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MODEL SOLAR CAR

DESIGN OVERVIEW

ISSUE 12 APRIL 2011

This document is an abridged version of the DESIGN GUIDE which contains significantly more in depth information on Model Solar Car design and construction than this document. As the title implies, this is only an overview and the complete DESIGN GUIDE should be referred to for full details.

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FOR VICTORIAN MODEL SOLAR VEHICLE COMMITTEE

GENERAL SOLAR CAR DESIGN

INTRODUCTION: ("Roadmap to success")

Firstly obtain a copy of the current regulations, read and understand them, then design and construct your car to conform to the regulations. In the past many non-conforming cars have been presented for scrutineering. Even minor non-conformities slow up the scrutineering process, delaying everyone and reducing the practice time available while the car is modified to conform and passed through scrutineering again.
NOTE: The Victorian regulations are based on the National Regulations which are changed every year. Your car must conform to the National regulations if you wish to compete at that level for details go to www.modelsolaraustralia.org for the latest National regulations.

The key point to remember in designing a model solar car is that you have very little power available from your solar panel. For the shortest race time you must use all the power available at the highest efficiency possible to propel your car.

Following is a listing and brief description of the basic elements that make up a "good car" and successful project.

PROJECT MANAGEMENT

This item is not at the top of the list by accident. You can have the best resources and car design in the world but poor or no management of the project will assure failure.
Following are some critical items to consider.

- Define the project: Exactly what is involved in the total project?

- Feasibility study: Have you got or can you get whatever is required to successfully complete the project? Some of the things to consider are listed below.

  Time
  Funding
  Equipment
  Skills
  Sufficient personnel
  Materials for construction

If you cannot say yes to the above then it is time to stop.

- Time line: Produce a timetable detailing the start date, finish date and duration of every section of the project. Work backwards from the event date to ensure completion in time. Note that in many instances activities can overlap. For example, car construction can already be underway before all materials are available. Some of the things to consider are listed below.

  Car design
  Material & equipment procurement
  Manufacture of car
  Testing & modifications as required
  Poster

- Detail car design: This area is critically important. It is imperative you know exactly what you are going to build and what materials you need.
  Produce drawings and sketches of components and an overall assembly drawing of the car and draw it to scale. Many hours of work and much material is wasted remaking components that did not initially fit into the car as intended all because it was not clear exactly what the components were to look like and the actual dimensions required to assemble into the complete car.

  It is suggested that photographs and videos of cars from previous events be examined and investigated and the various State solar car web sites consulted for additional data and ideas.

  Some of the sub assemblies/design areas to consider are listed below.

  Overall dimensions
  Wheel details, number and placement, drive wheel?
  Motor
  Electronics
  Solar panel
  Guiding, placement & dimensions of guides
  Gears
  Track clearances
  General conformance to regulations
  Body shape (aerodynamics) & material

- Materials & equipment procurement: Be certain to order and obtain any materials or items needed for your construction in plenty of time so they will be available for use when you need them. As an example, Faulhaber motors are in limited production in only one factory in Europe. Quantities held here in Australia are also limited. Should local stocks become exhausted in about May then it could be late August or early September before more motors become available. The reason for this is simple as the factory in Europe closes down for summer vacation over the June/July period and so there will be a waiting period for the next run to be scheduled down the production line if there are no stocks of this motor on the shelf in the factory.

- Decisions & action: Regularly review your position and make decisions and take action as required to maintain progress.

- HELP!!!! Remember the Model Solar Vehicle Committee in Victoria runs workshops from time to time and technical advice and other challenge help is always available through contacting any of the state or national Committees at the details listed in the regulations or on any of the challenge websites.

  Box Hill High School in Victoria have an active Model Solar Car programme and are willing to provide assistance to other schools or students. They have a test track which is erected from time to time particularly near the event date. Any students are welcome to come and make use of the track at these times.

CAR WEIGHT & WEIGHT TO POWER RATIO

- Weight to power ratios of about 160 grams per watt have been typical for light weight cars in the past few years. The new ballasting formulas for 2011 as well as no longer having egg drivers will allow for even lower ratios than this to be possible on well designed and built cars. Only time will tell what competitors are able to achieve in 2011. (The test car Photon Cruncher MK IV (see design guide for details of this car) has a weight to power ratio of about 220 gm/watt and outperforms many cars with better ratios only because it is accurately built).

- While weight is not the only or most important parameter that controls car performance, it does have a significant effect. Every effort should be made to keep chassis weight to a minimum. This not only improves acceleration and allows the car to reach full speed more quickly but also reduces rolling resistance and loads on other components such as axles, wheels and guides.

- Any ballast required should be carried as low down in the car as possible to increase stability. The best location for any ballast will be influenced by the number of wheels and their position. For example, a 3 wheel car with the single wheel offset from the center line will tend to roll over more easily in one direction than the other. Good placement of ballast can help reduce this effect.

BUILD QUALITY

- It is important to manufacture your car with its critical components correctly aligned and with the required clearances. Your car must be strong and stiff enough in critical areas to maintain these clearances.

- Poor build accuracy can easily cost 5 seconds in race time. (Axles 3mm out of parallel has about the same effect as adding around 700 gm to the car weight on a 4 wheel car without steering).

- Ensure axles are parallel and steering, if fitted, is free to move but does not shimmy. Test to ensure your car is not “crabbing” down the track or pushing hard on the guide rail. The car must run smoothly with no wheel wobble or bouncing.

