam, bondo, fiberglass, and body putty, is an exact representation of the shape that is to be built. From this

The first part to be made was the belly pan, a piece that attaches to the underside of the frame. The belly pan has plug, a female mold is made, The mold is constructed of several layers of fiberglass on both sides of a 1.0" thick balsa wood core. From this mold all the body parts were constructed. two purposes. First it is a structural member acting as a shear panel for the underside of the frame, and second, it supports the main body. The belly pan is constructed of three layers of carbon fiber cloth (plain weave #242 by Hexcel) with a rib around the outer edge of the pan. The rib has a foam core, about 1/2 inch thick, with six layers of cloth along its top edge to create a tension member. The rib provided stiffness for the part, and a means for attaching the belly pan to the frame. The belly pan when finished was attached to the frame at six points that supported vertical loads, and six points that carried shear loads for the frame. The belly pan weighed in at 25 lbs.

The Main Body The main body is comprised of two pieces: the lower piece; and the upper piece. Each piece was made separately then joined together. The bottom section was layed up with two layers of cloth on both sides of a foam core. A rib bordered the opening in the bottom of this piece to provide stiffness for the lip that attaches the main body part to the belly pan. The weight of the whole body is transferred to the frame through this lip.

The top section of the main body part provides the surface of the main solar panel and the framing for the canopy section. The top solar panel substrate is two layers of carbon fiber cloth on both sides of a 1/2 inch foam core. Around the canopy opening is a rib, again for stiffness and support for the canopy section. After both main body parts were made, they were joined along a seam that extended along the side panels, around the midpoint of the nose and the trailing edge of the tail. The two pieces when joined together weighed 87 lbs.

Canopy Section The canopy section consists of a rectangular panel on which solar cells are mounted with a tinted, bubble canopy type windscreen covering only the driver's head. First, a male mold of fiberglass with a balsa wood core was made from the female body mold for the entire canopy section. This male mold duplicated the shape of the body for the rectangular panel of the canopy section. On top of this male part, the bubble canopy of wood, foam and bondo was shaped and finished. From this male mold, a female mold of the entire canopy section was made, again using fiberglass with a balsa wood core. From the female mold, the canopy section was made, along with another male mold of just the canopy bubble. This male mold was made of a special cement with hemp added for strength. The cement male mold was given to Aircraft Windshields in Los Alamitos, California who used it to make the canopy. They stretched .10" thick, tinted acrylic sheet over the mold to produce the shape. The canopy was made in two pieces, front and rear. The two pieces were then bonded into the canopy section to complete the assembly. The canopy section was then attached to the main body with a piano hinge along the rear edge of the canopy section.

When the body was complete, it was taken to TRW and put into a large oven for post curing. The intent here was to cure the composite structure at a temperature in excess of that which the body would experience in the race. The post curing process at an elevated temperature raises the glass transition temperature of the composite thus allowing the structure to maintain its integrity when it gets hot. The glass transition temperature is the temperature at which the matrix material (epoxy) begins to soften. As a general rule, the composite structure should be cured at a temperature higher than the expected operating temperatures for the structure. We expected that the operating temperature for the vehicle could go as high as 160 degrees in direct sunlight. The structure was post cured at almost 200 degrees Fahrenheit.

The body was finished with primer and paint. The emblem was hand painted and protected with a clear finish. The solar panel areas were covered with a clear finish to provide extra insulation for the solar cells since the carbon fiber on the body is both electrically and thermally conductive.

MODELING VEHICLE PERFORMANCE

There is a fundamental equation that governs the performance model of the Solar Eagle in terms of its use of energy. The equation accounts for power consumption in three areas:

1. Aerodynamic drag
2. Rolling resistance
3. Climbing hills

Before the model can be used as a tool for race strategy, a complete understanding and determination must be made of the parameters in this equation. For example, the drag coefficient must be determined along with the frontal area of the vehicle. These two parameters determine

the power consumption due to aerodynamic drag. The drag coefficient can be estimated from wind tunnel tests on a model, and the frontal area can be measured and calculated. However, the actual drag coefficient must be determined from actual road test data with actual vehicle. Second, a determination must be made of the rolling resistance of the wheels. There is no way as of yet to determine the coefficient of rolling resistance in the laboratory. Again, this must be determined from the actual vehicle tests. Lastly, the power used in hill climbing can be simply calculated from the known vehicle weight and the grade of the roadway.

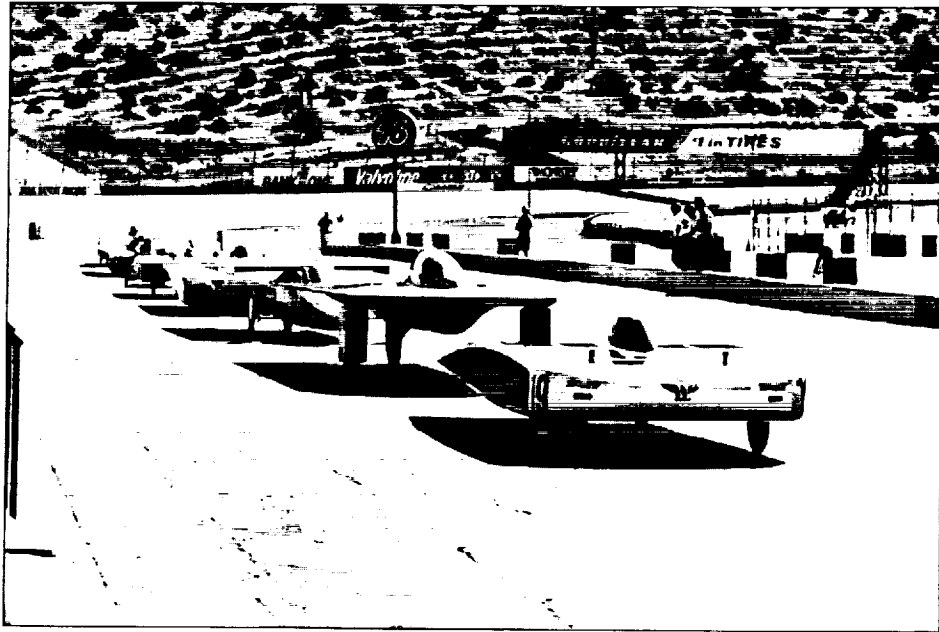
After the vehicle was finished and as part of the vehicle testing program, measurements were made on the vehicle as to its energy consumption at various speeds. For the data from these tests to be of any use, a reliable and accurate instrumentation system is required. From what was learned from the Solar Eagle (I) project, we were able to build an instrumentation system that had the level of accuracy that made the collection of performance data meaningful. The data from this instrumentation system was checked and verified with a very accurate amp-hr integrator that was purchased from Solectria. From the numerous road tests that were conducted, information about vehicle characteristics was collected that allowed us to piece together the values of the various coefficients in the performance equation that was to become the final version of the performance model.

