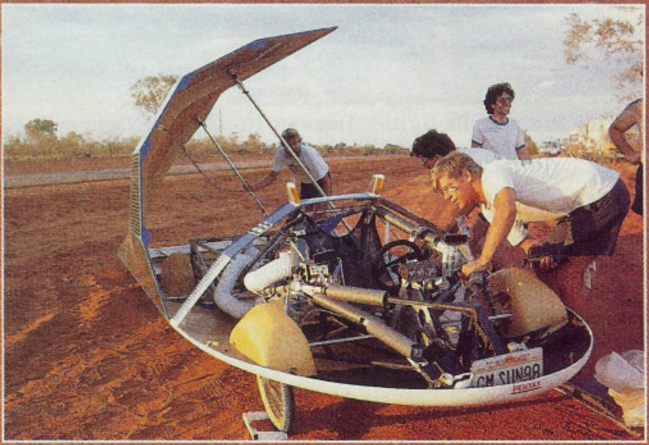
Chasing Sunraycer

Twenty-four teams from around the globe brought their photon-powered cars to the first Pentax World Solar Challenge race across Australia. Right from the starting line, General Motors' superbly efficient Sunraycer pulled a disappearing act that left the nearest competitor 23 hours behind at the finish 1,880 miles away in Adelaide. Ford of Australia fought hard with a Swiss team for second place, while an incredible caravan of vehicles built by privateers, students, and dreamers stretched out across the vast outback—the slowest car taking more than a month to finish. A Popular Science editor was present to witness this historic demonstration of advanced aerodynamic design and the potential of new photovoltaic, battery, and electric-motor technology.

across Australia



GM's Sunraycer (left) glides quietly through the outback. Car's approximate drag coefficient is an ultra-low 0.13. Strakes above cockpit and fins under tail aid stability in crosswinds. After a day's racing (above), team members monitor battery-charging rate and scold onlookers who let their shadows fall on the high-efficiency gallium-arsenide solar array. The author (top) snuggles up to a 62-wheeled road train. These leviathans traverse Australia's remote and railroadless Northern Territory region, generating ferocious air turbulence.

By STUART F. BROWN
Photos by the author

DARWIN, AUSTRALIA

In Darwin, no one goes outdoors without a broad-brimmed hat for protection against the withering sun. November is springtime here, and the humidity is edging upward. The daytime temperature in this tropical coastal city of 70,000 inhabitants climbs to 105 degrees F in the shade. Even the palm trees look listless. I head downtown and get myself one of those hats.

Holed up in garages, basements, and trailer parks all over town are the participants in the Pentax World Solar Challenge car race ["Racing With the Sun," Nov. '87], which will leave here Nov. 1, 1987, for an 1,880-mile trek south to Adelaide.

Attending a few evening barbies (barbecues) featuring a buffa-barra menu (grilled water buffalo and a delectable fish called the barramundi) washed down with various golden Aussie beers (in heat-defeating foam holders), I begin to meet the international collection of solar-car designers, builders, drivers, and well-wishers that comprise this ambitious sun-powered odyssey. I learn the whereabouts of the two highest-profile entries.

General Motors Corp., with its multi-million-dollar Sunraycer effort, is camped out at the local Holden's Motor Co. dealership (GM's Australian subsidiary). Development

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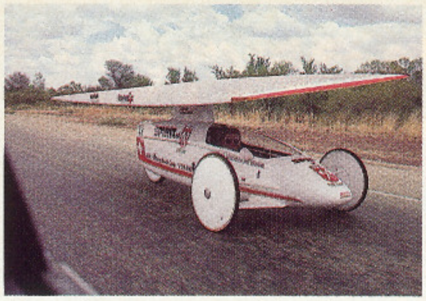
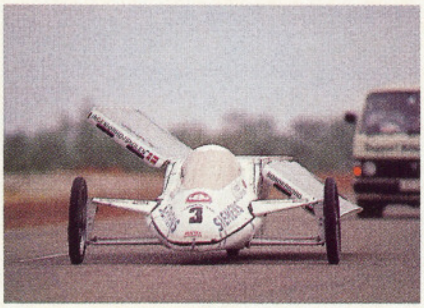
Solar power isn't the only kind used by John Paul Mitchell Systems' Mana La car, with its uniquely arched solar array. Chanting members of the Hawaii-based team join hands around their vehicle on qualifying day. Quartz crystals—presumably ones with spiritual uses—were part of team's tool kit.