- Correct clearances in bearings and gears, bearings lubricated with light oil. The chassis must be strong and stiff enough to maintain clearances and alignment if good performance is to be achieved.

AERODYNAMICS

- Good aerodynamics, by which is meant a car with low aerodynamic drag, is critical if your car is to have the best performance possible (a car with excellent aerodynamics can be 22 metres ahead of an identical car with poor aerodynamics at end of 2 laps in high sun level).

- Aerodynamic drag is the largest retarding force acting on an average car by the time it exits the first corner in a race.

- Aerodynamic drag varies with velocity squared so is high for the entire second lap of a 2 lap race.

- Car aerodynamic drag is typically about twice the rolling resistance as the car crosses the finish line.

- As a general rule the rear of the car is often neglected but is quite important as a poor shape here will lead to high wake drag.

- Significant aerodynamically generated lift or down force is unlikely unless you deliberately design for it. Even then there will be a significant unwanted drag force generated which probably negates any advantage.

TESTING & RELIABILITY

- Testing is critical to obtain a car that runs well. It shows up any bad design and poor build quality, allowing you to rectify any faults before the event.

- Reliability is critical if you hope to win. Your car must function correctly every time it is placed on the track. Adequate testing and rectification of any problems revealed during that testing will result in a car that is reliable.

- Attention to detail is also critical to success and many cars have been seen to either fail to complete a race or run poorly due to oversights and unnecessary failures (ie cars have lost wheels during races or not been turned on at the start line and just roll down the hill).

- Have a pre-planned race strategy and stick to it. Do not just change gears etc. just because you think you must do something.

ENERGY UTILISATION

It is important to use as much of the energy collected by your panel as possible to drive the car. The use of electronics is strongly advised for new starters as it will assist in this. Ensure you have selected the best gear ratio (use of the mathematical simulation as outlined in the Design Guide will give a starting point).

By knowing where the energy is used you can take steps to use it effectively.
Energy is used in the following areas (the factors influencing energy use are in brackets).

- Overcoming air drag (shape and frontal area)
- Giving the car Kinetic Energy (car mass and velocity)
- Electronics (unit efficiency and correct adjustment)
- Motor (motor characteristics and operating point)
- Rolling resistance (use of tyres, bearings fitment and lubrication, axle alignment and use of steering)
- Driving of car (tyre on drive wheel if required and gear reduction. Is the reduction ratio correct? Are the gears correctly meshed and in alignment)

SOLAR PANEL

- Only silicon based solar cells are allowed.
- Provided that panel power is between 6 and 10 watts, the ballasting formula in use this year means that there is little or no advantage or disadvantage given to a particular power over the length of a race (for a well designed and constructed car).
- It is more important to use a good quality solar panel. Solar cells have both series and parallel internal resistances in varying ratios and the ratio of these resistances (within the cells and externally when assembled) can ultimately give a panel a ballasting advantage or disadvantage.
- Low quality panels are more likely to have an undesirable ratio of resistances if power measured at 50% Sun. See the section on solar panels in the Design Guide for details.
- Solar panel output varies with temperature. Panel power drops by nearly 0.5% per Deg C temperature rise. (Caution: beware of electronics set point if playing around with panel temperatures as the maximum power point will shift)
- Voltage suitable for both the motor and electronics unit. Most electronics units will not operate below 11 Volts. In general, as a rule of thumb for best results the panel voltage at maximum power output should be between 2 and 3 times the motor's rated voltage.
- Able to be configured to suitable voltage and current if it is intended to run without electronics.
- Panel should be light enough so that it is not heavier than the required panel plus ballast weight. Otherwise your car will be carrying a handicap.

STEERING

- The use of steering reduces drag while cornering thus improving performance.
- Steering, if used, must be stable. Cases have occurred where the steering mechanism goes into a wobbling mode shaking the car from side to side wasting a lot of energy.

MOTOR

- Voltage, power, torque constant and voltage constant must suit solar panel selected.
- Should be high efficiency & preferably lightweight (Typically 85% and 80 grams)
- Not worn or damaged
- The majority of cars now use the Faulhaber 2232 6 Volt motor. However Maxon also have some excellent motors worth considering.

GEARS:

- Good quality with properly formed teeth.
- Adjusted for correct mesh.
- Correct ratio chosen for the car.
- The main gear is best if manufactured from plastic and this allows satisfactory operation without lubrication even if the pinion gear is metal. The use of lubrication on open gears holds dirt and consequently increases wear and power losses.

BEARINGS:

- Clean and undamaged
- Correctly installed with no preload.
- Lubricated with light oil (INOX has been found to be the best). Running bearings without lubrication has been found to have 250% more friction than when lubricated.

ELECTRONICS:

- High efficiency at operating point
- Correctly set to panel power point. Caution: the maximum power point voltage drops rapidly with increasing panel temperature.

WHEELS:

- Must run freely and true especially radially.
- Be in correct alignment particularly if steering is not used.
- A tyre on the drive wheel(s) can improve performance by reducing wheel spin on take off, but will increase rolling resistance. There is a cutoff point where a tyre will not improve performance but in fact reduce performance. (At 90% sun on the test car Photon Cruncher MK IV a tyre reduced race time by 0.2 seconds.)
- The number of wheels and their position has a significant effect on car stability.