The performance model became the heart of a computer simulation program written to assist the strategy team in making decisions based on input information regarding such things as the current and predicted weather conditions, the distance to be traveled before stopping for the day, the current state of charge in the batteries, the desired level of charge at the end of the day, the expected solar conditions for the day which included the position of the sun relative to the solar panel, and the route conditions ahead in terms of the hill grades that were expected. With all of these inputs made, a running speed could be calculated that would satisfy these conditions. This computation could be made at any time during the race day with updated inputs should race conditions change unexpectedly. The computer simulation model proved to be an invaluable, reliable and accurate tool for race strategy.

RACE RESULTS

Performance in Sunrayce 93

Sunrayce 93 was a seven-day race, which began June 20, 1993, running 1,000 miles from Arlington, Texas to Minneapolis, Minnesota, involving 36 entries representing universities from the U.S. and Canada. The race day began at 9:00 am and ended when the vehicle reached the designated end point for the day, but no later than 6:30 p.m. The team with the fastest time for the seven days was the winner. The following is a day-by-day account of Solar Eagle II's performance in the race.



With Solar Eagle II winning the pole position in qualifying, the expectations were that we would do well in the race. All that we had learned with Solar Eagle (I) had been incorporated into Solar Eagle II. Many more of the details were addressed in the design and construction of Solar Eagle II. The performance of Solar Eagle II exceeded that of Solar Eagle (I) by 15%, the strategy for running the vehicle was better, the system program to help with strategy was superior, the weather forecasting was significantly better, and the logistics for handling the car and attending to the team was greatly improved.

The team arrived in Arlington, Texas five days before the race. We spent the first two days in a practice run, driving the car up the race route to Tulsa. A scout team went ahead four days along the race route. The car was running flawlessly, and the battery pack was performing beyond our expectations. We did everything that we could think of to be ready. The only failure that we encountered was a broken motor mount that was fixed quickly. There was nothing to point to the problems we experienced on the first day of the race.

The start of the race took place in cloudy weather. Having pole position, we flew off the starting line not knowing how close we were being followed since cars started at 30 second intervals.

The first leg of the race to Ada, Oklahoma was a 162 mile run. With fresh batteries, and the expectations of arriving early to charge, we set out from the starting line at fast clip. After about two hours into the race, the driver radioed that he had lost all power. This message followed a loud noise that could heard in the chase vehicle. We pulled over, removed the body

of the car and began looking for the problem. After checking the fuses, control cables, and other parts of the system, it was decided that the controller had failed. In our attempt to change out the controller with a second unit, the second controller also blew out. With no more in terms of back-up, we were essentially out of the race. It took 15 to 20 minutes before the other cars caught up to us where we had broken down, indicating that in a two hour period, we had a substantial lead on second place.

The only option open to us at that time was to find James Warden, the president of Solectria who was somewhere on the race route and get help if possible. He was found, and when he arrived, he installed a new controller he had as a spare. We were on the road again after being down 3-1/2 hours. When we pulled back on the road we were in 27th place. The problem continued to occur, only this time the driver would release the throttle and let the car coast to a stop. Once stopped the controller would reset itself for forward movement and we would continue on. These occurrences suggested the problem was probably not with the controller but caused the controller to fail. By the time we reached our stop in Ada, it was 6:00 pm which did not leave much in terms of sunlight to charge. We knew that our bad luck on day one was also going to hurt us on day two since we were denied a good charge that our competitors who had arrived earlier had enjoyed. The good news was that we were still in the race and we had passed 10 cars after getting on the road, putting us in 17th place by the time we reached Ada.

That night we worked on the car with the help of James Warden. The next morning we started with about one-half of a full charge in the batteries. We passed four other cars ahead of us before we left the city limits of Ada. The problem with the controller, despite the work of the night before, was still there forcing us to pull over and stop occasionally.

The second leg of the race took us to Tulsa where we had moved up to seventh place overall. Part of the day was spent playing cat and mouse with George Washington University, because of the controller problem they ended up ahead of us. There was nothing we could do at that point as far as fixing the system. We were waiting for one of James Warden's associates to arrive with new hardware.

At the end of day three, we were the fourth car to roll into Fort Scott, Kansas, in fifth place overall. It was at this point, we changed out both the motor and controller for a totally new system. The throttle was also changed out since it was suspected by James Warden to be the problem. The original throttle control cable to the controller passed through a D-connector. The new throttle control cable was connected directly to the controller bypassing the D-connector. A new potentiometer was installed for the throttle control. The new controller was set in place in the car surrounded by a foam pad to completely isolate it from the car. The entire power system, motor and controller, were now isolated from the frame and body. Also, that evening while making an electrical check, a voltage appeared on the frame of the vehicle. It was traced to the panel and a short on the panel was found and fixed. All in all, many issues were addressed that evening that could have been the cause of the problem that had begun on day one.

After a television appearance on *Good Morning America* for four of the vehicles (including Solar Eagle II), day four began with high hopes except for the anticipation of bad weather ahead. It was also expected to be a difficult day because the race route passed through some hilly and difficult areas around Kansas City. Day four for us turned out to be a good one. There were no more problems with the power system and we ended up in first place for the day, into Cameron, Missouri. We made it through Kansas City ahead of very heavy rains that caught the slower cars. We played another round of cat and mouse with George Washington University. This time we won because they ran out of batteries about a mile or so from the finish for the day. Coming in first in Cameron was quite an event for us. The entire town it seems was waiting for us. The mayor along with other dignitaries were there, speeches were made and a plaque was awarded to us. The downside to that day was that the storm that caught many of the cars outside of Kansas City was moving in with a vengeance. There was no sun for charging that evening and nearly all the teams had very little left in terms of battery power.

Day five started with a downpour delaying the race. It was certain that most if not all of the teams would not make the end point for the day. Batteries were very low and there was no sun. We made it through the mid day stop to about 30 miles from the finish after a day of moving very slowly trying to run off the sun. Except for the University of Michigan, all the teams had to trailer their vehicles to the finish in Des Moines, Iowa. Michigan was able to limp through the day to the finish because they had configured their motor winding the night before to run very efficiently at low speeds. Trailering in incurs a large penalty--two minutes per mile plus 9.5 hours for the whole day. This put Michigan substantially ahead of second place without any hope of catching them, unless they broke down.

Iowa State had put a fresh battery pack in their car in order to cross the finish line for the day as a show for the home town folks. This incurred a large penalty. Since they were not doing well anyway, it didn't matter. At this point in the race, our principal opposition was George Washington University. They were unable to make it to the mid day stop and had to trailer their vehicle substantially further than we did. Their penalty was bigger than ours putting us in a solid third place in the race, with Pomona and Michigan solidly in second and first, respectively.

Day six was sunny and cooler, and the Solar Eagle II was running flawlessly. Our race strategy was working and everything was running as we had always hoped. We easily pulled in first for the day in Albert Lea, Minnesota. Since Michigan had a large lead, they were probably not pushing it to ensure that they did not break down. That afternoon, the sun was perfect for charging and by the end of the evening, the batteries were essentially full.