Ford of Australia's second-place Model S was developed over 2½ yrs. by volunteer engineers. The Ford effort included a mobile weather unit using satellite data and a chase vehicle monitoring race-car functions and making strategic decisions. Tilting array uses "space technology" silicon cells.



Three-time veterans of the European Tour de Sol race, the College of Engineering team from Biel, Switzerland, fielded a beautifully designed three-wheeler with a sun-tracking solar array. These meticulous engineers squeezed maximum performance from a modest budget to finish third behind Ford.

Desert Rose, built by the Darwin Institute of Technology staff and students along with engineers from the Royal Australian Air Force, finished fifth. Powered by a modified swimming-pool-filter motor, the car's tilting solar array can pivot 4° forward to increase stability when road trains pass.



From Denmark, Chariot of the Sun was built at the Sonderborg Teknikum engineering school by students who took out a bank loan to air-freight the car to the race. The three-piece silicon solar array has hinged side panels that angle toward the sun. Array is kept flat at noontime.

BOTTOM PHOTOS BY KEITH PHILPOTT

A team from Crowder College in Missouri built a solar car in 1984 and drove it across the U.S. in 45 days. Sadly, Crowder's 242-lb. Solar Trans Australia Racer got caught in storm winds and flipped upside down. Here, crew members dismount the roof panel and solder new solar cells in place.

Its thicket of 14 antennae earned this vehicle the nickname "porcupine." The mobile communication center's radio equipment enabled GM team's support vehicles to talk to each other and make telephone calls worldwide.

of the beetlelike solar car was directed by AeroVironment, a small California company headed by Dr. Paul MacCready, the noted designer of human- and solar-powered aircraft. Engineers and scientists from a number of GM divisions worked together with AeroVironment on the project.

Ford Motor Co. of Australia Ltd. will be showing off its Model S at the Sheraton Hotel, where the Massachusetts Institute of Technology's Solectria IV-B team has transformed the loading dock into its own workshop area.

I meet Dr. Chester Kyle, a consulting engineer and founder of the International Human-Powered Vehicle Association, who designed the Sunraycer's wheels. He has spent an entire week dashing around town filling out specification sheets describing every vehicle entered in the race, and tells me the residents of Darwin are going out of their way to help the racers with materials, tools, and places to work. The field will quickly stretch out when the race gets underway, Kyle predicts, with the fast cars separated from the slower ones by as many as hundreds of miles.

Speed, stability, and braking

Having accepted an offer from the GM team to ride along in one of its chase vehicles, I suddenly realize I'd better take a careful look at the field of entries; it might be the last I'll see of many of them. My second day in town provides the opportunity. Gathered on a shimmering roped-off section of the transcontinental Stuart Highway, the cars must make radar-timed qualifying runs for starting positions, demonstrate their brakes to the scrutineers, and

—most dramatically—prove that they remain stable at speed when passing a "road train" coming from the other direction at 50 mph.

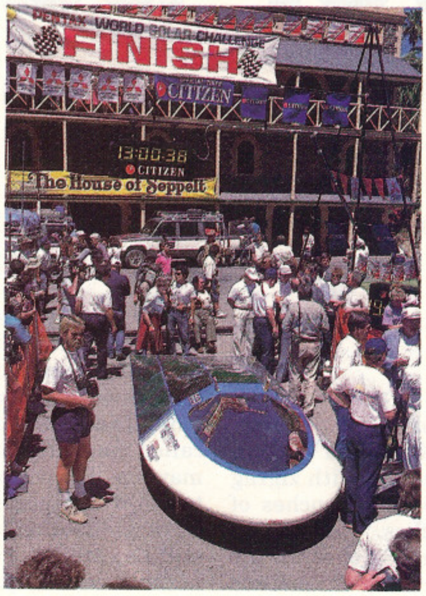
It is one thing to hear a description of these longest of trucks and quite another to see one belching black smoke and barreling at you on a narrow road. Its wake can be strong enough to shake a full-size tourist bus, and the third trailer wagging from side to side at the end of the train is an unsettling sight—particularly if the load consists of gasoline tankers.

After several scorching hours out on the highway, most of the vehicles have passed the braking and stability tests and have made their top-speed runs. For this last test, each car has a radar-reflecting square of aluminum foil taped onto its nose to ensure a clear reading on the police radar used to clock speed.