WHEEL SLIP:

- When using an electronics system it is possible and in fact common to experience wheel spin on takeoff in high Sun and this will cost race time (0.2 seconds has been measured in testing). Either increasing the weight on the drive wheel or fitting a tyre which, unfortunately, also increases rolling resistance can improve this situation.
- The track surface has an effect on wheel grip. The Victorian track is painted with a flat acrylic paint and has moderate to good grip properties. The New South Wales track on the other hand has a plastic coating which has the frictional properties of a sheet of glass.

GUIDES:

- Guides are subjected to high forces when the car is cornering at speed. The side forces acting on the guides when cornering at speed can exceed the weight of the car. Consequently, the guide anchor points and the guide rollers and their bearings deserve as much attention as the wheels.
- Must be properly aligned and positioned.
- Should be as low to the track as possible without touching.

STABILITY:

- At speeds in excess of 6.5 m/sec calculations indicate that on the Victorian track a car will take off over the crest of the hill. If the car is not stable and running straight it will probably not land with the guides engaged on the guide rail and consequently crash. (Photographic evidence exists of a car about 20 mm off the track with the guide rollers clearly visible above the guide rail.)
- Similarly, calculations indicate that for a car with a center of gravity 80 mm above the track surface, roll over (or at least roll far enough to disengage the guides) will occur when cornering at a speed above about 9 m/sec. This is based on a smooth and level

corner section of track and bumps or a slight outward track slope will cause roll over at a lower speed than this. The actual crash mechanism is not likely to be a complete roll over, but lifting of wheels on the inside of a corner will be sufficient to disengage the guides and allow the car to spear off the track out of control.

BALLAST:

- If the solar array and its support structure weigh less than the total minimum required by the appropriate formula in the regulations, additional weight in the form of ballast is required to be carried in order to bring the weight up to the required minimum level.

- Ballast will not be supplied by the scrutineers. You must bring your own to the competition.

WIRING:

- To keep electrical losses within the wiring low, ensure that it is as short as reasonably possible and in a reasonably large diameter wire.

- Use multi strand wire to minimise the possibility of fracture.

- Colour code wiring to make trouble shooting easier.

- Solder all joints if possible.

- Insulate all joints.

- Check wiring regularly for damage and repair as required

REGULATIONS & IMPLICATIONS FOR PERFORMANCE:

The regulations are changed every year primarily to force teams to build a new car. The changes are carefully chosen to ensure cars built previously are easily identified as “old design” and, if possible, disadvantaged in performance by the new regulations.

The regulation changes for 2011 are extensive. The intent was to significantly simplify the regulations as they had gradually become more complex over time.

The 2011 regulations allow much simpler cars to be constructed. In the simplest format they could be a ladder type frame chassis with a solar panel on top and the 200 square cm drag plate. This type of car is very simple to build and will have good performance due to its light weight. However a more complex heavier car employing a body with a good low drag aerodynamic shape would be expected to have even better performance.

What power solar panel should be chosen? Significant effort has been expended by members of the National committee in evaluating different ballasting formulas and computer modelling has indicated that there was no significant difference or advantage for any one power from 5 Watts upwards (provided that the car is of good design, high build quality and correctly set up).

Electronics or not? The new ballasting formula is generous for cars not using electronics. Computer modelling has indicated that a slight advantage exists for a car without electronics when considering the 2011 ballasting formulas (the size of the advantage varies with sun intensity) although it must be remembered that this is however only true for a top car that has been correctly set up. If incorrectly set up, car performance can be seriously affected and may in some cases even lead to a car failing to complete a race. Identifying the correct setup for a non electronics car is significantly more difficult and the car will need constant adjustment if Sun levels vary by more than about 5 or 10%.

Overall, the secret to designing and building a winning car is to simply design a car considering all of the areas outlined throughout this document and then construct it to the highest possible build quality and accuracy. Once completed, plenty of practice will help identify and eliminate any bugs as well as allow for other car improvements to be made before an event. Finally, paying attention to detail during preparation and racing will help get the best possible performance out of the car at an event.

WARNING!!! A top car built to the current regulations will be running very fast in high Sun conditions. On the Victorian track take off over the hill will occur ** and roll over or dislodgment of guides around the corners is very possible. To remain on the track and finish a race you may need to consider slowing the car down in high Sun conditions.
There are many options for slowing the car, including adding a plate or similar to form an air brake, changing gear ratios or partly shading the solar panel. Which is best for your car?

** Calculations indicate take off will occur at speeds over about 6.5 metres per second, do not fall for the trap of thinking adding extra weight will hold the car down as it will not. Check the Physics texts. The only way extra weight will help is mainly by slowing the car down due to increasing its rolling resistance.

2011 MODEL SOLAR CAR CHALLENGE
SYNOPSIS OF CAR SPECIFICATIONS

The following is intended to be used as a quick reference guide only. It contains the important basics but does not cover all the detail. YOU MUST REFER TO THE COMPLETE REGULATIONS FOR FULL DETAILS.

