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MODEL SOLAR VEHICLES PROVIDE MOTIVATION FOR SCHOOL STUDENTS

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(Communicated by Jenniy Gregory)

Abstract—This article will discuss the development of a project in which school students design, build, test and enter in competition model cars powered only by solar energy. The initiation of the concept, distribution of solar materials to schools, organisation of the Australian events including raising sponsorship, race regulations, vehicle design concepts, track design and construction, establishment of support systems for teachers, developing media interest in the project, teacher and student feedback will all be considered. Copyright © 1996 Elsevier Science Ltd.

1. INTRODUCTION

After being involved in his state's first Model Solar Car Challenge, Metcalfe (Metcalfe, 1992), then a year 12 student said "Most people think of solar energy as some sort of mysterious futuristic thing beyond the everyday person, but events such as this enlighten people to the use of renewable energy sources and its practicality." Since 1990, Australian secondary students have been able to design and build model cars powered by an 8 W solar panel which are then entered in a race against all the other cars built in their state.

The idea of an event for school students to develop model solar cars was conceived as a result of the first transcontinental race for solar vehicles, the 1987 World Solar Challenge (Scutt, 1987). Two of the managers of student teams in that event recognised the great learning opportunity that the race had given their students and wished to make a similar opportunity available to a wider range of school students, without the considerable costs of money and time required for a full scale vehicle.

Accordingly, a sponsor was found, regulations developed, publicity sent to schools, an artificially lit indoor track and an outdoor track were built in preparation for the first event of student designed and built, tenth scale model solar cars. This event was held in Melbourne in May 1990.

Other states in Australia followed and since 1993, the top 4 cars from each state have been invited to participate in an Australia wide event, held in a different city each year. On 3 November 1996, competitors from other countries will be invited to compete over the 100 m figure "8" shaped track against the best Australian entries in an International event in Adelaide, timed to coincide with the end of the 1996 World Solar Challenge.

2. EDUCATIONAL RATIONALE

Perhaps one of the best summaries of the benefits of project work in technology education is that made by Cramer (Cramer, 1992) when discussing the outcome of the design at the Technical University of Darmstadt in Germany of an entrant in the Swiss Tour de Sol race for solar powered cars. Cramer stated "Modern engineering education must not restrict itself to teaching science and technology alone. What we want is the development of something we might call action competence; to control the process of creating a simple product or a technical system of highest complexity from the first idea to its perfection. The ability to solve mathematical equations is only one without any doubt very important component of this competence. The ability to proceed systematically, to communicate in a team, to present status and results of a project ..., to motivate others in the case of problems, to think in terms of milestones and money, and last, but not least, to create ideas."

Smith, Chairman of General Motors (Tuckey, 1989), claimed that in addition to the technical benefits to GM of building Sunraycer, winner of the 1987 World Solar Challenge, "Another purpose of the project was to inspire high school and university students... We hope that when students get a glimpse of the fascinating possibilities that curiosity and ingenuity can lead to they'll be stimulated to get more involved in scientific and technological education and ultimately in the research and development that leads to tomorrow's products and to a rising standard of living for people everywhere".

Sir Monty Finniston, Chairman of the review of the engineering profession in England in 1980 (Finniston, 1984), stated that "Since most careers are concerned with solving problems in real life, there would seem to be a case for relating subjects taken as part of the curriculum in the education of children in some way or other to such problems rather than to abstract academic exercises".

Loney (Loney, 1976) discussed the educational benefits to secondary students of group projects which involved designing and building a functional product. Such benefits included integration of multi discipline concepts, solving open ended problems, developing creative solutions, learning to serve others, gaining the skills and satisfaction that develops from team work, establishing project management skills and writing a technical report.

Churches (Churches *et al.*, 1985) discussed feedback from tertiary engineering students on such projects which claimed motivation increased when the finished project culminated in a functional product which was to be publicly displayed. They also identified the importance of the creative conceptual stage, the value of construction of what has been designed and that "working in groups appeared to be the key factor... for many of the students".

Wellington (Wellington, 1984) claimed that in addition to the technical benefits of such projects, students gained increased levels of communication and interpersonal skills and the ability to work under pressure to meet deadlines.