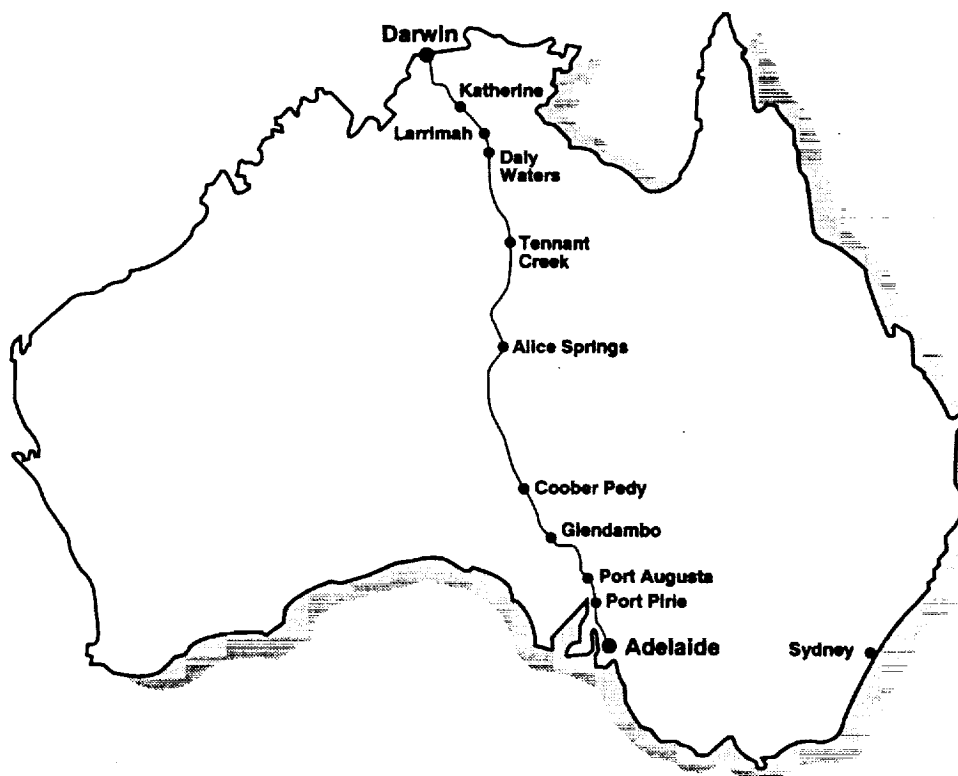
The leg for the final day was 87 miles long. Our batteries were full and we were first in line to leave. We calculated that with the excellent solar conditions expected for the day, we could drive the speed limit and still have batteries left over. We pulled out of the starting line behind the pace car, a 1993 Camaro. Solar Eagle II and the Camaro drove the speed limit together all the way to Minneapolis. The cross winds were severe, but we managed to maintain enough stability to drive 55 MPH. We followed the Camaro across the finish line after two hours

and five minutes averaging 43 MPH for the day, breaking our own record for the fastest day, a record we established on the first day of GM Sunrayce USA in 1990. George Washington University crossed the finish line 10 minutes later followed by Michigan and Pomona.

Not winning this race was a bitter pill for the team, since it was clear that we had a faster car. We were consoled by the fact that we had finished first three of the seven days of the race, more first place finishes than any other team, and after the motor problems had been straightened out, we ran very competitively with an excellent race strategy. Final results for the Sunrayce 93 are shown in Appendix A.

Performance in The 1993 World Solar Challenge

The World Solar Challenge is a race held every three years running from Darwin in the north to Adelaide in the south, 2,000 miles across the outback down the Stuart Highway through the Northern Territory towns of Katherine, Tennant Creek, and the midway point Alice Springs, and into the Southern Territory through Coober Pedy, Port Augusta and into Adelaide. The race route is shown below.



The car and trailer were packed and shipped to Adelaide by the end of September. The trip would take some four weeks. The advance team met the car in Adelaide, got through customs, purchased some supplies that could not be shipped with the car, rented a small bus, and on the 25th of October headed north to Darwin, arriving three days later in Darwin, a garage space was reserved for us in the center of town, near the starting line for the race.

The first task in Darwin was to activate and charge the batteries. This was a process that took two days. The solar panel was checked for bad cells. Some were found and replaced. A practice run was scheduled four days before the race. The purpose of the run was to put a full discharge cycle on the batteries and do a final check on the car. Everything went well except for an incident involving the motor and controller which was similar in nature to the problem we had in Sunrayce. The speculation this time was that the humidity might be causing a problem with the control signals which ran through a D-connector to the controller. For insurance, we changed the throttle control as we had done in the Sunrayce. We replaced the throttle control on the steering wheel with a potentiometer in a box attached to the frame on the left side of the driver compartment and ran the control cable directly to the controller bypassing the D-connector. The new throttle did not have a spring return and acted like a cruise control. Since we would be traveling on an open road with no traffic or traffic lights, this was not seen as a problem. After the change was made, there were no further problems with the motor and controller.

The batteries were fully recharged for scrutineering. We passed scrutineering but later had problems with the battery pack seal that was installed by the officials. The seal consisted of a spring that was laid over the batteries in such a way as to indicate if any tampering had occurred. The string, however, got soaked with battery fluid and became conductive. This provided a current path that shorted the cells. The seal was a bad idea and eventually removed. Since the battery pack in our car was in a box with a cover, a tamper proof seal was placed on the cover of the battery box. The speed run on the final day of scrutineering placed us in 10th position for the start.

On the second day of the race we became aware that the panel was not producing the power expected. Our tests on the panel before the race were conducted while the panel was stationary and very hot from the sun. Under such conditions, the panel was not expected to produce what we would expect during the race because of the heat. But with the car moving and the cells being cooled by the air flow, we would expect more energy. It became clear that was not happening. The batteries were running very hot which was not good for silver-zinc batteries. The body of the car around the battery box and where the Maximizers were mounted seemed unusually hot. We began to speculate that the Maximizers were cutting back on panel power because of the thermal protection circuit built into the Maximizers. For the next two or three days, we tried various means to cool the Maximizers so that they would not limit the power of the panel. No matter what we tried, the panel power had a ceiling of about 850 watts of power, at least 100 watts less than we expected, and what the panel had produced in the Sunrayce.

Despite the lack of panel power, the weather during this race was better overall than what we experienced three years before. Also, Solar Eagle II was far more efficient than Solar Eagle (I) and our strategy and weather forecasting were far better. All of these factors contributed to finishing the race in two days less time than our run of three years earlier. Below are the race results for both the 1990 and 1993 World Solar Challenge for Solar Eagle (I) and Solar Eagle II:

1990			1993		
<u>Day #</u>	<u>Dist(Miles)</u>	<u>Speed(MPH)</u>	<u>Day #</u>	<u>Dist(Miles)</u>	<u>Speed(MPH)</u>
1	175	21.9	1	331	37.5
2	215	24.9	2	321	37.0
3	235	26.8	3	350	39.6
4	278	31.0	4	326	36.9
5	193	22.0	5	280	31.7
6	275	31.0	6	258	39.0
7	247	28.1	Finish 2:47 pm Day 6		
8	250	37.1	Average speed: 37.0 MPH		
Finish 2:56 pm Day 8			Overall ranking: 13th out		
Average speed: 27.7 MPH			of 54 entries.		
Overall ranking: 10th out					
of 36 entries.					