- **Maximum body dimensions:** 550 mm long, 320 mm wide, 180 mm high and less than 190 mm from centre line of guide rail at all times.
- **Wheels:** minimum width 1mm or 0.6 mm radius at contact point with track.
- **Guiding:** must be on the outside of the guide rail
- **Side panels:** one each side, minimum 100 mm long by 50 mm wide.
- **Drag Plate:** a fixed, flat, rigid, transverse, vertical rectangular plate of minimum area 200 sq. cm. and 2 mm thickness. Plate to be easily removable for scrutineering.
- **School & Car name:** visible when racing, letters minimum 10 mm high not on the side panels.
- **Solar array:** fully removable from car, silicon technology only and no devices mounted on panel.
- **Wiring:** all wiring and electronics must be visible, otherwise circuit diagram required.
- **ON-OFF switch:** commercial switch required easily visible to the starter, on and off clearly marked.
- **Energy storage:** not allowed, except capacitors up to 0.2 farad provided they are discharged immediately prior to race starting. Inductors up to 1 mH allowed.
- **Panel power:** maximum allowed power is 10 watts. Panels producing greater than 10 watts will be masked by scrutineers to produce less than 10 watts. There is no lower power limit.
- **Electronics:** teams must elect to either use or not use electronics systems before each round of knockout races and then stick by this decision during that round. The total required minimum weight of the solar array, its support structure and ballast will be reduced significantly for cars not using electronics.
- **Array and array support structure weight:** will be calculated using the formulas:

Total weight <u>with</u> Electronics = 250P - 900 [grams]

or

Total weight <u>without</u> Electronics = 150P - 650 [grams]

Where P is the panel power in Watts

- **Ballast:** If the solar array and its support structure weigh less than the total minimum required by the appropriate formula above, additional weight in the form of ballast is required to be carried in order to bring the weight up to the required level.

BIOGRAPHY OF A WINNING CAR
Syndal South Primary School car "SCORPION" (2009)

This article was written to show just how easy it is to build a good competitive car for the **Model Solar Vehicle Challenge.** It describes a car designed and constructed to the 2009 regulations. This year (2011) it will be significantly easier to build a car due to the greatly simplified regulations.

The car is pictured below on the track and surprisingly managed first place at the Victorian event by beating the car that eventually finished second at the Australian-International Model Solar Challenge.

Syndal South Primary School car "SCORPION" (right)

The car "SCORPION" was one of the 2 cars constructed by the students at Syndal South in 2009. In practice and previous races there was practically no difference between these cars and they had incredibly similar performance. The second Syndal South car "Lean Green Speed Machine" finished in third place.
Both Syndal South cars were very basic. There was no other option as they had to be constructed on a table top using only the most basic of hand tools. Consequently the simplest of construction techniques and off the shelf components were used.

The big question is why was this team so successful? There is no simple answer but the following points all contributed to the success.

- The School has been very supportive of this program for the past 12 years. This includes financially and by releasing students from normal classes for about 1.5 hours each week from the start of term 2 to participate in this program. The teacher and parents have also made themselves available to take the students to the Museum Event ** and to Box Hill High School to both work on their car in the technology area as well as to test the car on the test track.
- There is a long history within the school of car manufacture and many sample cars from previous years.
- A succession program is in place where each year at least one year 5 student is included in the team to gain experience and expertise and become a team leader in year 6.
- The first few weeks of the project are spent in workshop type sessions where the students learn about the basic components and functioning of model solar cars. Particularly important is the discussion and understanding of the regulations governing the car design. Emphasis is placed on build accuracy as this is critical for good car performance.
- The students produce a timetable to allow for car completion before the Museum event. This gives plenty of time for producing their poster and testing their car before the Victorian event in October.
- A car design sketch is produced and this is used to manufacture a cardboard model of the car which, in turn, is used as a guide for manufacturing the actual car.
- The one thing that has the most influence on success is practice. The cars from Syndal South are always completed to the stage that they can participate in the Museum event and are brought to Box Hill High School in the September holidays for another 2 full day's practice and tuning on the practice track there. It cannot be stressed enough how important practice and tuning can be in improving car performance. Improvements in race time in the order of 5 seconds after only a few hours of practice have regularly been seen in the past. Practice also improves the car's reliability while giving the students the skills and confidence to operate their car effectively and autonomously.

** Museum Event: this is an event run by the Victorian Model Solar Vehicle Committee at the Melbourne Museum each year about 4 weeks before the actual event. It is conducted as a pursuit race on a single lane track and the main purpose of this event is to give students an aiming point to finish cars before the last minute, plus provide an opportunity to practice in a race type environment

THE CAR:

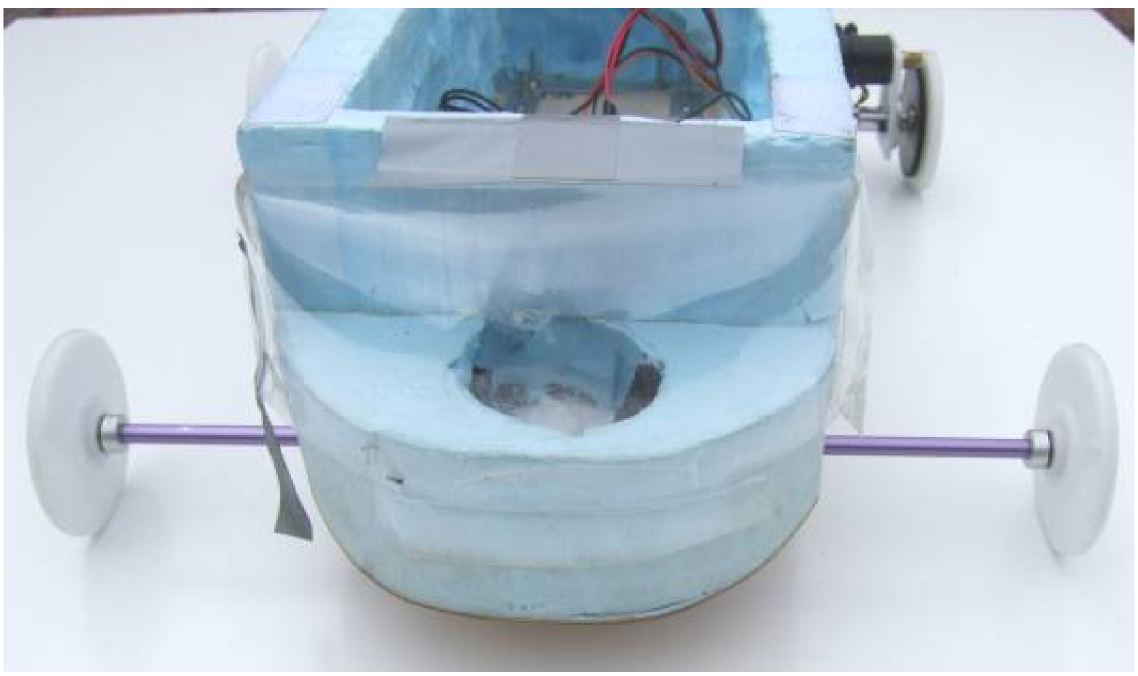
Because of the limited manufacturing facilities available at Syndal South Primary, the car construction had to be simple and utilise as many off the shelf components as possible. Body construction used is high density polystyrene foam, hot wire cut and glued to a 0.8 mm thick plywood base. Axles are arrow shafts secured to the body with standard ¼ inch pipe saddles. Wheels, gears, motor mount and guide rollers are all off the shelf components from R & I Instrument and Gear co. and steering is not used. The motor is a Faulhaber 2232 6 Volt unit which is in almost universal use in Victoria and all over Australia for model solar cars. The solar panel is from Scorpio Technology being 2 Number 6 Solar Panels connected in series and mounted on an aluminium base plate. The solar panel is secured to the car body

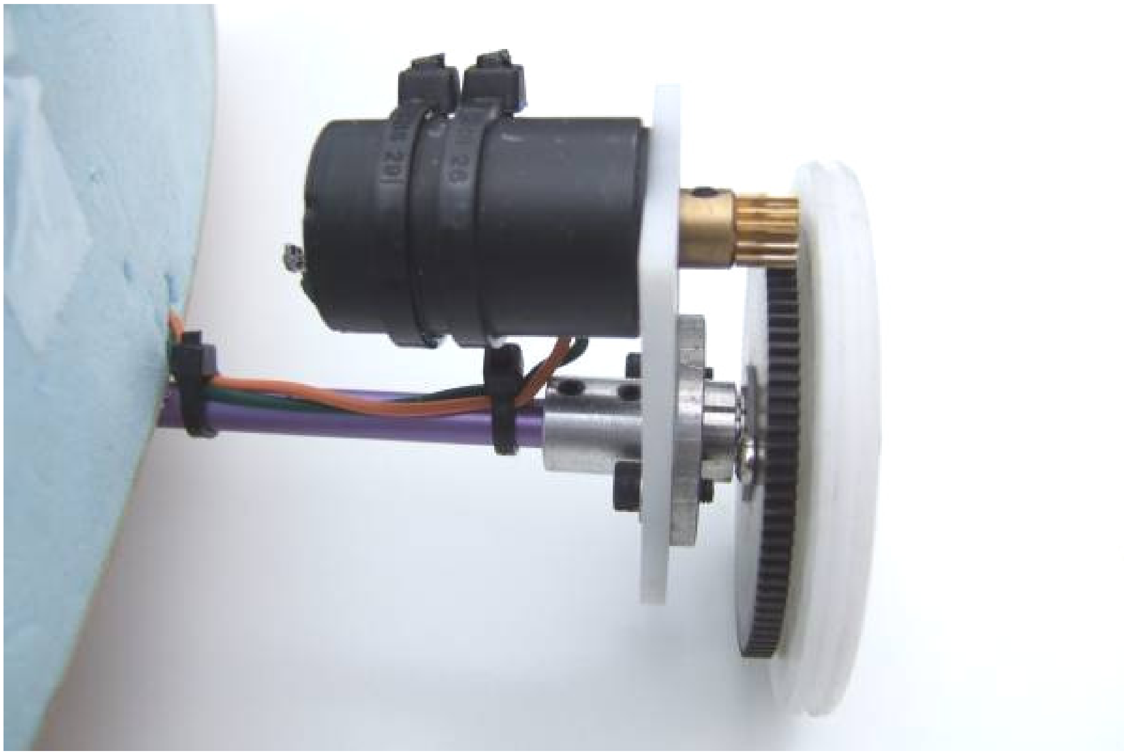
with Velcro. An electronics unit is used to control the panel power. There are several electronics units commercially available but the unit used in this car was assembled by students in a previous year. Required ballast was made up of lead sheet wrapped in tape and laying on the car floor.
The car was designed to meet the 2009 regulations and a synopsis of these requirements is given in appendix A.

