# MODEL SOLAR VEHICLE MATHEMATICAL SIMULATOR QUICK START

This document has been produced to make it quicker and easier to learn to use the Mathematical Simulator.

The information and data in this document is a brief overview of that available in the full Instructions PLEASE REFER TO THEM. They are included in the Design Hints available from the Victorian Model Solar Vehicle web site.

The Simulator is a mathematical approximation of a car on the figure of 8 track, it is not 100% accurate. However with accurate input data the simulator predictions are typically within 5% of results obtained from track testing.

Listed below are some of the factors which influence the Simulators accuracy.

ACCURACY OF INPUT DATA;

For best results the input data in the PARAMETERS section must be accurate. Remember GIGO garbage in garbage out.
Careful testing of your car is required to obtain these parameters.

CAR AND OPERATIONAL ADJUSTMENTS:

Car build standard. (square straight and clearances good)
Adjustment of electronics
Panel Temperature (power falls as panel heats)
Correct gear ratio fitted.

SIMPLIFYING ASSUMPTIONS: A number of simplifying assumptions are made in the simulation, some are listed here.

The track is laid out on flat ground.
The sections of track between the corners are straight.
Joints in the track are in perfect alignment.
The surface of the track is flat (not undulating & no hollows)
No wind.
Sun level constant
Motor Torque vs RPM graph is treated as a graph with 3 straight line sections. As it is in fact a curve, errors are introduced in representing it as straight line sections.

To use the Simulator, just enter your cars characteristics into the parameters section, the predicted results of a race will then be displayed in the results area.

Below is a copy of the input output section of the Simulator showing the layout.
The data loaded is for PHOTON CRUNCHER MK IV this is the data loaded in the excel spreadsheet when you received it. Use this data to practice with the simulator as described later.

## Model Solar Car Simulator

| Parameters | | | | | | Results | |
|---|---|---|---|---|---|---|---|
| **Car Name:** | PC IV MODIFIED FOR WHEEL SLIP | | | | | **1 LAP RACE** | |
| **Sun Power:** | 88% Sun Solarex SX 10 | | | | | **Time:** | 19.5 |
| **Motor Type:** | Faulhaber 2232 6Volt Engelec Electronics | | | | | **Velocity:** | 6.897 |
| **Guide Roll CoEf:** | | 0.015 | **Wheel Slip Coeff** | 0.9 | | **Mtr RPM:** | 14694 |
| **Mass(kg):** | | 2.1 | | | | **Air Drag** | 0.333 |
| **Wheel Roll RS:** | | 0 | **Roll CoEf:** | 0.097 | | **Rolling R:** | 0.2037 |
| **Air Drag Coefficient:** | | 0.007 | **Steering(Yes/No):** | NO | | **Mtr Torque:** | 4.008 |
| **Wheel Diameter(mm):** | | 64 | **Steering Drag(N):** | 0.13 | | | |
| **Acceleration Gear Ratio:** | | 7.14 | **Change RPM:** | 0 | | **2 LAP RACE** | |
| **Final Gear Ratio:** | | 7.14 | | | | **Time:** | 31.9 |
| **Transmission Effy:** | | 92 | | | | **Velocity:** | 7.373 |
| **Motor Tourque:** | **Finish RPM:** | | **Start T(mNm):** | **Formula** | | **Mtr RPM:** | 15710 |
| **Section 1:** | | 5600 | 17.8 | 0.001429 | | **Air Drag** | 0.381 |
| **Section 2:** | | 10300 | 9.8 | 0.00083 | | **Rolling R:** | 0.2037 |
| **Section 3:** | | 24000 | 5.9 | 0.000431 | | **Mtr Torque:** | 3.570 |