The main reason for our lower finish ranking is the remarkable increase in the number and quality of the entries, primarily the result of an almost fanatical effort by the Japanese auto industry. The winner, Honda, completed the course at an average speed of 52.5 MPH, demolishing the record established by the GM Sunraycer of 41.5 MPH in 1987. Accomplishing such a speed would have been considered unthinkable prior to the race. Rumors have it that Honda spent between \$40 million and \$80 million on the project. In 1990, the record for the race was still held by the GM Sunraycer, but in 1993, five cars beat that record. The fifth place finisher had an average speed of 45 MPH. The second place finisher was the winner of the 1990 race, the Biel Institute averaging 49 MPH. 1993 World Solar Challenge race results through Day 6 are shown in the Appendix B.

Participating in the event was a great experience for our team which consisted of six students, two members of our technical staff, two faculty members, and a photographer and a videographer from the CSLA Creative Media Services staff.

ADMINISTRATION

The following sections describe some administrative aspects of the Solar Eagle II project. Included are the following:

- 1) Corporate Sponsors
- 2) University Support
- 3) Media Coverage
- 4) Awards and Recognition
- 5) Public Awareness Campaign
- 6) Future Directions

Corporate Sponsors

The Solar Eagle II project would have not been possible had it not been for the generous support of our corporate sponsors listed below:

AB2766 - Mobile Source Air Pollution Reduction Review
Committee
Automobile Club of Southern California
Caltrans
Hewlett-Packard Company
Los Angeles County Metropolitan Transportation Authority
MacNeal-Schwendler Corporation
NASA Langley Research Center
Nippon Oil Company
Optical Coating Laboratory, Inc.
SAMPE
South Coast Air Quality Management District
Southern California Edison Company
TRW

Many of the sponsors of our original Solar Eagle project came forth again to support our second effort, the Solar Eagle II project. Those companies and organizations are: Southern California Edison, TRW, Los Angeles Department of Water and Power, Automobile Club of Southern California, NASA Langley Research Center, South Coast Air Quality District, Optical Coating Laboratory, Inc, MacNeal-Schwendler Corporation, and SAMPE.

Assembly Bill 2766 provided us with the resources to support the team's participation in the national and international competitions as well as to put on a comprehensive public awareness campaign. Automobile Club of Southern California contributed cash support and continued to support the project by providing a vehicle and public awareness at many of their events. The Auto Club invited us to join them at their exhibition at the L.A. Auto Show in January 1994. Caltrans, a new sponsor, provided us with financial support to fabricate the vehicle and to support

the team's transportation to the competitions as well as support of our outreach program. Thanks to Caltrans, we were able to use a portion of the I-105 freeway to test-drive the car before the freeway was opened to the public. Hewlett-Packard donated a programmable load bank that was used to test the batteries. Los Angeles County Metropolitan Transportation Authority provided financial assistance to the project. MacNeal Schwendler Corporation made a financial donation to the project and provided finite element software which was used in analyzing and designing the car's frame. NASA Langley Research Center provided us with financial support. Nippon Oil Company donated huge quantities of carbon fiber for use in the design of the shell. Optical Coating Laboratory, Inc. (OCLI) donated a portion of the costs of the cover glass for our solar cells. Society of Automotive and Materials Processing Engineers (SAMPE) contributed financial support to the three California schools participating in the Sunrayce 93. The South Coast Air Quality Management District provided us with financial support. Through our support from the Southern California Edison Company, a research project entitled, "Method of Improving the Energy Efficiency of Electric and Solar-Electric Vehicles," was conducted and a final report was prepared for Research Department at Edison.

Additional in-kind support was received from the following vendors:

Toray Industries
Nippon Petrochemicals
Techniweave
Tonen Energy
Motorola
Hexcel Corporation
Mazda R&D
Rohm Tech, Inc.
Monicor
Vicor

A special thanks to Stu Moore, former Industry Advisory Board Member, who hosted a reception of the team and alumni in the Dallas/Fort Worth area at the Hughes Training Inc. Facility in Arlington, Texas on Friday, June 18, 1993.

We owe a great debt of thanks to the following individuals at each of these organizations.

AB2766 (Mobile Source Air Pollution
Reduction Review Committee)

Laurie Hunter
Dr. Carol Sawyer
Jim Vint
Judith Hathaway-Francis

Automobile Club of Southern
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Tom McKernan
Mike Appleby
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Caltrans

**Jerry Baxter
Margie Tiritilli**

Hewlett-Packard

**Fred Smith
Nancy Levitt
Kevin O'Connor**

**Los Angeles County
Metropolitan Transportation
Authority (MTA)**

**Franklin White
James Ortner
Michael Bustamante**

**Los Angeles Department of
Water and Power**

**Eldon Cotton
Carl Haase
Tom Doughty
Tim Cherry
Mindy Berman**

MacNeal-Schwendler

**Richard MacNeal
John Caffrey
Ken Ranger
Dan Orozco
Kenn Morris**

NASA Langley Research Center

**Daniel Goldin
Samuel Massenberg
Bob Yang
Yvonne Freeman**

Nippon Oil Company

Andy Marshall

Optical Coating Laboratory, Inc.

**Herb Dwight
Bob Leeds
Guy Rector
Brenda Ledyard**

SAMPE

**Fred Tervet
Susan Ruth
Dan Plaskon
Charlie Hammermesh**

**South Coast Air Quality Management
District**

**James Lents
Jonathan Leonard
Alan Lloyd
Mike Bogdanoff**

Southern California Edison

Charlie McCarthy
Mike Merlo
Michel Wehrey
Richard Schweinberg
Diane Wittenberg
Doug Whyte
Nick Patapoff
David Briery
Richard Keeler

Spectrolab, Inc.

Dieter Zemmrich
Ron Diamond
Greg Glenn
Jerry Kukulka
Dave La Fort

TRW Space and Defense

Alice Byrne
Marshall Cannady
Pete Staudhammer

TRW Electronics Systems Group

Richard Lewis

U.S. Department of Energy

Richard King

We would be remiss if we did not acknowledge the sponsors and organizers of the Sunrayce 93 and the 1993 World Solar Challenge. Sunrayce 93 Sponsors: U.S. Department of Energy, General Motors Corporation, National Renewable Energy Laboratory (NREL), Society of Automotive Engineers (SAE), Chevrolet, Midwest Research Institute, U.S. Environmental Protection Agency, Sandia National Laboratories, Electronic Data Systems Corporation, Canadian Department of Energy, Mines and Resources. The sponsor for the 1993 World Solar Challenge was Daido Hoxan Inc. Official suppliers and supporters were: The Australian Department of the Arts, Sports, The Environment and Territories, The Northern Territory Government, General Motors Holden's, United States Department of Energy, Australian Department of Primary Industries and Energy; GS Batteries, Sumitomo Corporation, Sumitrans, JTB, Omega, and The Government of South Australia.

University Support

The University also provided major support to the project. Financial support was provided from Lottery Funds, the President's Reserve, Office of the Vice President for Academic Affairs, Instructionally Related Activities Fund, Equipment Funds, Associated Students, Inc., Continuing Education and individual members of the campus community. University Auxiliary Services

made a significant financial contribution by waiving the administrative charge on monies contributed to the Solar Eagle II project.