BASIC CAR DIMENSIONS:

- Body dimensions, length 520 mm maximum width 155 mm height 100 mm.
- Body weight 525 gm with electronics but no egg.
- Solar panel 173 mm wide by 500 mm long
- Solar panel power 12.16 Watts (At Vic. 100% Datum not AM 1.5 as now required)
- Axle length 320 mm.
- Distance between axles 250 mm.
- Forward body overhang ie. distance from front axle to front of body 80 mm.
- Rear body overhang ie. distance from rear axle to rear of body 185 mm.
- Distance between guide roller centers 60 mm.
- Guide roller clearance to track 3 mm.
- Wheel diameter 64 mm. Guide roller diameter 25 mm.
- Gear ratio, main gear 100 tooth pinion gear 14 tooth.

NOTE: The Design Guide contains full details of R & I components and assembly details used in the construction of Photon Cruncher MK IV. The same components and construction techniques, except for the body construction are used on the Syndal South cars.
Detailed photographs of the car Scorpion follow:



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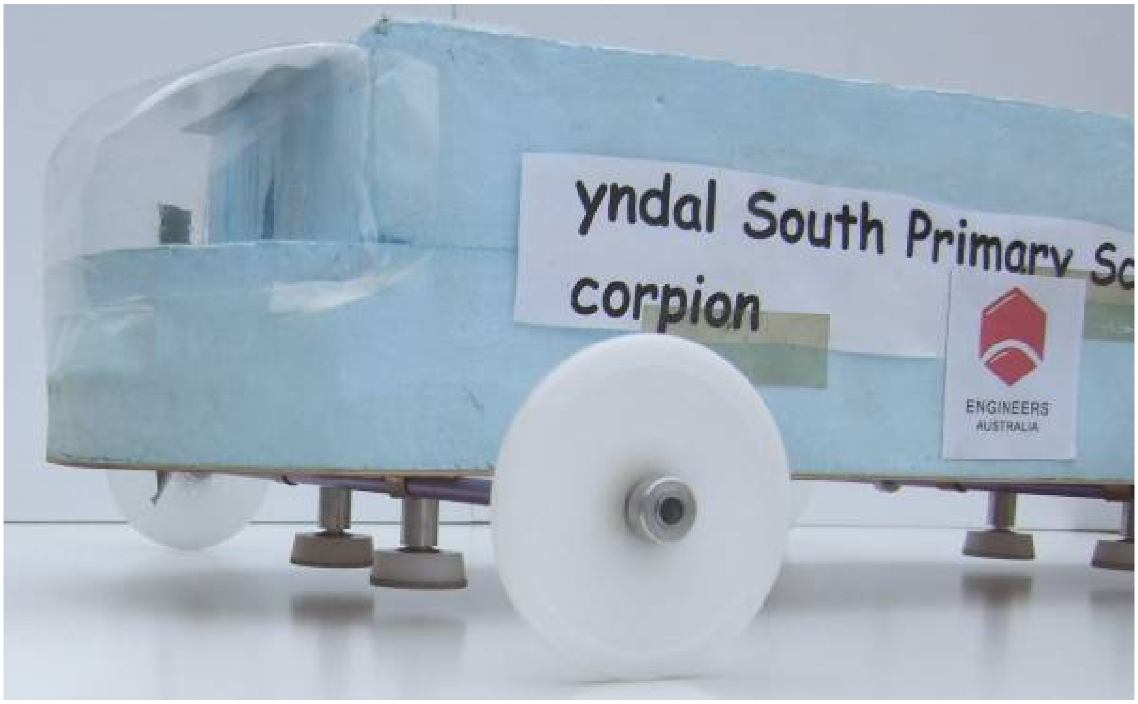
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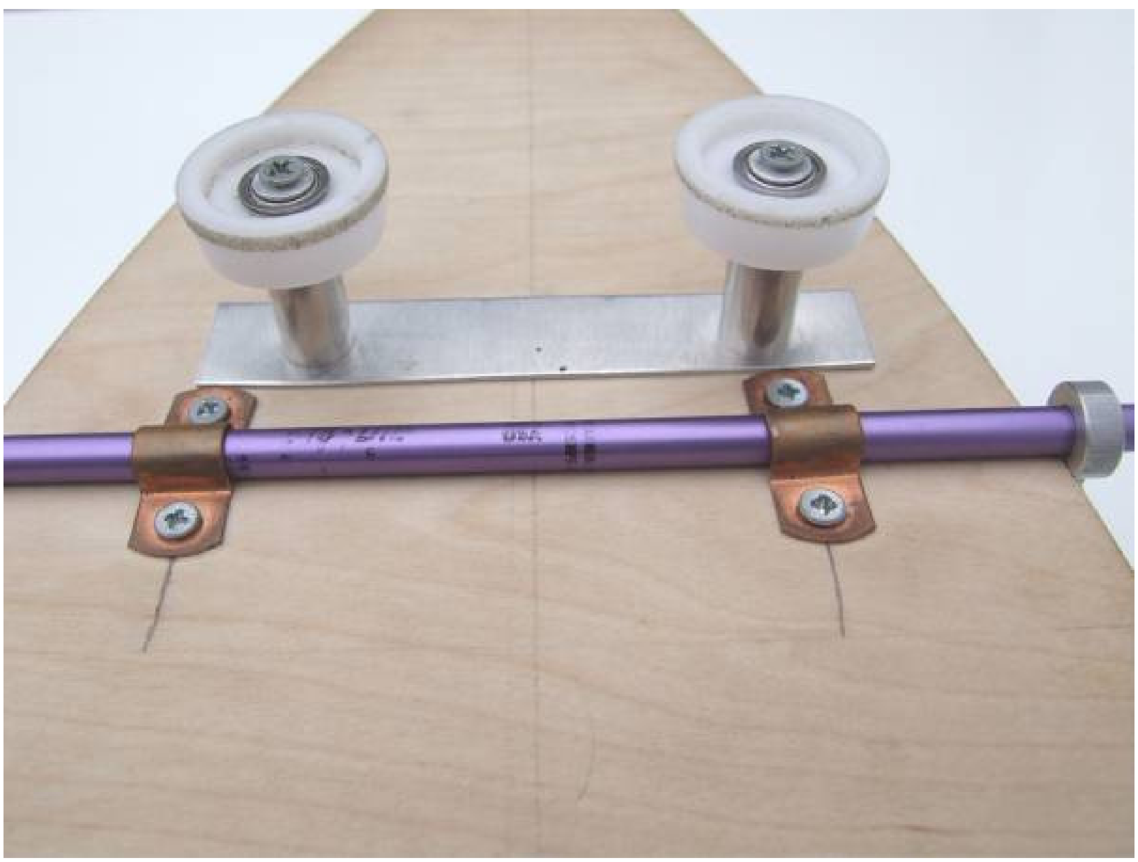