GM's Sunraycer captures the pole position with a blast through the radar at 71 mph. John Paul Mitchell Systems' Mana La car from Hawaii grabs everyone's attention by qualifying for the second starting position at 58 mph. This car, with its spectacular arched solar array, is soon being referred to as "the hair dryer"—Mana La's sponsor is a producer of hair-care products, and he wears an identification tag listing "hairdresser" as his title. *Australian Geographic* magazine's gracefully contoured Team Marsupial machine clocks in at 53 mph, with the Ford Model S registering 50 mph. Sixteen other cars are timed at speeds descending to less than 13 mph; the remaining cars will pass last-minute technical inspections before the race starts at nine the next morning.

Looking over the solar cars, I see an incredible diversity of design ideas—precisely the point of the rules governing their construction. Several cars, including the Ford and the Swiss entry, Spirit of Biel, use a strut-mounted solar panel that pivots to face the sun early and late in the day. Most of the others have roof-mounted flat panels, some of them with folding edges that can be moved up or down to catch oblique sunlight. GM's Sunraycer is the only car with fixed solar cells integrated into a teardrop-shape body.

As starting time approaches on race day, one MIT team member pumps air into a tire, while another fiddles with a cranky drive chain; MIT's car has been repaired after suffering an electrical fire that singed the driver's hair the previous day. The Australian Alarus team puts the finishing touches on a car that was gravely damaged when the truck transporting it here went off the road and rolled over several times. All over the starting area, the teams tinker nervously with their machines.



Sunraycer at the finish line at a winery outside Adelaide. To right of car, wearing cap and light-blue jacket, is GM President Robert C. Stempel.

They're off!

With nine o'clock only moments away, the Hawaiian car and the Sunraycer sit at the head of a long double row of silently waiting cars with opalescent-blue solar arrays. Then, as seasoned Australian racing-car driver John Harvey put it later, "I could see that the crowd was so close there wasn't enough room for us to depart side by side. So I made sure I got the Sunraycer through that hole in the crowd first."

GM's media bus has headed south out of Darwin half an hour before the race begins to intercept the leading cars as they go through the town of Katherine, 199 miles down the road. The outback along this stretch has steeper hills and more of them than I had imagined. Spindly eucalyptus and gum trees cling to the parched reddish-brown earth under a hazy blue sky dotted with cumulus clouds.

As our big diesel bus groans up and down the hills, a radio operator at a special console up front chatters with a helicopter overhead (call sign: "sunflyer"), and with vehicles called "scout," "observer," and "porcupine." A special truck behind us tows a big dish that beams television pictures to the Aussat satellite up in space. Going solar racing with GM is beginning to look like a camping trip with NASA and the Department of Defense.

Pretty soon the Sunraycer glides briskly into town for a 10-minute pit stop, accompanied by its half-mile-long retinue of support vehicles. Driver Harvey is grinning and reports that the gold-plated canopy is doing its job of reflecting the sun's radiation to keep the cockpit temperature bearable. About 20 minutes later the Hawaiians arrive, attracting what must be a big crowd by Katherine

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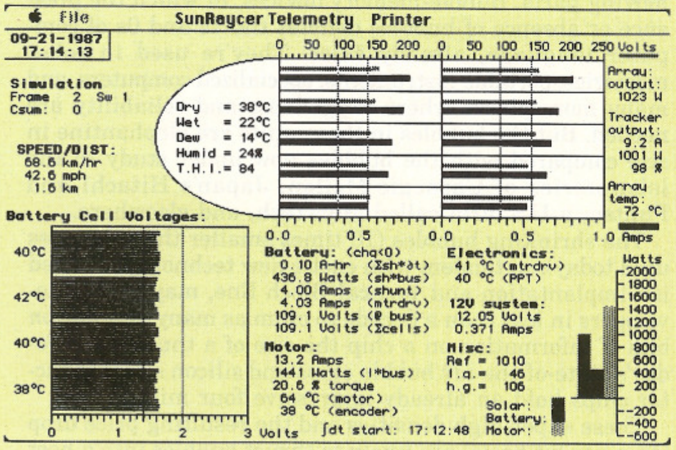
Taking Sunraycer's pulse