Our thanks to the following university personnel who were instrumental in arranging both financial and other forms of University support:

James Rosser
Mary Elizabeth Shutler
Margaret Hartman
William Taylor
Raquel Soriano
Dawn Marie Patterson

Particular thanks go to President Rosser and Provost Hartman who were enthusiastic supporters of the Solar Eagle II project throughout. Their encouragement and support were key to the success of the project.

Many other University personnel went "beyond the call of duty" in supporting the Solar Eagle II project through their time and effort. Carol Selkin was marvelous in writing our press materials and generating media coverage; Lillian Colores helped us immensely with the purchasing process; and Dave McNutt and his staff provided great creative talent. We also appreciated the many members of the campus community who gave us encouragement through their enthusiasm for the project.

Media Coverage

The Solar Eagle project received extensive media coverage. The Cal State L.A. Office of Public Affairs in coordination with the School of Engineering and Technology, Creative Media Services and media representatives from our sponsoring organizations (L.A. DWP, Southern California Edison, Automobile Club of Southern California, and L.A. County MTA) developed a comprehensive communication plan for the Solar Eagle II project.

The communication plans developed key messages to be disseminated and the vehicles that would be utilized to disseminate the messages. The team at CSULA worked on local media relations and a Washington D.C. public relations firm, Ogilvy Adams & Rinehart, worked on our national press campaign. This arrangement was made possible through our contacts at Southern California Edison. The purpose of the national campaign was to expose National Press about the Cal State L.A. Solar Eagle II and our participation in the upcoming Sunrayce 93.

Three key media events were held for the Solar Eagle II.

1) On Tuesday, April 13, 1993 the Solar Eagle II was unveiled to the public in a "Roll-Out" celebration in the campus stadium. On-air personality from KIIS-FM, Chris Leary served as MC for the roll-out event. A Sponsors Recognition Luncheon was held following the event. The Mayor's Office proclaimed Tuesday, April 13 -- Solar Eagle II Day -- in the City of Los Angeles.

2) A "Welcome Home" Celebration/Parade was held on Thursday, July 22 on the University's central walkway. A representative from Los Angeles Councilman Richard Allatore's office acknowledged the team for their accomplishments.

3) On August 25, 1993, representatives from the team receive official proclamation from the City Council acknowledging the students and faculty of Cal State L.A. for their accomplishments in the Solar Eagle II project, their participation in the Sunrayce '93 and best of luck in the upcoming international competition.

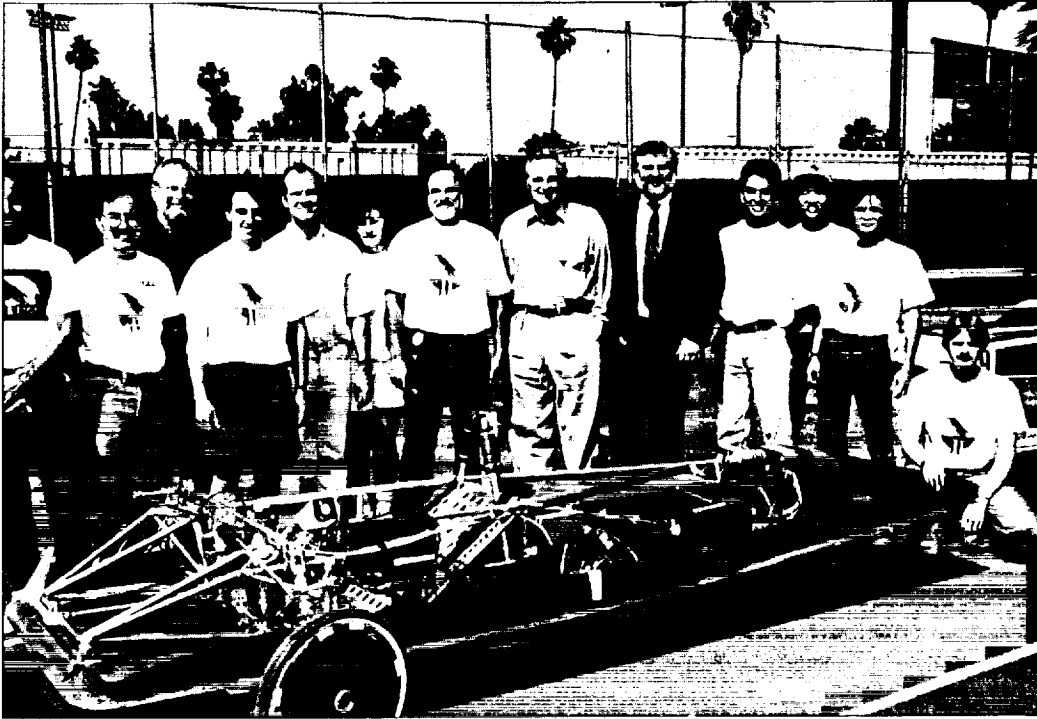
The Office of Public Affairs drafted media materials, arranged photo shoots, worked with Creative Media Services to build signs, decorated sites and videotaped various events, sent personalized pitch letters to local media, and followed up with telephone calls. A media packet with detailed technical information, press releases, photos, team biographies and information about the Sunrayce was compiled and distributed to local media. B-roll footage and press releases were also made available to local television media the day of the race. Media and photo opportunity advisories were drafted and sent out separately over the wire service, and new releases were distributed on the day of each event. Periodic updates were sent out during the course of the race, taken from telephone call-ins from Cal State L.A. representatives in the field, and distributed to media. Several television stations around Los Angeles covered Cal State L.A.'s participation in the Sunrayce 93.

Chief print media targets for the sendoff events and subsequent Cal State L.A. Solar Eagle II news in the Los Angeles media were the Los Angeles Times, Daily News, Pasadena Star News, Alhambra Post Advocate, San Gabriel Valley Tribune, Los Angeles Sentinel, La Opinion, and the International Daily News. Many articles and photos appeared in the above mentioned newspapers.

The University received extensive electronic media coverage from the Solar Eagle II project. Electronic targets included both radio outlets (KNW, KFWB, KFI) and television outlets (KCBS, KNBC, KTLA, KABC, KTTV, CNN and others) in the greater Los Angeles area as well as major wire services (UPI, AP and City News Service). Los Angeles area electronic media covered every key event on campus.

Some examples of the national and local electronic media coverage include:

1) Both on the Cal State L.A. campus and during the Sunrayce 93, the vehicle and team were filmed for an episode of the PBS Special, "Scientific American Frontiers," hosted by Alan Alda. The program aired on KCET in Los Angeles in December 1993.



2) Ricardo Espinosa, Student Team Leader, was interviewed by Paula Zahn of the *CBS Morning News* on day three from the Sunrayce 93. The interview was broadcast nationwide.

Awards and Recognition

The Solar Eagle II has received numerous awards and honors as listed below:

Sunrayce 93

Regional Qualifier: Fastest time trial in fifty laps (50.40 mph). Won pole position for the Sunrayce 93.

Overall finish: Third place of thirty-four entries

Daily Race Results: First place (three times)

Society of Automotive Engineers Safety Award: Third place in "Excellence in Engineering Design."

Sunrayce 93 Officials - Second place award in Technical Innovations in the area of body/chassis design.