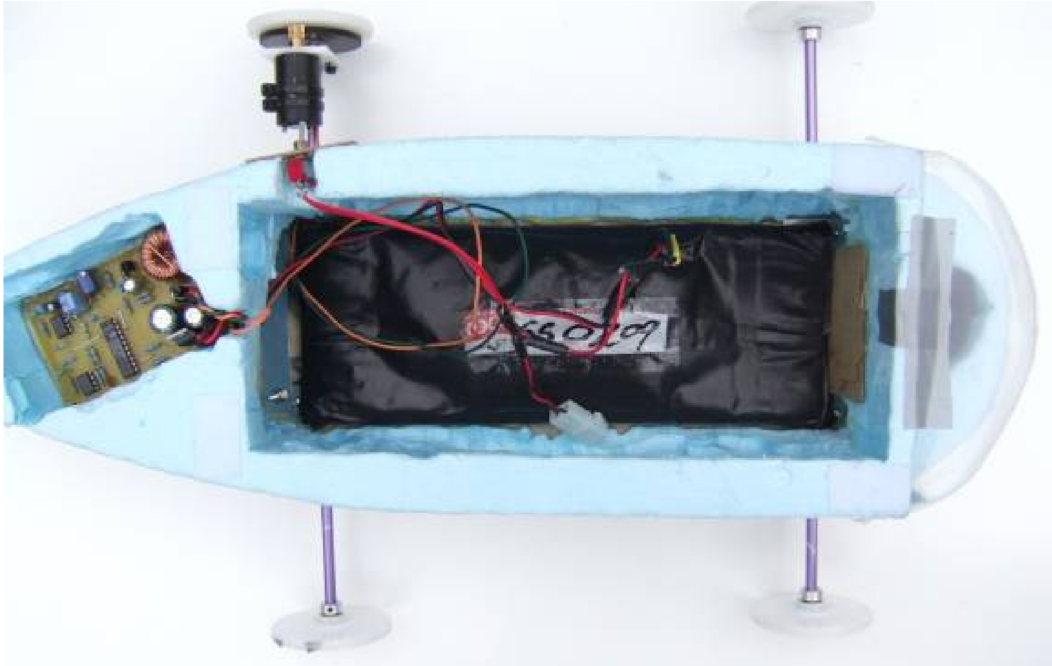


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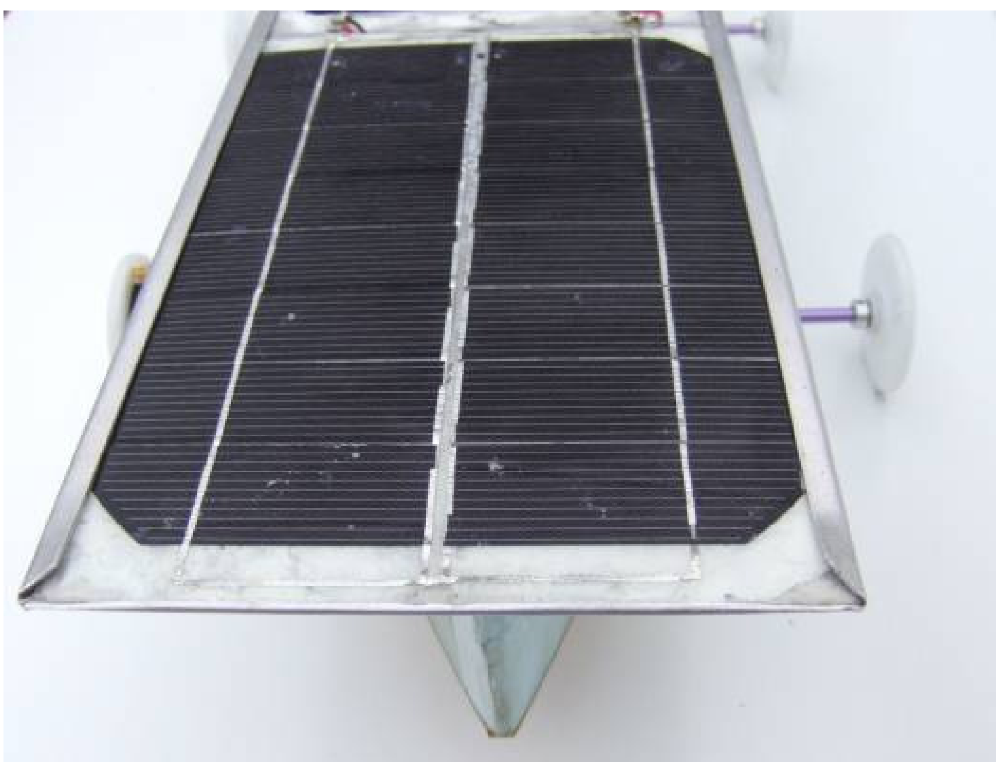