Harley (Harley 1993), staff coordinator of the Lynall Hall Community School, the winner of the 1990, 1991 and 1992 Victorian events, identified the range of subjects which had been brought to bear on their project, including Science, Technology Studies, Mathematics, Computer Studies, Communication Studies and Environmental Studies. He goes on to discuss the physics of photovoltaic panels, motor selection, wind drag, gear ratio selection, mathematical modelling of the course and an approach to developing a competitive vehicle. Experimental techniques for evaluating motor efficiency and drag in a wind tunnel developed at Lynall Hall are also discussed.

With these concepts in mind, the design and construction of a model solar vehicle seemed to be an ideal way for school students to gain experience of working on a realistic problem which addresses long term social and environmental issues. The project requires skills from several science and technology disciplines, but has also been used for other studies including geography, art and English. To have a chance of success, the designs would need to be creative, involve team work, personal and group management skills and have the motivation fostered by public display and competition. They are also a means of opening up the challenge and excitement of technology to a wider range of students, especially girls who have traditionally been under represented, at least in Australia.

3. HISTORY OF THE EVENT

The idea of a competition for schools was developed from the 1987 World Solar Challenge, where all who participated—professional car makers, staff and students from universities and secondary schools and many enthusiasts—found it to be an unforgettable experience.

In 1981, the worlds first solar powered car, the "Quiet Achiever" drove from Perth on Australia's west coast to Sydney in the east, a distance of 4500 km at an average speed of 23 km h^{-1}. Twelve years later, the winner of the World Solar Challenge drove 3000 km at an average speed of 85 km h^{-1}. This astounding improvement indicates the potential for harnessing new, non-polluting technologies to address one of the world's most serious sources of pollution in the form of car exhaust emissions. To provide motivation and help in developing expertise for the engineers of the future who will be faced with the dilemma of bringing new clean technologies to bear on conventional vehicles, a Model Solar Car Challenge for secondary school students was developed in Australia in 1990.

The team managers of the Warragul Technical School and Chisholm Institute of Technology entries in the first World Solar Challenge analysed the benefits of the race to both their groups of students. Both agreed that it had been a marvellous learning experience which should be available to a far wider spectrum of students, but the high cost in terms of time and resources put such a project out of reach of most schools. Hence, the possibility of a model solar race, requiring far less time and money but maintaining the same emphases on designing, building and testing a functional vehicle and putting it into competition with others was envisaged.

Although developed quite independently, the Victorian event was found not to be the first event for school students competing with model solar cars. The UK section of ISES had organised an event with BP sponsorship (Carroll, 1989) in 1989, for radio controlled vehicles running under lights indoors. The Australian organisers elected a different approach—the event to be run under sunlight with artificial light to be used only for seeding and in emergencies, the cars to be guided by a guide peg running in a plastic channel, slot car fashion, and limitations to be put only on vehicle dimensions and the solar cells used, so as not to give richer schools an advantage by buying better cells.

When Energy Victoria, a committee consisting of state government electricity, gas and renewable energy authority representatives heard of the project several months later, they requested a grant application to be prepared and within a week a seeding grant of A$30,000 was provided. A committee comprising members of the Chisholm Institute and Warragul Technical School solar teams, interested teachers, educational curriculum developers, sponsor representatives and the manufacturer of a purpose designed and built solar panel was formed.

4. STRUCTURE OF THE COMPETITION

Cars are required to use an 8, 10 or 12 W solar panel to provide all of the motive power. The most common solar modules are made specifically for the event by a local Victorian company, Appsys, that have encapsulated quarter polycrystalline silicon cells between a sheet of glass fibre-epoxy resin and a transparent acrylic top panel. The quarter cells are aligned in four rows of six, allowing the panel to be wired for 3, 6 or 12 V outputs. This panel is a nominal 8 W. As a result of increasing panel costs, the national committee has approved several cheaper commercial panels, rated at up to 12 W to be used but with a weight penalty to compensate for their extra power. No batteries are allowed.