Fastest one-day speed for Sunrayce 93 event: 47 mph

World Solar Challenge

Thirteenth place finish among the fifty-four car field.

Public Awareness Campaign

After its return from Australia in late December, 1993 the Solar Eagle II vehicle was used as a part of a public awareness campaign under the sponsorship of Assembly Bill 2766 and the South Coast Air Quality Management District. To assist us in our outreach efforts for the Solar Eagle II project, we hired Roman Vasquez, a civil engineering student and Solar Eagle II team member, to coordinate all of the outreach activities and to take the Solar Eagle II vehicle to all public events.

Between January and June, 1994, the vehicle was frequently on display at environmental and trade show events and at local junior high and senior high schools. Highlights included display from January 6 - 16 at the Los Angeles Auto Show and participation in the Alhambra/San Gabriel Chinese Parade on February 12.

Here is a list of some of the other interesting activities that the Solar Eagle II has been displayed at.

- 1) On July 28 and 29, 1993, the Solar Eagle II vehicle was filmed for an upcoming BBC special.
- 2) The Solar Eagle II was featured on the morning show on KTLA Channel 5 on September 17, 1993.
- 3) In August 1994, the Solar Eagle II was on display at the "TEXPO" Conference at the Ronald Reagan Presidential Library in Simi Valley.
- 4) In October 1994, the Solar Eagle II did an exhibition run and was on display at the Sixth Annual Career Opportunities Fair sponsored by the National Hot Rod Association and Automobile Club of Southern California at the Pomona Fairgrounds.

In February, 1994, we developed a new presentation entitled, "What is Engineering" using the Solar Eagle II vehicle as a case study of an engineering project. A letter was sent out to 150 educators in local high schools offering this presentation to their math and science classes. The response was overwhelming. The purpose of this new presentation was to educate local students about the following things; 1) What is the Solar Eagle II project? 2) What is engineering? What do engineers do? 3) How does engineering apply to this project and 4) Why is there a need for environmentally clean transportation systems? The Solar Eagle II has traveled to thirty-two junior high and high schools since then. An estimated 8,000 students have been exposed to the Solar Eagle II vehicle. Please see Appendix C for a comprehensive listing of all of the Public Awareness Activities for the Solar Eagle II.

Update on Solar Eagle I Project

While the Solar Eagle II was being shipped to Australia for the 1993 World Solar Challenge the Solar Eagle (I) was on display at several schools and community events.

In Spring 1994, the original Solar Eagle vehicle was given on long term loan to the new Petersen Automotive Museum for display. This world-class auto museum opened in early June, 1994. Located at Wilshire and Fairfax in Los Angeles, the museum attracts several thousand visitors each day. The Solar Eagle vehicle is prominently displayed as part of the museum's collection.

Future Directions

Future directions for the Solar Eagle II project can be placed in two categories.

- 1) Activities using the Solar Eagle II
- 2) Groundwork for Solar Eagle III

Activities using the Solar Eagle II

We plan to continue to use the Solar Eagle extensively for outreach and public relations activities. Specific areas of current and future activities are:

- 1) Exhibiting the car at off-campus locations with a particular concentration on high schools and community colleges.
- 2) Bring high school and community college students to see the Solar Eagle II in the Solar Eagle Display Room in E&T C156.
- 3) Giving audio-visual presentations on the Solar Eagle project to groups of students and to other community and professional groups.

4) Distributing Solar Eagle posters, buttons, videotapes, and curricular material to students as part of our outreach/recruitment efforts.

5) The Solar Eagle II vehicle and Display Room are always one of the tour stops when we entertain visitors to the School of Engineering and Technology or the University.

Groundwork for Solar Eagle III

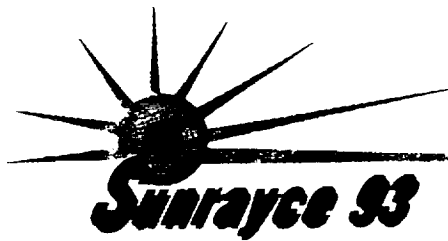
We are in the process of considering whether we should launch a third project to build a Solar Eagle III. There is a high level of interest among our students, key University Administrators seem favorable and our Industry Advisory Board gave us a vote of confidence at our November 1994 Board meeting.

CONCLUSION

The Solar Eagle II project has been a remarkable achievement of a team of Cal State L.A. students, faculty and staff. Third in the United States, Thirteenth in the World. The Solar Eagle II achieved unprecedented success and brought significant recognition to the University. The project engendered a high level of enthusiasm and pride all across the campus community. It has demonstrated once again that Cal State L.A. can achieve a high level of excellence which matches or exceeds that of the most prestigious universities in the nation.

APPENDIX A

SUNRAYCE 93 FINAL RESULTS



Overall Standings
for Sunrayce 93

Position	Team	Total Elapsed Time	Total Average Speed
1	University of Michigan	1:16:39:18	27.29
2	California State Polytechnic University, Pomona	1:18:09:20	26.32
3	California State University, Los Angeles	1:21:26:58	24.41
4	George Washington University	1:22:06:55	24.06
5	Stanford University	2:04:48:46	21.01
6	University of Maryland	2:07:42:30	19.92
7	University of Oklahoma	2:16:18:36	17.25
8	University of Massachusetts, Lowell	2:18:39:20	16.65
9	Kauai Community College	2:20:52:39	16.11
10	Iowa State University	2:22:17:42	15.78
11	McGill University	2:22:34:35	15.72
12	California State University, Fresno	3:03:30:23	14.69
13	Arizona State University	3:06:04:24	14.21
14	Queens University	3:06:14:48	14.18
15	Rose - Hulman Institute of Technology	3:07:41:30	13.92
16	Mankato State University	3:07:52:53	13.89
17	Drexel University	3:09:04:11	13.69
18	Western Michigan University	3:09:09:32	13.67
19	University of Missouri - Columbia	3:10:57:17	13.37
20	Virginia Polytechnic Institute	3:13:14:13	13.02
21	University of Minnesota	3:13:17:23	13.01
22	Rochester Institute of Technology	3:13:45:47	12.94
23	Stark Technical College	3:14:02:02	12.90
24	Colorado State University	3:15:02:00	12.75
25	Auburn University	3:18:04:22	12.32
26	University of Ottawa	3:18:19:11	12.28
27	University of Puerto Rico	3:19:06:11	12.18
28	Clarkson University	3:19:51:14	12.08
29	University of Missouri - Rolla	4:00:07:16	11.54
30	Mercer University	4:00:17:15	11.52
31	University of California - Berkeley	4:02:25:46	11.27
32	University of Texas - Austin	4:05:59:37	10.88
33	University of Waterloo	4:12:09:18	10.26
34	New Mexico Institute of Mining and Technology	4:21:48:11	9.42