Like a spacecraft, the Sunraycer is peppered with sensors that report on its well-being. Every five seconds, telemetry data from 80 points on the car are radioed to the nearby observer vehicle where they appear on the display at right, developed by Graham Gyatt of AeroVironment. Detailed battery-voltage and temperature data help strategists give Sunraycer's driver advice that keeps the 68-cell silver-zinc "fuel tank" in the 20- to 80-percent-charged range, where it is efficient and durable. The car outline at the top of the screen shows voltage and amperage of the 8,500-cell solar array's 10 sections; uneven readings are caused by oblique morning sunlight. The bar graph at bottom right indicates that the motor is using about 1,441 watts of power; 1,001 watts come from the solar array, the rest from the battery. At this moment, the motor is developing 20.6 percent of its peak torque. Going down a hill in strong sunlight, the battery bar may move below zero, indicating the solar array is both powering the motor and recharging the battery, or that regenerative braking is in use.—*S. F. B.*



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standards. The next racers in are the Swiss Biel car and the Ford Model S.

Piloting Sunraycer into the late afternoon at about 40 mph, Dr. Alec Brooks of AeroVironment is on the radio conferring with his team manager about where to stop. It's nearly five o'clock; within 10 minutes every car must park for the night, regardless of its location.

Choosing a good stopping place is an important part of race strategy, explains Paul MacCready. "You don't want to stop where there are a lot of trees on both sides of the road, because they will block the sun during the battery-charging periods from 6 to 8 a.m. and from 5 to 7 p.m. We have a scout vehicle ahead that's plotting possible places to stop. If he finds that the most likely spot is where Sunraycer will end up at 4:50 p.m., we'll stop a few minutes early. It's worth it if we can pick up a kilowatt-hour or two of battery energy we wouldn't have gotten ten minutes farther down the road."

Camping with the right stuff

For those of us in the support convoy, the five o'clock rule injects a novel randomness into where we will spend the night. It turns out that our first night's campsite 333 miles south of Darwin is on sun-hardened primordial terrain that bends steel tent stakes like coat hangers when we assault them with mallets, producing a lot of sweat and aggravation. Fortunately, the hard-working crew from Australian Pacific Outback Expeditions has already whipped up some "tucker" for the 60-odd campers. It's another buffabarra barbie... with icy beers and chilled Australian wines.

On the morning of day two, with 66 miles separating the Sunraycer from the second-place Biel car, I begin to fear I'll never see the other cars again. So I hitch a ride with a quartet of Australian auto writers and photographers who have an interesting specialty: Having covered marathon four-wheel-drive rallies across the outback, they've become skilled at blitzing back and forth through vast events to discover what's going on. Equipped with a pair of bush-worthy Holden station wagons, we speed back north —seat belts securely fastened—soon passing the Biel and Ford cars.

By mid-morning we find the Hawaiian car parked at the side of the road. The crew confesses they ran too hard through the hills trying to catch the Sunraycer on the first day, exhausting their batteries, and never got the wind boost the car was designed to exploit. Their battery specialist estimates it will take about 40 hours in the sun to recharge. Mana La is out of the competition.

Sprinting farther north we encounter no more solar cars and decide to turn back to catch the Sunraycer. It takes six hours running at about 90 mph to reach the GM team. This race has quickly become too stretched out to witness firsthand. I decide to spend at least part of each remaining day in GM's media bus, with its radios and telephones bringing in news from the rest of the field.

The storm

As we move south the air is getting drier, the earth redder and flatter, the vegetation scrubbier and less plentiful. For the next few days the Sunraycer's story is one of running under varying skies at average speeds of about 42 mph. On the third day, the team passes through Alice Springs, the town emblematic of Australia's "Red Center." Sunraycer leaves town with clear blue skies ahead—and an ominous storm front moving across the road just behind it.

Everyone else got caught. At one point, Ford team members spread their bodies over their car's solar panel to shield the fragile satellite-grade mono-crystalline silicon cells from a barrage of large, painful hailstones. Parts of the array were smashed anyhow. Some cars had to wait for rainwater to drain away from flooded sections of the road. High winds flipped the car built by Crowder College in Neosho, Mo., right onto its back. The belted-in driver was unhurt, but the solar array required extensive repairs (see photo).

Rolf Disch of West Germany had been a strong runner until his car's silicon solar cells began to peel away from their concave panel. Disch was bailed out by the Crowder College team, who gave him 240 spare cells. The MIT car burned out both its original and spare motors, putting it on the sidelines until GM air-freighted a new motor to the team. All of the cars still in action made slow progress in the dismal solar conditions.