The competition is held as a series of match races between pairs of cars, with the loser being knocked out and the winner proceeding to the next round. The cars must all be fitted with a steering peg as shown in Fig. 1, which fits into a plastic channel, guiding the cars around the course. A series of knock out rounds are held until only two vehicles are left to fight out the final over the best of three races. This is considered to be the only fair structure in view of changing solar intensities over the course of the day.

To maintain maximum drama, all vehicles undergo a time trial over a 15 m straight, chip board track, illuminated by 20 1500 W lights, evenly distributed along the length of the track as part of scrutineering, and the fastest vehicles are seeded so as not to compete against each other in the earlier rounds. Each car is electronically timed over the 15 m and the seeding is then carried out so the fastest cars in the time trial do not meet until the finals. The indoor track is also available so that winners can be determined on the scheduled day if the outdoor event is disrupted by rain or heavy cloud.

For the first four events, May 1990, November 1991, November 1992 and October 1993, the track used was an "S" shape with carefully designed corners, so as not to favour either lane. Materials such as chip board and fluted plastic sheet were tried as the rolling surface, but presented problems with buckling causing a less than smooth surface. Attached to the base were two continuous "U" shaped plastic channels, 600 mm apart, in which the steering pegs fit.

In 1994, for the fifth event, a new figure-of-eight track was built from outdoor plywood skinned sandwich panels which had a light weight polystyrene foam core. Care has been taken to ensure the two tracks are identical with the radius of curves as shown in Fig. 2. The comparability of the two tracks has been proved by timing trials with cars achieving comparable times on each track when tested under similar conditions.

An overpass presented cars with an additional challenge—both in losing sunlight when passing under the metre and a half wide bridge and when having to climb the 350 mm high hill. However, most cars in the 1994 and 1995 events

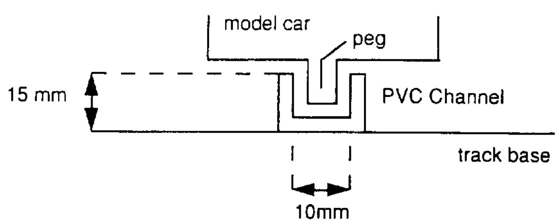

Fig. 1. Diagram of the guide peg in the channel (extract from 1996 Australian-International Model Solar Car Challenge Regulations, 1996).