**ABOVE IS SIMULATOR INPUT OUTPUT PANEL FOR PHOTON CRUNCHER MK IV USING AN ALUMINIUM DRIVE WHEEL,NO TYRE.**

## Model Solar Car Simulator

| Parameters | | | | | | Results | |
|---|---|---|---|---|---|---|---|
| **Car Name:** | PC IV MODIFIED FOR WHEEL SLIP | | | | | **1 LAP RACE** | |
| **Sun Power:** | 88% Sun Solarex SX 10 | | | | | **Time:** | 19.1 |
| **Motor Type:** | Faulhaber 2232 6Volt Engelec Electronics | | | | | **Velocity:** | 6.851 |
| **Guide Roll CoEf:** | | 0.015 | **Wheel Slip Coeff** | 1.67 | | **Mtr RPM:** | 14597 |
| **Mass(kg):** | | 2.1 | | | | **Air Drag** | 0.329 |
| **Wheel Roll RS:** | | 0 | **Roll CoEf:** | 0.11 | | **Rolling R:** | 0.231 |
| **Air Drag Coefficient:** | | 0.007 | **Steering(Yes/No):** | NO | | **Mtr Torque:** | 4.049 |
| **Wheel Diameter(mm):** | | 64 | **Steering Drag(N):** | 0.13 | | | |
| **Acceleration Gear Ratio:** | | 7.14 | **Change RPM:** | 0 | | **2 LAP RACE** | |
| **Final Gear Ratio:** | | 7.14 | | | | **Time:** | 31.55 |
| **Transmission Effy:** | | 92 | | | | **Velocity:** | 7.319 |
| **Motor Tourque:** | **Finish RPM:** | | **Start T(mNm):** | **Formula** | | **Mtr RPM:** | 15594 |
| **Section 1:** | | 5600 | 17.8 | 0.001429 | | **Air Drag** | 0.375 |
| **Section 2:** | | 10300 | 9.8 | 0.00083 | | **Rolling R:** | 0.231 |
| **Section 3:** | | 24000 | 5.9 | 0.000431 | | **Mtr Torque:** | 3.620 |

**ABOVE IS SIMULATOR INPUT OUTPUT PANEL FOR PHOTON CRUNCHER MK IV USING AN ALUMINIUM DRIVE WHEEL WITH A TYRE.** **(Tyre used is “O” ring BS032 fitted in a groove 0.050 inch deep)**

## PARAMETERS ENTERED

**Car Name, Sun Power, and Motor Type**, identify the test conditions for future reference.

**Guide Roll CoEf** : Used to calculate the rolling resistance of the guide rollers.

**Mass**: The Mass of the car in kg.

**Wheel Roll RS**: Used to calculate the wheel rolling resistance on the track.

**Roll CoEf** : Used to calculate the wheel rolling resistance on the track. (in conjunction with Wheel Roll RS above)

**Air Drag Coefficient**: Used to calculate the air drag on the car.

**Wheel Diameter** : The drive wheel diameter in mm.

**Acceleration Gear Ratio**: This gear ratio will be used in the calculations until the nominated motor RPM (Change RPM) is reached . The Final Gear Ratio is used thereafter.

**Change RPM**: The motor RPM at which you nominate the gear change from the acceleration ratio to the Final Gear Ratio to take place.

**Final Gear Ratio**: This is the gear ratio used for the remainder of the race after the change RPM has been reached.

**Transmission Effy.**: The efficiency of your transmission system between the motor and the drive wheel , an efficiency of 95% would be entered as 95.

**Motor Torque**: Motor Torque vs RPM graph is treated as a graph with 3 straight line sections. The 3 Sections listed under this heading correspond to these 3 straight line sections.

**Wheel Slip Coefficient:** Used in calculating the maximum drive force the wheel can exert before wheel slip occurs.

**Steering (Yes/No):** This sets the additional drag force which occurs during cornering when there is no steering, either on or off.

**Steering Drag (N):** The amount of additional drag force in Newtons which occurs during cornering when the car has no steering.