Sunrayce Scoring Information System

EDS

6/26/93

10:52 AM

1.1	1.1.1	1.1.2	1.1.3	1.1.4	1.1.5	1.1.6	1.1.7	1.1.8	1.1.9	1.1.10	1.1.11	1.1.12	1.1.13	1.1.14	1.1.15	1.1.16	1.1.17	1.1.18	1.1.19	1.1.20	1.1.21	1.1.22	1.1.23	1.1.24	1.1.25	1.1.26	1.1.27	1.1.28	1.1.29	1.1.30	1.1.31	1.1.32	1.1.33	1.1.34	1.1.35	1.1.36	1.1.37	1.1.38	1.1.39	1.1.40	1.1.41	1.1.42	1.1.43	1.1.44	1.1.45	1.1.46	1.1.47	1.1.48	1.1.49	1.1.50	1.1.51	1.1.52	1.1.53	1.1.54	1.1.55	1.1.56	1.1.57	1.1.58	1.1.59	1.1.60	1.1.61	1.1.62	1.1.63	1.1.64	1.1.65	1.1.66	1.1.67	1.1.68	1.1.69	1.1.70	1.1.71	1.1.72	1.1.73	1.1.74	1.1.75	1.1.76	1.1.77	1.1.78	1.1.79	1.1.80	1.1.81	1.1.82	1.1.83	1.1.84	1.1.85	1.1.86	1.1.87	1.1.88	1.1.89	1.1.90	1.1.91	1.1.92	1.1.93	1.1.94	1.1.95	1.1.96	1.1.97	1.1.98	1.1.99	1.1.100
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APPENDIX B

1993 WORLD SOLAR CHALLENGE
FINAL STANDINGS



RESULTS OF 1993 WORLD SOLAR CHALLENGE

POSITION	TEAM	COUNTRY	AVE. SPEED (km/hr)
1	Honda - Dream	Japan	84.56
2	Biel Engineering School - Spirit III	Switzerland	78.27
3	Kyocera Corp - Son of Sun	Japan	70.76
4	Waseda Univ. - Sky Blue Waseda	Japan	70.35
5	Aurora Vehicle Assoc - Aurora QI	Australia	70.1
6	Toyota Motor Corp - Toyota 56	Japan	64.71
7	NT University - Desert Rose	Australia	64.32
8	Cal-Poly Univ. Pomona - Interpid	USA	63.64
9	George Washington Univ. - Sunforce I	USA	63.08
10	Be - Pal Magazine - Be Pal III	Japan	61.96
11	Univ. of Michigan - Maize & Blue	USA	61.35
12	Nissan Motor Co - Sun Favor	Japan	60.01
13	Cal State L.A. - Solar Eagle II	USA	59.53
14	Stanford University - Sunburner	USA	58.38
15	Team Phillips - Solar Kiwi	New Zealand	51.32
16	Mabuchi Sunpower - Let's Sunjoy	Japan	49.99
18	Team Sofix - Sofix	Japan	48.57
19	Tokai University - Tokai - 51SR	Japan	41.08
20	Monash/Melb Univ. - Solution	Australia	39.84
21	Mino Family Tm - Mino Special II	Japan	39.49
22	Laughing Sun Race - Evolution 93/B	Japan	39.43
23	Ashiya University - Sky Ace	Japan	38.59
24	Team Solvogn Danmark - Solvogn	Denmark	38.42
25	Dripstone High School - Aquila	Australia	35.78
26	Team Alarus - Alarus	Australia	35.11
27	Solar Flair Team - Solar Flair	England	34.69
28	Annesley College - Eos	Australia	36.57
29	Hokkaido Auto Eng - Sulis IV	Japan	32.24
30	Solar Japan - Mainichi - go	Japan	32.28
31	Univ. of Oklahoma - Spirit II	USA	32.35
32	Morphett Vale II-Photon Flyer III	Australia	32.73
33	Panda-San Team - Hosokawa-go	Japan	37.96
34	KIA Motors - Con Sole	Korea	33.58
35	Team New England - TNE	USA	33.82
36	Hokiriku Electric Co - Phoenix	Japan	32.38
37	Puerto Rico Univ. - Discovery 500	Puerto Rico	24.4
38	Mitcham Girls High School - Isis	Australia	25.92
39	San Diego State Univ. - Suntrakker	USA	26.48
40	Team Doraemon - Solaraemon-go	Japan	35.16
41	Team Le Soliel - Le Soliel	Japan	27.69
42	Univ. of Western Ontario-SunStang	Canada	22.18
43	NT Inst of T.A.F.E. - Trader	Australia	21.36
44	Team TR50 - TR50	England	25.25
45	Meadowbank T.A.F.E.-Sunseeker	Australia	23.73
46	JCJC Solar CC-PhiOmegaSigmaPi	Japan	12.01
47	Villanova University - Solarcat II	USA	11.95
49	Helio Det Team - Helio Det	Germany	0
50	Heliox Team Heliox	Switzerland	0
51	Team Holy Cheat 1 - Holy Cheat 1	England	0
52	Team Moscow - Moscow	Russia	0
53	The Banana Ent - Banana Enterpr.	Brazil	0
54	Tm Hama Yumeka-Hama Yumeka	Japan	0

1. The first part of the document discusses the importance of maintaining accurate records of all transactions and activities. It emphasizes that this is crucial for ensuring transparency and accountability in the organization's operations.

2. The second part of the document outlines the various methods and tools used to collect and analyze data. It highlights the use of advanced software and manual processes to ensure that all relevant information is captured and processed correctly.

3. The third part of the document describes the procedures for reviewing and verifying the data. It details the steps taken to ensure that the information is accurate, complete, and consistent with the organization's policies and procedures.

4. The fourth part of the document discusses the importance of maintaining the confidentiality and security of the data. It outlines the measures taken to protect sensitive information from unauthorized access and disclosure.

5. The fifth part of the document describes the process of reporting and communicating the results of the data analysis. It emphasizes the need for clear and concise communication to ensure that all stakeholders are informed of the findings and recommendations.

6. The sixth part of the document discusses the importance of ongoing monitoring and evaluation of the data collection and analysis process. It highlights the need for regular reviews and updates to ensure that the process remains effective and efficient.

7. The seventh part of the document describes the role of the data in decision-making and strategic planning. It emphasizes that the data provides valuable insights that can be used to inform key decisions and guide the organization's future direction.

8. The eighth part of the document discusses the importance of training and development for staff involved in data collection and analysis. It highlights the need for ongoing education and skill-building to ensure that the organization has the necessary resources to succeed.

9. The ninth part of the document describes the overall framework and structure of the data management system. It outlines the key components and processes that make up the system and how they work together to support the organization's goals.

10. The tenth part of the document discusses the future of data management and the potential for new technologies and methods. It highlights the importance of staying current and adaptable in a rapidly changing environment.