The Swiss Biel team, which had dueled fiercely with the Ford car right from the start, beat Ford into Alice Springs, only to have a low-speed collision with a conventional automobile. Swiss driver Ernst Fuhrer was taken to the hospital, where he received several stitches in his foot; his car required six hours of repairs, during which the Ford Model S glided south through town.

Chasing after the Sunraycer, I learn that driver and Chevrolet-Pontiac-Canada engineer Terry Satchell, who

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designed the car's suspension, almost had an encounter with a giant flightless bird. "The scout car warned me over the radio that there was an emu running toward the road. I saw it and managed to avoid it," he says.

Cloud gazing, data crunching

Adjustments to the Sunraycer's battery-use schedule are continuously being calculated in the pursuing "observer" motor home, as a torrent of telemetry data (see box) pours in from sensors monitoring the Sunraycer's key systems. Driving a scout vehicle about 10 miles ahead of the solar speedster, AeroVironment meteorologist George Ettenheim reviews recent weather-satellite images received by facsimile and issues frequent radio reports on cloud conditions.

Ettenheim's sunshine predictions for the upcoming evening and morning charging periods are entered into a computer that has information in its software about hills and valleys on the route ahead. Working with the computer's output and the telemetry from the Sunraycer, strategists in the observer work out speed and battery-current recommendations for the driver in the racing car.

As we roll on through the treeless mining town of Coober Pedy—where countless opal pits dot a lunar landscape, and many residents live underground to escape the heat—the sun continues to drench GM's car. The Sunraycer is able to cruise for hours at its steady 42 mph while trickle charging its batteries with spare current. On the fifth night, we camp on beige-colored ground surrounded by wheat fields. The weather is cool, and the sleeping is easy. Adelaide is only about 100 miles from here.

On the sixth morning, the lead and chase vehicles close up around the 360-pound Sunraycer to protect it from the heavier traffic we encounter on the outskirts of Adelaide.

Sunraycer has officially covered the 1,880-mile distance from Darwin to Adelaide in 44 hours and 54 minutes of running time, for an average speed of 41.9 mph. The race formally ends in the nearby wine-growing town of Seppeltsfield, making the total distance traveled 1,950 miles. The only unscheduled stops were to change three flat tires—a remarkable achievement.

The Ford Model S finished second about 23 hours later and more than 600 miles behind, with the Swiss Spirit of Biel running just 2½ hours behind the Ford. Three Australian cars finished next. They were *Australian Geographic*'s Team Marsupial, Darwin Institute of Technology's Desert Rose, and Chisholm Institute of Technology's Desert Cat. In all, 13 of the 24 entrants made it across the outback, with the last diehard—a Japanese car called Southern Cross, which was powered by inefficient but cheap amorphous-silicon solar cells—crawling into Adelaide on Dec. 2.

Survival of the fittest

The cars that worked best generally share several features:

- Most of them use expensive silver-zinc batteries (developed for satellites and torpedoes), which have two to five times the energy density of conventional lead-acid batteries and are more efficient.
- They use compact, powerful, and costly rare-earth permanent-magnet electric motors.
- The cars show careful attention to aerodynamic efficiency and low rolling resistance.
- The builders use the most efficient solar cells they can afford. On most people's budgets, these will be silicon cells, which have an efficiency ranging from 7 to 18 percent. If the sky is the limit—as it was in GM's case—gallium-arsenide cells are the way to go. This exotic material developed for the latest generation of satellites is 19 to 22 percent efficient at cool temperatures and suffers only half the performance decline silicon cells do on hot days. It also costs about three times as much as the most expensive silicon cells.

What helped Sunraycer win? Obviously, the weather did. So did a light and powerful motor, battery, and solar array. Superb reliability, strategy, and preparation were major factors, too. In addition, Paul MacCready feels they hit on the right balance of ultra-low wind drag and rolling resistance with safety and stability.

To General Motors—a company that hasn't gotten much good publicity lately—the Sunraycer success is a priceless image builder. For wisely choosing the unique band of experts at AeroVironment to coordinate the project, and turning them loose in the engineering and technology supermarket its corporate divisions comprise, GM is entitled to brag that the Sunraycer was designed, built, and raced to a startling victory in only seven months.

For MacCready, "This project is bringing the time when we use hybrid-powered cars and battery-powered cars closer. The most important aspect is efficiency—demonstrating that you can go some forty miles per hour across a continent on only one and one-half horsepower." PS