**RESULTS DISPLAYED**

**Results are displayed for both a single and two lap race.**

**Time**: The total time in seconds taken for the car to complete the course. (Note a 90 second return for race time indicates the car has stopped. This occurs because simulator configuration will not allow a greater race time )

**Velocity**: The velocity of the car in Meters per Second as it crosses the finish line.

**Mtr RPM**: The motor RPM as the car crosses the finish line.

**Air Drag**: The air drag force in Newtons acting on the car as it crosses the finish line.

**Rolling R**: The rolling resistance in Newtons acting on the car as it crosses the finish line.

**Mtr. Torque**: The torque in mNm being produced by the motor as the car crosses the finish line.

# LEARNING TO USE THE SIMULATOR

Using the data as loaded in the simulator for PHOTON CRUNCHER MK IV at 88% Sun.
Run the simulator and make the changes suggested below.

1 EFFECT OF CAR MASS:

Run the simulator as supplied and note the race time.
Run the simulator with car mass increased and decreased by say 500gm.
Note the race time.

2 EFFECT OF AERODYNAMICS:

Run the simulator as supplied and note race time and air drag at end of race.
Run the simulator with the Air Drag Coefficient doubled.
Note the race time and Air Drag at end of race.
COMPARE THESE TWO SETS OF RESULTS.
THIS SHOWS THE EFFECT OF DOUBLING FRONTAL AREA
(Improving the cars shape can also significantly lower the air drag )

3 EFFECT OF STEERING:

Run the simulator as supplied and note the race time.
Run the simulator with steering turned on, note the race time.
Consider the differences in race time.
(remember changing car Mass will change steering drag)

4 EFFECT OF WHEEL DIAMETER & GEAR RATIO:

Run the simulator as supplied and note race time.

Change wheel diameter by say 20mm up and down, note race time changes.

At each wheel diameter you run in the simulator change the gear ratio up and down to obtain the best time.

Note the best race time and compare results.

5 EFFECT OF SUN LEVEL:

Run the simulator as supplied and note race time.

Change the motor data to that for a different sun level.

Note race time, change gear ratios to obtain best race time.

6 EFFECT OF ELECTRONICS:

Run the simulator with motor data at a selected Sun level with and without electronics, changing gear ratios to obtain best race time. Motor data without electronics is provided for the Solar Panel of 10 Dick Smith segments in attachment 1.

Particularly conduct this test at low Sun levels.

7 EFFECT OF TYRE:

Run the simulator with parameters for a car with a tyre and without.

NOTE: at high sun levels the additional drag caused by a tyre is compensated for by better wheel grip and reduced wheel spin on initial take off.

**NOW YOU HAVE GAINED AN INSIGHT INTO THE SIMULATORS OPERATION START USING IT TO DESIGN YOUR CAR.**

**There are 2 attachments to this document: (Both are included in Design Hints)**
**Dynamometer test results.**
**Photographs of cars with their air drag coefficients.**

## ATTACHMENT 1

# DYNAMOMETER TEST RESULTS --- GENERIC 8/06

Extensive testing of different ELECTRONICS systems for Model Solar Cars has indicated that there is only a small difference between them in terms of motor output so long as they are correctly adjusted according to the manufacturers instructions.
NOTE: This testing has been conducted with a FAULHABER 2232 6 VOLT motor , using both Dick Smith Segments and Solarex SX10 Solar Panels.
Results for other combinations are unknown but we suspect they will be similar.

Based on the above tests the following tables of motor output for various solar panels has been assembled.
The intent was to produce a set of tables giving motor output data that can be inputted to the Mathematical Simulator allowing initial predictions of car performance to be made without having to perform motor tests.
For more accurate predictions of performance you **MUST** have test results that are **specific to your particular motor and solar panel**. Just as **you MUST have tested your car** to obtain the other parameters such as rolling resistance etc. if you want the best possible accuracy in your predictions.

**ELECTRONICS UNITS TESTED:**

**ENGELEC MAX 4**

**NEW MODIFIED "WOITHE" (SCORPIO)**

With bobbin type inductor and new input and output low ESR capacitors.