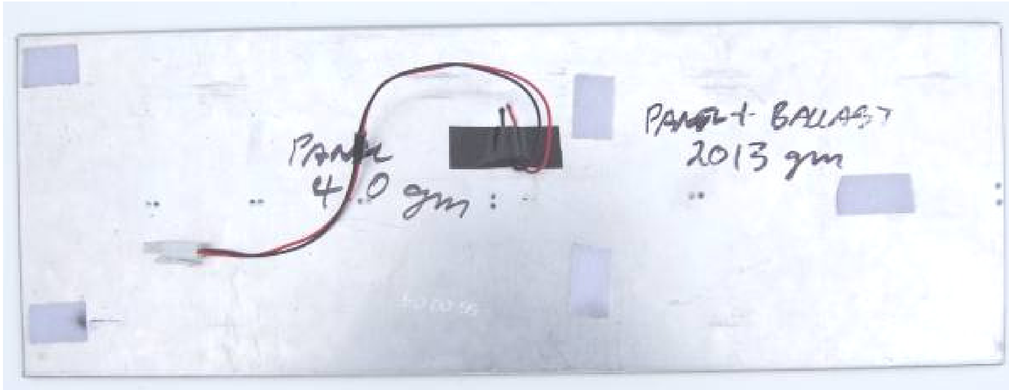

APPENDIX A: The specifications this car was designed to meet.

MODEL SOLAR VEHICLE 2009
SYNOPSIS OF CAR SPECIFICATIONS

MAXIMUM OVERALL DIMENSIONS:

550mm long
320mm wide Less than 200mm from centre line of guide rail. At no time may any part extend more than 250mm from the centre line of the guide rail.
180mm high

DRIVERS CABIN:

Must be a fully enclosed and sealed compartment at the front of the vehicle.
Have room for a 60 g egg driver.
The top 25mm of the egg must be visible from straight ahead to 90 degrees each side.
The windscreen must be transparent and have minimum 10mm clearance to the egg over the 180 degree visibility arc
3mm minimum clearance is required over the top of the egg.
Two 4mm wide frames are allowed in the visibility arc.

WHEELS:

Minimum width 1mm or 0.6mm radius at contact point with track.

GUIDING:

Must be on the outside of the guide rail.

CARGO SPACE:

An enclosed space behind the driver and beneath the Solar Panel large enough to hold 1 standard 2 litre plastic fresh Milk bottle. (Any orientation is allowed.)
The floor must be capable of supporting the full 2 litre plastic milk bottle standing vertically anywhere on your designated cargo area and the car capable of rolling without the panel attached. Only ballast is allowed to be in this designated space.

SIDE PANELS:

One each side, minimum 75mm high by 120mm long..
Allowed curvature 20mm vertically, 15mm horizontally.\

SCHOOL & CAR NAME:

In letters 10mm high visible when racing. Not on the side panel.

SOLAR ARRAY:

Must be fully removable from the car.
Maximum power 12 Watts.
Only commercially available silicon cells are allowed.
For power measuring at scrutineering a positive and negative lead with 10mm of bare wire must be provided.
Must not have any devices mounted on it including the ON/OFF switch.
Panel power measured will be standardized to 25 Deg C.

WIRING:

All wiring and electronics must be reasonably visible.
If wiring enters sealed areas a circuit diagram and explanation will be required.

ON—OFF SWITCH:

An on off switch visible to the starter (ie. Left hand side or top) is required.
Switch must have on and off positions clearly marked.

ENERGY STORAGE:

No batteries allowed.
Capacitors up to 0.2 Farad allowed but must be discharged before the race. Inductors to 1mH allowed.

BALLAST:

The required weight of the solar array and support structure plus ballast (TOTAL WEIGHT) is given by the formula.

TOTAL WEIGHT = 175(P-6) + 600 gm.
Where P is Panel power (standardized) in Watts

Ballast weight required can be calculated simply by

BALLAST WEIGHT = TOTAL WEIGHT – SOLAR ARRAY & SUPPORT STRUCTURE WEIGHT

Any ballast required can be carried anywhere in the car.
Bring the ballast you require to scrutineering NO ballast will be provided by the scrutineers.

USE OF ELECTRONICS:

If teams elect to use electronics the total BALLAST + SOLAR ARRAY WEIGHT required will be INCREASED BY 20 % over the value as calculated above.

TEST CRITERIA:

All references to car behaviour and measurements assume the car is on a flat level section of track in full racing configuration.