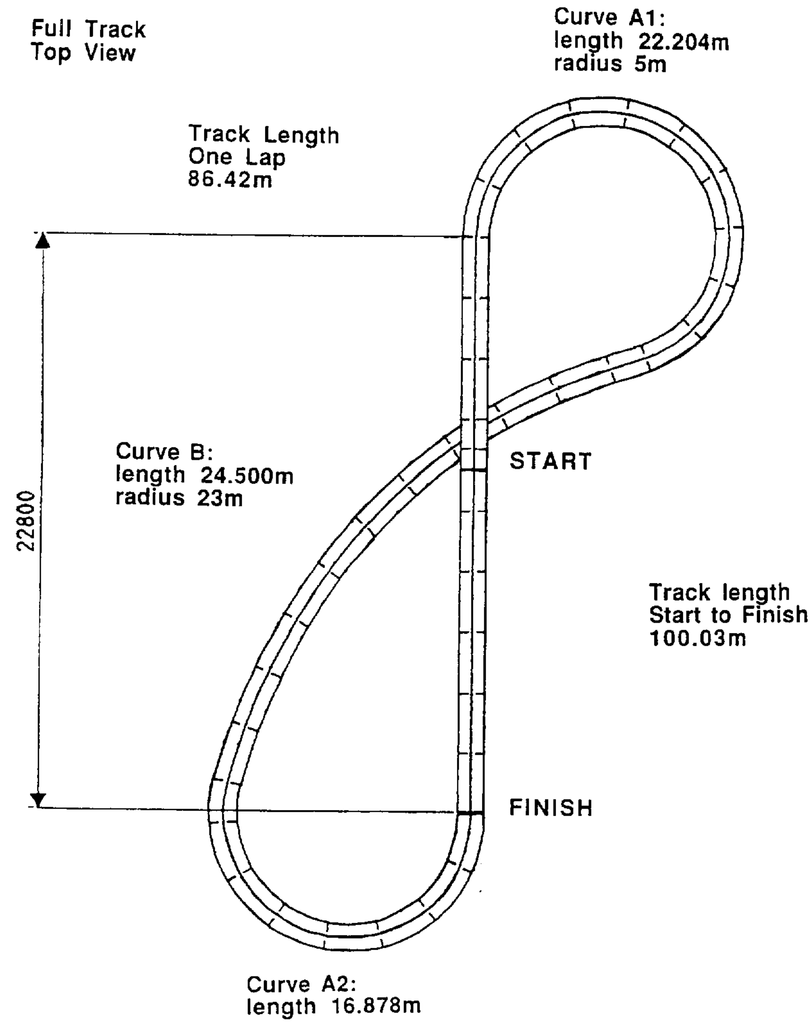

Fig. 2. Track layout and orientation (extract from 1996 Australian-International Model Solar Car Challenge Regulations, 1996).

sped under the bridge with little apparent decrease in speed, having built up considerable momentum over the first half of the course. Even when the sun was obscured by light cloud, those cars which had chosen appropriate gearing, were still able to cope with the gradient.

5. ORGANISATION OF THE INITIAL AND SUBSEQUENT EVENTS

Different states have developed their own organisational structures, but the current article will concentrate on the Victorian event being the first such event and the model for other states.

Having had funding of A$30,000 approved, a committee of interested teachers, a representative of the major sponsor, a local manufacturer of suitable solar modules and curriculum developers with an interest in the area was formed. The committee members were responsible for promoting the event, mailing information to schools and packaging and mailing kits. Members of the solar vehicle teams undertook to formulate regulations and develop a track. Following moderate success in the first event in 1990, the committee expanded to involve more teachers from participating schools, who are now playing a more active role in publicising the event and running workshops for new teachers and writing articles in appropriate school directed journals. Part of the budget in the second year was set aside to employ a project officer to take over responsibilities in organising the event—preparing the printed program, developing lists of entries, welcoming schools on arrival at the race venue, etc. This position has changed to become a more active one throughout the year, taking responsibility for all inquiries as well as organising kits for schools, ordering lights and grandstands for the event and preparing financial reports.

In 1993, a student who had been involved in the previous event was invited to become a member of the committee and this year there is one present and one former student actively involved in writing articles and providing feed-back from the student perspective.

6. TEACHER SUPPORT

In the first year, 1990, the committee provided each entrant with a heavily subsidised solar module from APPSYS which could be used at 3, 6 or 12 V, *Solar Technology Resource Book* (McIntyre, 1990), 1987 *World Solar Challenge* (Scutt, 1987), a video on solar car racing and a set of race regulations (Burnett, 1990). A work-shop was held several months prior to the event for both students and staff, with members of the organising committee and members of the Monash (formerly Chisholm) Solar Vehicle team discussing organisational and technical issues. In subsequent years, a design guide *Model Solar Car Racing* with information about how to use the project in conjunction with the curricula of various subjects has been produced by Harley (Harley, 1993), co-ordinator of the school who won the first three Victorian events. This guide not only recommends ways of testing compo-nents, selecting gear ratios and highlights the major design principles but also discusses spon-sorship and team organisation. The design guide is supplemented by a computer simulation which schools can buy to help in their design process. The committee has also been running workshops for teachers several times a year.

Three videos have been produced of the 1990, 1992 and 1994 events (Scutt, 1991, 1992, 1994). These documentaries include coverage of the race as well as interviews with Peter Brock, a leading Australian auto racing personality who was invited to judge the prize for the Best Engineered Vehicle, and students and teachers about their designs and the event.

7. COMPETITION REGULATIONS

The first regulations developed for the 1990 race (Burnett, 1990), were based in many aspects on those used in the 1990 World Solar Challenge. Hence major sections included details of organisational issues, how to enter, vehicle specification, track specification, the scrutineering process, allowed functions of the crew on the day of the race, the course and race details and prizes which would be given. The obvious difference in race format is that the model races are to be run as match races between two cars, the winner continuing to the next round, the loser being eliminated.