**BOX HILL HIGH SCHOOL**

V 2

V 4.1 Programme 1.6

## RESULTS FOR SOLAREX SX 10 PANEL: (9.8 W at 100% Sun)

| PANEL ISC | SUN % | SECTION 1 START TORQUE | SECTION 1 FINISH RPM | SECTION 2 START TORQUE | SECTION 2 FINISH RPM | SECTION 3 START TORQUE | SECTION 3 FINISH RPM |
|---|---|---|---|---|---|---|---|
| 600 | 88 | 17.8 | 5600 | 9.8 | 10300 | 5.9 | 24000 |
| 500 | 74 | 16.6 | 4800 | 9.0 | 10300 | 4.8 | 24000 |
| 400 | 59 | 15.1 | 4200 | 8.0 | 9600 | 3.8 | 23500 |
| 300 | 44 | 12.5 | 4900 | 5.0 | 10200 | 2.4 | 23500 |
| 200 | 28 | 10.0 | 2600 | 5.0 | 7200 | 2.0 | 18000 |
| 100 | 14 | 5.4 | 1500 | 2.8 | 6100 | 0.8 | 12000 |

## RESULTS FOR 9 DICK SMITH SEGMENTS:
**(6.16 W at 100% Sun)**

| PANEL ISC | SUN % | SECTION 1 START TORQUE | SECTION 1 FINISH RPM | SECTION 2 START TORQUE | SECTION 2 FINISH RPM | SECTION 3 START TORQUE | SECTION 3 FINISH RPM |
|---|---|---|---|---|---|---|---|
| 450 | 80 | 15.3 | 3600 | 8.4 | 9000 | 4.2 | 18200 |
| 280 | 50 | 12.0 | 5000 | 4.5 | 10300 | 2.1 | 17200 |
| 110 | 20 | 7.2 | 2900 | 2.6 | 9200 | 0.6 | 15200 |

## RESULTS FOR 10 DICK SMITH SEGMENTS:
**(6.86 W at 100% Sun)**

| PANEL ISC | SUN % | SECTION 1 START TORQUE | SECTION 1 FINISH RPM | SECTION 2 START TORQUE | SECTION 2 FINISH RPM | SECTION 3 START TORQUE | SECTION 3 FINISH RPM |
|---|---|---|---|---|---|---|---|
| 450 | 80 | 16.0 | 7500 | 6.0 | 16500 | 2.5 | 20500 |
| | | 3.6 | 10000 | 3.0 | 16500 | 2.6 | 20500 |
| 280 | 50 | 12.5 | 8500 | 3.0 | 16600 | 1.0 | 19500 |
| | | 2.3 | 10000 | 1.7 | 16500 | 1.2 | 19500 |
| 110 | 20 | 6.5 | 4000 | 2.0 | 11000 | 0.5 | 16200 |
| | | 0.9 | 5000 | 0.7 | 10500 | 0.65 | 16200 |

Figures in RED are for NO Electronics.

## RESULTS FOR 11 DICK SMITH SEGMENTS:
**(7.56 W at 100% Sun)**

| PANEL ISC | SUN % | SECTION 1 START TORQUE | SECTION 1 FINISH RPM | SECTION 2 START TORQUE | SECTION 2 FINISH RPM | SECTION 3 START TORQUE | SECTION 3 FINISH RPM |
|---|---|---|---|---|---|---|---|
| 450 | 80 | 16.0 | 7500 | 6.0 | 18000 | 2.0 | 22200 |
| 280 | 50 | 13.5 | 6300 | 4.0 | 19000 | 1.0 | 21500 |
| 110 | 20 | 8.0 | 3500 | 2.0 | 13000 | 0.6 | 16800 |

## RESULTS FOR 12 DICK SMITH SEGMENTS:
**(8.26 W at 100% Sun)**

| PANEL ISC | SUN % | SECTION 1 START TORQUE | SECTION 1 FINISH RPM | SECTION 2 START TORQUE | SECTION 2 FINISH RPM | SECTION 3 START TORQUE | SECTION 3 FINISH RPM |
|---|---|---|---|---|---|---|---|
| 450 | 80 | 18.0 | 9000 | 5.0 | 20000 | 2.0 | 23500 |
| 280 | 50 | 14.5 | 8000 | 4.5 | 19500 | 1.0 | 22500 |
| 110 | 20 | 8.0 | 5000 | 2.0 | 12000 | 0.6 | 16500 |