APPENDIX C

**SOLAR EAGLE II PUBLIC AWARENESS
CAMPAIGN APPEARANCES**

Solar Eagle Events to Date

Dates	Car	Event	Media	Attendance	Time(hr)
Jul-93					
20	1	Petersen Museum Press Conference	tv	50	2.5
	2	BBC Filming @ Long Beach	film	100	5
31	1	Long Beach Model-T Show	n/a	300	3
Aug-93					
12	1	Route 66 Rest.aurant	n/a	200	4.5
25	2	Department of Water and Power Offices	tv	200	5
26	1	Loreto Street Elementary School	tv	300	3
Sep-93					
13	2	CALSTART Exhibition	n/a	15	4
16	1	San Joaquin Air Quality(AAA)	tv	100	4.5
17	2	KTLA Car Dudes Show	tv	na	1.5
22	1	ELAC Recruitment	n/a	300	2.5
25	1	Centro Maravilla Job Fair	n/a	300	4
Oct-93					
1	1	LACC Recruitment	print	200	2.5
2	1	Kern Rideshare Fair (AAA)	n/a	1200	9.5
5	1	UCLA Rideshare Fair	print	1000	4
6	1	Pierce College Recruitment	print	300	2.5
7	1	CSLA MEP Presentation	n/a	10	0.5
8	1	PHIE / Industry Hills Sheraton	n/a	200	7
9	1	Burbank Public Service Event	n/a	150	4.5
11	1	Display for President Rosser on campus	n/a	none	0
13	1	Engineering Mixer on campus	n/a	100	2
14	1	Caltrans opening of I-105 fwy	tv/print	200	3.5
15	1	Caltrans opening of 23-118 fwy	tv/print	100	2
16	1	Bechtel Petroleum	n/a	150	4
Dec-93					
9	1	Display for h.s. students on campus	n/a	20	0.5
Jan-94					
5	2	L.A. Auto Show	n/a	0	1
6-16	2	L.A. Auto Show	tv/print	20000	95
21	1,2	Japanese Student Tour	n/a	20	0.5
29	2	Pepperdine Environmental Law Conference	n/a	200	2
Feb-94					
1	2	Temple City High School	print	100	3
5-6	2	Monterey Park Chinese Festival	tv/print	2000	16
8	2	Youth Science Center	n/a	8	2
12	2	Alhambra-San Gabriel Chinese Parade	tv/print	3000	3
16	1,2	Display for 4th graders in lab	n/a	60	1.5
22	1,2	Display for E&T Week	print	60	2
24	1,2	Presentation in Lab	n/a	60	2
Mar-94					
1	1	Rosemead High School	n/a	300	6
4	1,2	NSF Workshop Presentation	n/a	30	1
23	2	Ramona Convent	n/a	90	2
25	2	El Monte High School	n/a	250	4.5

Dates	Car	Event	Media	Attendance	Time(hr)
26	2	AAA-Bakersfield Festival	n/a	200	5
Apr-94					
8	2	Disney RoadRally Expo	tv/radio	300	4
15	2	Bret Harte Elementary	n/a	150	1
15	2	Thomas Edison Elementary	print	300	2
16	2	UCLA Issues Conference	n/a	15	1
21	2	Cantwell Sacred Heart H.S.	n/a	250	3
22	2	Mountain View Elementary	n/a	200	2
27	2	La Salle High School	n/a	150	4
28	2	Loretto Conaty High School	n/a	120	4
29	2	Chaffey College Eco Fair	print	200	4
May-94					
2	2	Daniel Murphy H.S.	n/a	120	2
3	2	Mark Keppel H.S.	n/a	200	4
5	2	Hamilton H.S.	n/a	200	4
6	2	Imaculate Heart H.S.	n/a	200	3
10	2	JPL RideShare Event	print	200	3
16	2	Holy Family H.S.	print	200	4
17	2	Fajardo School display in lab	n/a	120	3
19	2	Fremont H.S. College Fair	n/a	300	2
20	2	CSLA E&T Open House on campus	n/a	300	3
21	2	Monterey Prk. Play Days Pard.	tv	5000	3
23	2	Mesrobian H.S.	n/a	200	2
24	2	Pasadena Cont. School	n/a	100	2
26	2	Maranatha H.S.	n/a	300	3
27	2	Loreto St. Elem. School	n/a	400	2
Jun-94					
2	2	Miraculous Medal Elem. S.	n/a	200	2
3	2	Wilson H.S.	n/a	300	3
8	2	Venice H.S.	n/a	150	3
9	2	TRW Ride Share Event	n/a	100	3
10	2	Arcadia H.S.	n/a	300	5
14	2	MTA Vendor Fair	print	2000	7
21	2	Association of Energy Professionals	n/a	60	3
Jul-94					
15	2	East Los Angeles College	print	200	3
18	2	Miraculous Medal Elem.	n/a	30	1
20	2	Association of Energy Professionals	n/a	50	3
22	2	NASA Sharp Plus Students	n/a	30	3
28	2	Howard Hughes Center Event	tv/print	1000	5
30	2	Sadaqoy Bridge Parade-AAA	tv/print	1000	5
Aug-94					
1	2	Killian Elementary School	n/a	30	1
24	2	American Eagle Ride Event	n/a	400	6
25-28	2	Texpo- Reagan Library	tv/print	400	16
Sep-94					
2	2	Sunrayce Officials view car	n/a	1	1
7	2	Marshall High School	n/a	150	3
12	2	Jefferson High School	n/a	600	6
13	2	Garfield High School	n/a	400	4
21	2	Cerritos College-Rideshare	n/a	30	5
26-29	2	Wescon	print	3000	20

Dates	Car	Event	Media	Attendance	Time (hr)
30	2	Caltech Rideshare Event	print	300	2
Oct-94					5
5	2	Kaiser Enviromental Fair	tv	600	4
6	2	JPL Rideshare Event	print	300	4
17	2	Calstart Anniversary Event	n/a	300	5
18	2	GM Impact Preview Event	print	1000	3
21	2	E & T Open House	print	300	3
22	2	Groundwater Festival	tv/print	500	1
22	2	NASA Visit	n/a	10	3
24	2	El Camino College Transfer	print	400	5
25	2	AAA-Tranportation Symposiom	tv/print	100	5
26	2	AAA-NHRA Career Fair	n/a	500	
Nov-94					1
12	2	Boy Scout Troop 156	n/a	10	5
16	2	Huntington Park High School	n/a	200	4
23	2	El Rancho High School	n/a	400	4
29	2	Eagle Rock High School	n/a	400	
Dec-94					3
2	2	SCE Solar II Challenge Event	tv/print	300	
Jan-95					30
4-15	2	Los Angeles Auto Show(AAA)	tv/print	20000	3
18	2	Duarte High School	n/a	400	3
19	2	Pride Day on campus display	n/a	600	7
20	2	Venice High School	n/a	150	1
25	2	Mekhitarian School(on campus)	n/a	30	3
27	2	San Marino School	print	200	
Feb-95					4
1	2	Lancaster (AAA)	n/a	1000	2
7	2	Dean of Cont. Ed./Rotary Club	n/a	200	3
8	2	Hoover High Shcool	n/a	300	
Total				80329	

Year	Population	Area	Population Density	Urban Population	Rural Population
1950	100,000	100 km ²	1,000/km ²	20,000	80,000
1960	150,000	100 km ²	1,500/km ²	30,000	120,000
1970	200,000	100 km ²	2,000/km ²	40,000	160,000
1980	250,000	100 km ²	2,500/km ²	50,000	200,000
1990	300,000	100 km ²	3,000/km ²	60,000	240,000
2000	350,000	100 km ²	3,500/km ²	70,000	280,000
2010	400,000	100 km ²	4,000/km ²	80,000	320,000
2020	450,000	100 km ²	4,500/km ²	90,000	360,000