Only solar power collected by the photovol-taic panel provided could be used, no batteries were allowed, vehicles were limited to a maxi-mum size of 600 mm long, 150 mm high and no wider than the solar panel (280 mm). Each car would be ballasted with a weight of up to 1 kg (in bright sun but reducing in low light condi-tions) so as to ensure a reasonably strong chassis was built. Each car had to be fitted with a height adjustable steering peg which fitted into a plastic "U" shaped channel which provided a guideway to steer the cars around the track. Although components from commercially avail-able models can be used, the vehicles cannot use commercially made bodies or chassis.

Subsequent changes (Australian Model Solar Car Regulations, 1996) have seen the ballast replaced by a mannikin who must be placed in a suitable driving position and a requirement to have a separate chassis as the panel could be used to provide sufficient strength and stiffness to act as the body structure. Alternative panels which are commercially available and hence cheaper have been allowed provided they have the same power to weight ratio—if not, a lead ballast is added. The track has also changed from an "S" to a figure-of-eight shape with corners with a 5 metre radius in which there is an overpass with a slope of approximately 1 : 8 and a height of 200 mm. Cars start on the down hill slope and then have to climb over the overpass to reach the finish line giving a total course length of 100 m.

8. VEHICLE DESIGN ISSUES

A variety of design concepts have been devel-oped and tried. The most successful car entered in the first race used a panel sloped from front to back obtaining slightly more power than a flat panel, being tilted slightly towards the sun. However, the better teams soon realised that this design required a larger frontal area, gener-ating more drag and flat panels have now become standard. Motors are usually fitted into an aerodynamic fairing and drive the front wheel or wheels, although many cars drive one or sometimes both rear wheels. Body structures in 1990 were mainly aluminium, polystyrene foam or balsa wood, but newer designs feature carbon fibre tube from kite frames or arrows.

Motor selection has varied from using second hand motors from cassette players to the top of the range Swiss made DC-Micromotors from Minimotor SA which are rated at 83% efficient and are available with reduction gear heads. Some designers have used a single 12 V motor but many use two 6 V motors (Armitage, 1996). Most entrants use injection moulded plastic gears with a typical ratio being a 12 tooth motor gear to an 80 tooth gear on the drive shaft (Armitage, 1996). Hence in bright sunlight, a car with the motor shaft driving at 3000 rpm and a 12 to 80 gear ratio would be using wheels of about 29 mm diameter. Some cars keep the gear ratios constant and change wheel diameters to cope with changes of solar intensity. With recent national events being held in quite overcast conditions, correct gear selection made under the pressures of the tight race schedule, and the ability to quickly change gears without sacrificing alignment or intermeshing tolerances is of paramount importance. Changes which can be implemented quickly and accurately in the last minutes before a start are now being considered by the more competitive teams. A number of schools are also considering electronic controllers to change voltage during the race but the top entries in 1995 were still driving directly from the cells to the motor.

Issues such as wheel alignment and good quality ball races for the wheels and on the steering peg to reduce friction have become standard. Some cars have developed steerable front wheels which will also lower friction when cornering, and help improve stability. Many designers have realised that on the smooth track, rubber "O ring" tyres actually absorb energy and hard plastic or even aluminium wheels may offer lower rolling resistance.

9. EVENT PROMOTION

Initial publicity which led to the nationalisation of the event included Anderson (Anderson, 1991) in *New Scientist*, Keyt (Keyt, 1993) in *Sun World*, the Alternative Technology Association's Soft Technology 1992, Wellington and McIntyre in *Lab Talk*, 1992, CSIRO's *The Helix*, 1992.

Exhibitions and workshops were held at the 1991 ANZSES conference in Adelaide, at Energy '92 in Sydney, at the Energy Museum in Perth in 1992 as well as at numerous environmental, educational and energy related events in Melbourne.

Radio interviews and television coverage have been steadily increasing as the events become more established. The event has also been outlined in national and international conferences and meetings including the '91 Renewable Energy Education Symposium at Borlange, Sweden.

10. SPONSORSHIP

The cost of running the state events in Australia varies significantly depending on the degree to which the schools in each state are subsidised. In Victoria, major sponsorship has covered the costs of administration, publicity, subsidies for kits and race costs. The major expenditures for the race include hiring 1500 W super flood lights and support structure and a grandstand capable of seating approximately 250 people.