## ATTACHMENT 2

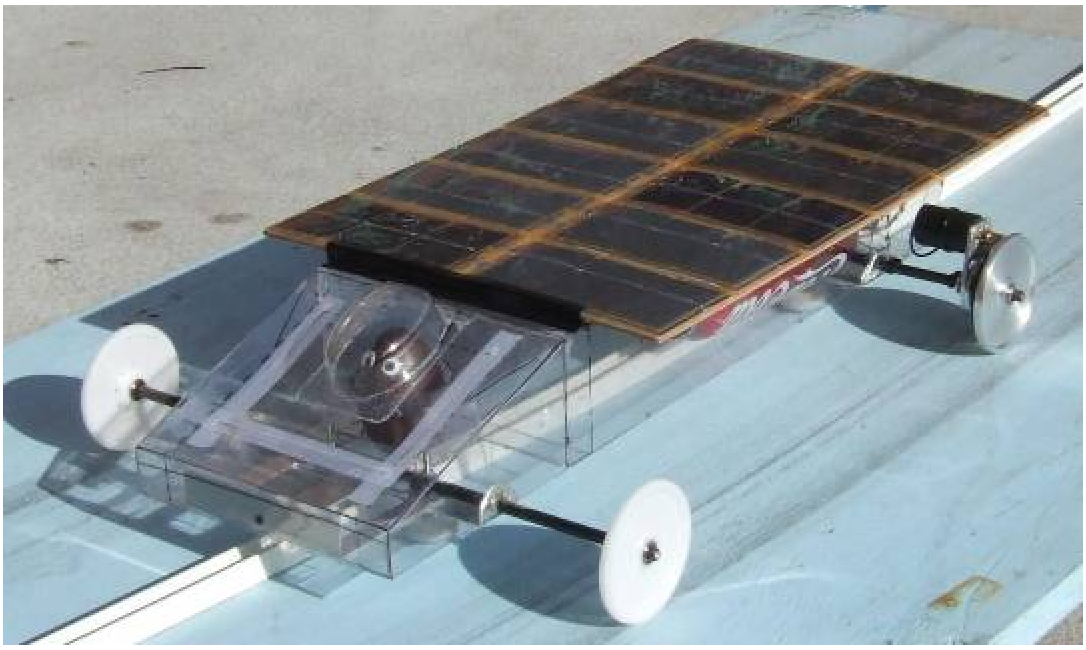
# AIR DRAG COEFFICIENT

NOTE: You MUST do wind tunnel testing of your car to determine its drag coefficient. (Values in the order of 0.03 for a flat plate of 200 cm square to 0.003 for a low drag aerofoil shape of 200 cm square would be typical.)

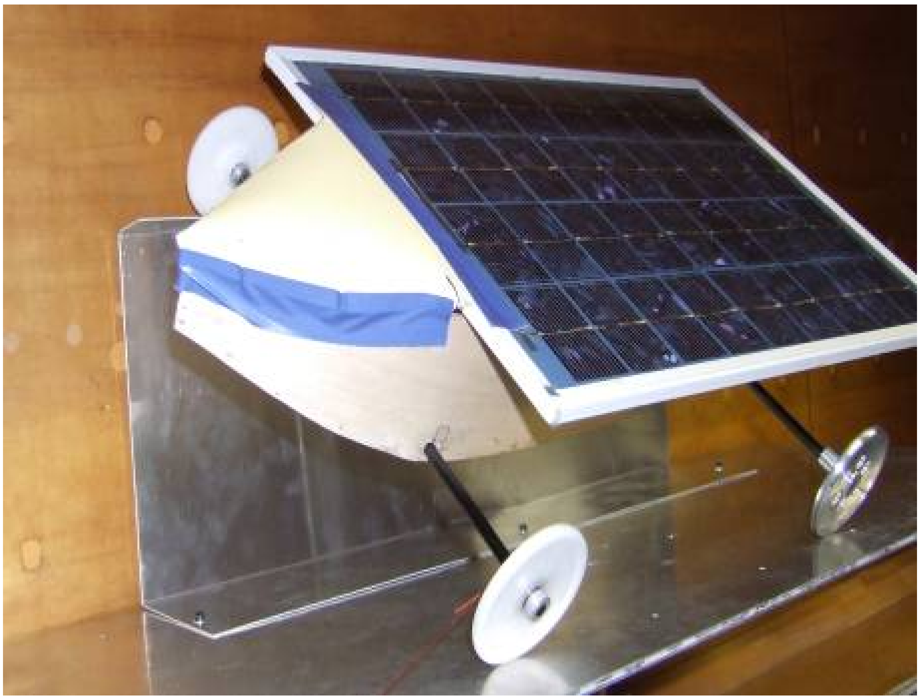
If you cannot perform wind tunnel testing you can make an estimation of drag coefficient by taking the 0.03 drag coefficient for a flat plate of 200 cm square and calculate the drag coefficient for your car with a simple ratio calculation based on your cars frontal area compared to the 200 cm square.
This will give a worst case drag figure as it is based on a flat plate.
As a help to determining your drag ratios some drag ratios of actual cars that have been tested in a wind tunnel are given below.

**CAUTION:** The air drag coefficients listed here are not cd values or Drag Coefficient values as normally seen. They are derived from testing of a particular car and the coefficient includes cd values as well as frontal area and air density all rolled into the one coefficient. Consequently we cannot compare the aerodynamic performance of different cars without considering their frontal area.

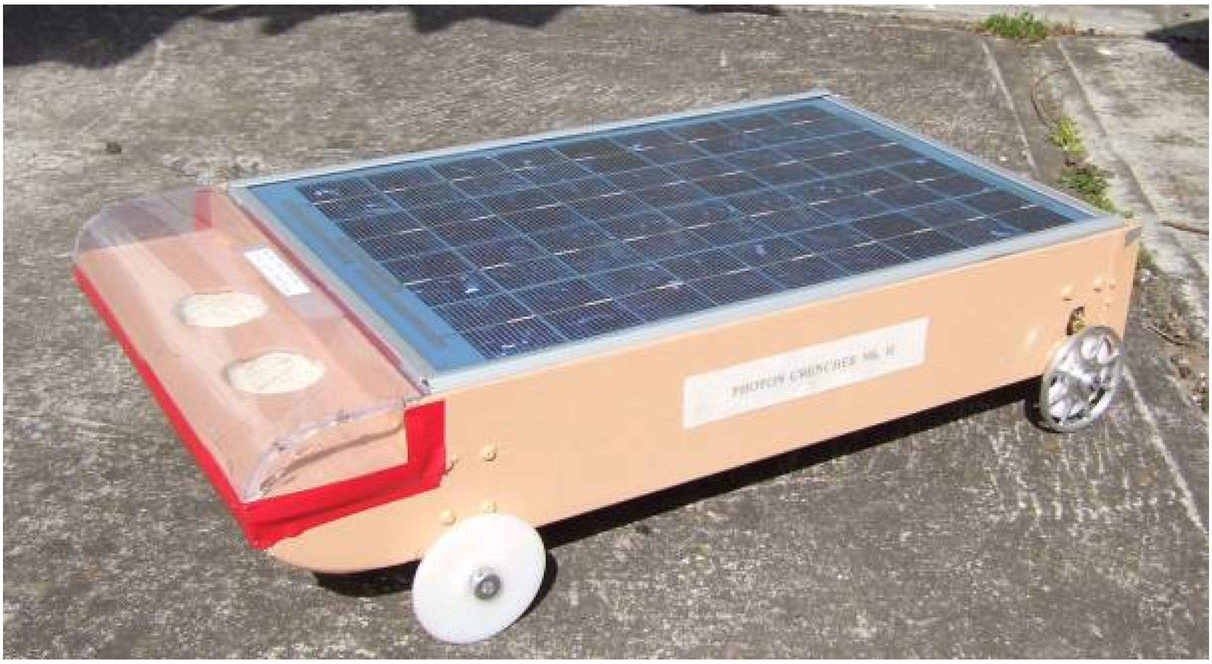
PHOTON CRUNCHER MK IV : SIMULATOR AIR DRAG COEFFICIENT 0.007