For the first 5 years, Energy Victoria, a state government instrumentality with the objective of promoting alternative energy and energy efficiency has been the major sponsor. With a recent change in their range of responsibilities, they have had to reduce their support substantially. However the Faculty of Engineering at Monash University agreed to direct an educational grant from Esso Australia Ltd to sponsor the event in 1995. Other states have their local energy supply companies as major sponsors with Science Museums being heavily involved as event organisers. Federal Government departments for Industry and the Environment have been major supporters of the national events. Other sponsors have included General Motors Holden Automotive, the Society of Automotive Engineers, solar panel manufacturers, Solarex, CAD suppliers and component distributors.

Most minor sponsorship has been spent on prizes for not only the winning teams but also for discretionary awards including the Best Engineered Car, the Most Innovative Design, the Best First Year Entrant, the Best Team Effort, the Best All Girls Team and the Best Junior Entry. These are only loosely specified awards and are selected by sponsors or other invited guests, and are designed to provide additional motivation for schools unlikely to compete for one of the top four prizes. The prizes for the four fastest vehicles include cost of travel and accommodation to attend the national finals. The minor prizes include CAD software, plaques, books, sponsors products and cash.

In return, major sponsors have exclusive naming rights, and their logos are displayed on all publicity. Minor sponsors are recognised in the event program, at the award ceremony and in exhibition presentations. Shelton (Shelton, 1994) identified major factors in prompting sponsorship of full size solar vehicle projects as including support of the educational principles, to advance technology, for purely philanthropic reasons, to enhance the corporate image, for advertising purposes and to promote local spirit. These factors also seem valid for sponsorship of the Model Solar Vehicle event. Many individual competitors have also been successful in raising support from local industry.

11. GROWTH AND NATIONALISATION

The first event in Victoria saw only 29 entries although over 80 schools had received solar panels and curriculum materials. That year many schools, having little background or other teams to learn from, had trouble in building a functional car. However by 1992, the number of Victorian entries was holding firm and the states of Western and South Australia were holding their inaugural competitions in their state capitals, Perth and Adelaide. Members of the Victorian organising committee held exhibitions or workshops in those states in 1991 or early 1992 and liaised closely with them to help them get started. The publicity achieved in 1990 and 1991 for the concept saw New Zealand develop a similar race for radio controlled cars and all other Australian states had a competition in place by 1993 (see Table 1).

At the end of the 1993 World Solar Challenge, an event was held for the best model cars from each Australian state and New Zealand. The success of this event lead to the formation of a national organising committee who arranged national finals held in Melbourne in 1994 and Canberra in 1995.

11. FORMAT AND RESULTS OF THE NATIONAL COMPETITIONS

A variety of formats has been used for each of the state events, although a knockout competition in which cars compete in a series of match races between pairs of cars, the winner continuing to the next round and the loser being eliminated, is the most common. However, in the national final, four invitations are offered to the top entries from each state, resulting in 24 starters. In view of the small number of entries, it was decided to run the first round as a round robin competition with four separate groups each of 6 cars, all of which race the other five cars in their group. The groups were seeded on the basis of their times under lights so as to be as evenly balanced as possible.

Each car raced each other car in its group, with the two least successful cars being eliminated after the five group races. The remaining 16 were then seeded with the more successful cars from each group matched against the less successful from another. In these later rounds, the competition sees the losers eliminated although for semi-finals and finals, the decisions are based on the best of three (semi-finals) and best of five (finals) races with the cars alternating between lanes.

In 1993, the final was held on the oval of one of Adelaide's most prominent schools, Prince Alfred College. Sunny weather prevailed and keen competition saw Eastern Hills from WA win in a time of approximately 21 s, defeating Victoria's Lynall Hall by about 1 s.

In 1994, the event was held at Science Works museum in Melbourne, where again Western

Table 1. Entries since inception

Year	No. of entries	States	Venue	Conditions	Winner
1990	29	Vic.	Melbourne	Part Cloud	Lynall Hall
1991	19	Vic.	Melbourne	Bright Sun	Lynall Hall
1992	50*	Vic. WA. SA	State Caps.	Varied	
1993	119+100	All Aus, NZ	Adelaide	Bright sun	Eastern Hills, WA
1994	170	All Aus	Melbourne	Light Cloud	Perth College, WA
1995	250	All Aus	Canberra	Heavy cloud	Perth College, WA

[a]Exact numbers of entrants are not available from SA in 1992 but the approximate numbers are given for total schools involved. New Zealand developed a similar event using the same cells but organised their event using a radio control system. Some 100 schools participated in New Zealand with the winner coming to Adelaide in 1993. Resulting from loss of sponsorship, the NZ event is no longer held, as far as the author can discern.

Australian teams dominated with three of the first cars coming from that state. The 1994 event was run on the new figure-of-eight course which was a much smoother course, making direct comparison with the 1993 event difficult. The weather conditions were cloudy, but did not interfere with the race schedule although some cars had trouble in completing the course because of insufficient power. The all girls team from Perth College won the final in a time of 26 s from Albany Senior High (both from Western Australia) by a margin of about 5 s.

The 1995 event was held in Canberra adjacent to the national science museum Questacon in the worst conditions yet. Rain caused a suspension to racing late in the round robin and although solar intensities of under 100 W were registered, the best cars, with appropriate gearing, were able to finish the distance. Both the organisers and contestants were reluctant to shift the competition under the indoor lights and so the races continued on the outdoor track despite the poor light. Some races were judged on the distance travelled as some of the weaker entrants were unable to finish the course. At solar intensities as low as 90 W per square metre, less than one tenth the intensity of full sun, several cars were still able to complete the course despite taking up to 66 s to do so. Weather conditions improved toward the finals with solar intensities of approximately 300 W (see Table 2) per square metre allowing Western Australia's Perth College to win for the second successive year in a time of 24.9 s by a margin of less than 1 s from Queensland's Shalom Catholic College.

The fastest time ever recorded was approximately 19.5 s in 1994 set by Victoria's Lynall Hall, but their inability to effectively adjust gearing to cater for deteriorating weather conditions has seen them eliminated before the final rounds in both 1994 and 1995. As a result of variations in wind and light conditions changing during races, it is not possible to quote accurate data correlating race time and speed with solar intensity but Table 2 indicates the times and average recorded intensity for the winning times posted by the top entrant in 1995.

Table 2. Effect of solar conditions on winning times

Time Perth College (s)	Solar intensity (W)
21.16	450
23.10	330
25.07	290
40.42	80
27.20	350
23.94	380
23.74	300
24.62	290
21.64	440
24.95	290

12. DESIGN ANALYSIS OF THE PERTH COLLEGE ENTRANT

Rees (Scutt 1994) highlighted the importance of developing a stable as well as a fast design and of extensive testing under diverse weather conditions so as to ensure appropriate gear selection to suit the conditions. Key elements of the design included: four wheels instead of the more common three for improved stability; a single 12 V brushless motor driving the rear left hand wheel giving good torque at low speeds ideal for poor weather conditions; hollow carbon fibre tube chassis for high stiffness and light weight; light weight foam block for mounting points; drilled out aluminium wheels for light weight and good traction; front wheels steered round corners by variable steering geometry rather than fixed; high precision bearings to minimise friction losses; easy gear adjustment mechanism; aerodynamic fairing over the mannikin.

13. EVALUATION

The success of the project needs to be determined in terms of the numbers of entrants, their on-going participation, feedback from teachers and students and comments from sponsors.

13.1. Analysis of entrants

Victoria was the only state to run the event until 1992 when it was also run in Perth, WA, and Adelaide, SA. Table 3 shows an outline of numbers of schools who have entered 3 or more Victorian events and Table 4 the breakdown of country and city schools and single-sex girl, boy and coeducational schools in 1995. Approximately 50 schools have already registered for the 1996 event.