PHOTON CRUNCHER MK V :  SIMULATOR AIR DRAG COEFFICIENT 0.0045



SYNDAL SOUTH 2006  CAR :  SIMULATOR AIR DRAG COEFFICIENT 0.0045



PHOTON CRUNCHER MK II : SIMULATOR AIR DRAG COEFFICIENT 0.012
(Note:This car designed to meet the 200 sq.cm. transverse panel requirement.)

ENIGMA : SIMULATOR AIR DRAG COEFFICIENT 0.012
(Note:This car designed to meet the 200 sq.cm. transverse panel requirement.)

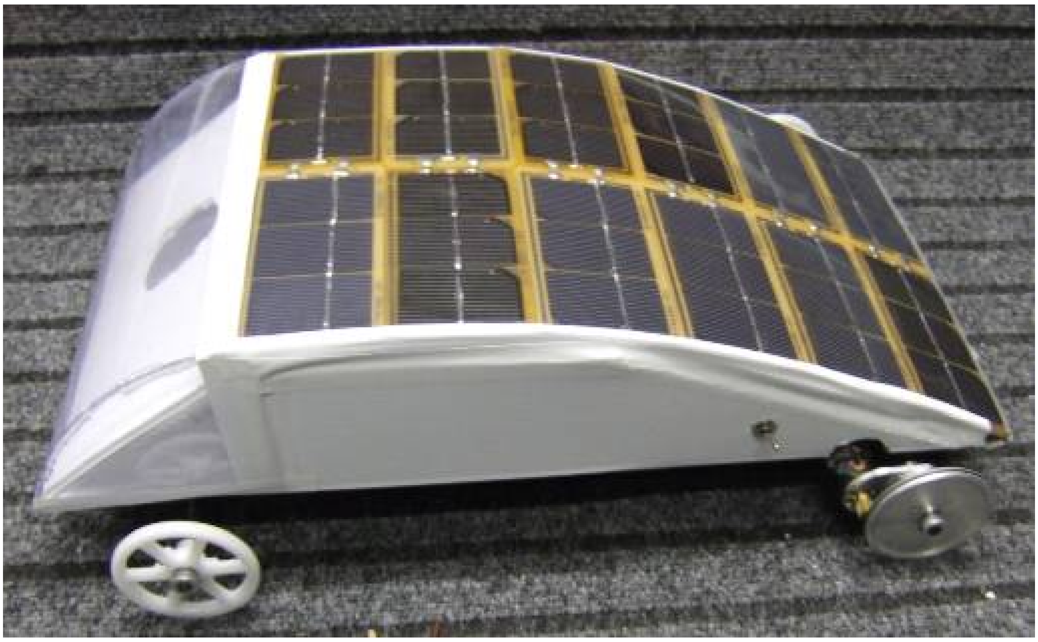

HELIOS : SIMULATOR AIR DRAG COEFFICIENT 0.004
(Note:This car designed to meet the 200 sq.cm. transverse panel requirement.)


CARBO TRUDIS: SIMULATOR AIR DRAG COEFFICIENT 0.0039

# EFFECT OF WHELLS AND GUIDES ON DRAG

In order to show how important apparently small items can be when it comes to air drag, wind tunnel tests were carried out on a car to evaluate the effect exposed motor, wheels and guides has on air drag. A sample car made for workshop demonstrations was tested as a body only then as a complete car. Please note the chassis is that from PC IV so is shown in detail in the Design Hints.
NOTE: This car was designed to meet the transverse milk carton regulation.

BODY ONLY : SIMULATOR AIR DRAG COEFFICIENT 0.0035



COMPLETE CAR : SIMULATOR AIR DRAG COEFFICIENT 0.008

CHASSIS ONLY (SHOWN HERE STILL ATTACHED TO CAR)
: SIMULATOR AIR DRAG COEFFICIENT 0.0045