Table 3. School involvement in 3 or more events

No. years entered	No. schools
6	1
5	4
4	7
3	8

Table 4. Summary of school geography and admissions

No. city	No. country	Female	Male	Coed
31	17	5	3	40

13.2. *Feedback from teachers*

At least 15 Victorian teachers have supervised teams who have entered at least three events and approximately 10 have served on the organising committee. Listed below are comments from a number of these co-ordinators:

Harley and Carroll (Harley and Carroll, 1993) stated "The project was integrated into the school curriculum and was the basis of student work requirements in Maths, English, Science and media studies... In addition, team involvement and responsibility combined with a broad curriculum approach to the project can lead to the development of personal qualities in students in a way not possible in the classroom".

Sismanes (Sismanes, 1994) claimed "Our school recognised the Model Solar Car Project as an opportunity to provide an exciting focus for our technology studies this year. It certainly has! Our students, their parents and the community of Kinglake West have become enthusiastically involved in this most challenging endeavour. As part of the project the children have made circuits, switches and electromagnets; they have looked at how motors work and will conduct tests to find the most effective motor, they will investigate wheels and gearing. They are highly motivated to design, discuss, test and improve models; developing attitudes and skills that will hopefully lead them to undertake technology related subjects in later schooling and onto bigger and better things in the future".

Friedman (Friedman, 1995) claimed "As a direct result of their involvement in the Model Solar Challenge, our top two science students in VCE in 1994 decided to enrol for the Science Engineering double degree at Monash Clayton instead of Medicine or Law which their results would have enabled them to do".

13.3. *Feedback from students*

Questionnaires completed by students from Victorian schools have shown a high level of enthusiasm for the challenge of the designing, building and racing and for the team work which has gone into the project. A brief analysis of results from Or (Or, 1995) is given in Table 5.

In response to unstructured questions on their motivation for undertaking the project, 30 students included the words fun or interest in their response, far greater than any other reason given. In response to a similar question on the aspect of the project which they liked most, 24 said "racing" and building or building and designing was the answer from approximately 20 more.

Table 5. Responses to student questionnaire

Question	Yes	No	No reply
The project was part of my school work	43 (43%)	58 (54%)	6 (6%)
The project was extra curricular	68 (64%)	35 (33%)	4 (4%)
I enjoyed working as a team member	100 (93%)	4 (4%)	3 (3%)
The project has influenced me for the choice of my future study or work	27 (25%)	72 (67%)	8 (7%)
I have discussed the project with people other than those in my team.	76 (71%)	20 (19%)	11 (10%)

13.4. *Specific comments made by students*

Truong and Wijewardena (Truong and Wijewardena, 1995) stated "There was a lot of sophisticated knowledge to take in. For testing, we used a special Excel program in which we could check the effects of various variables such as mass, friction, wheel diameter, gear ratio, etc. on speed and acceleration. We also used ticker tapes, voltmeters, ammeters etc. to help us see the amount of energy the cell was giving out under varying weather conditions. We wanted to find a way to achieve maximum power. We followed a scientific procedure and this will, no doubt, help us in our future studies".

Metcalfe (Metcalfe, 1993) claimed "I believe the best part of the project was what we learnt from it. Everybody on our team and I'm sure all the other teams learnt a lot about engineering, mechanics, design, management, and how to live on 3 h sleep a night. The sort of practical experience that you can't easily learn in a classroom. Most people think of solar energy as some sort of mysterious futuristic thing beyond the everyday person but events such as this enlighten people to the use of renewable energy sources and its practicality".

13.5. Feedback from sponsors

The continued support from sponsors such as Energy Victoria and General Motors Holden Automotive over the first 5 years of the project and the continued commitment of SECWA and SEQEB in Western Australia and Queensland indicate their belief that their sponsorship money is being well spent. Organisations such as ANZSES, the Society of Automotive Engineers have also been significant supporters over the years.

14. CONCLUSION

As a means to involve secondary school students in hands on experience with solar energy in an educational project with high inherent motivation, model solar car racing has certainly been a great success throughout Australia. It could be used as a model to develop similar benefits for school students in many countries. The Australian committee will enthusiastically arrange copies of the design guides, videos and regulations to anyone interested and will provide assistance with any aspect of the organisation of similar events overseas. Accordingly, we would like to invite entries from any country to participate in the 1996 International Model Solar Car Challenge in Adelaide in November 1996.

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