ChassisSim
The Winner's Edge

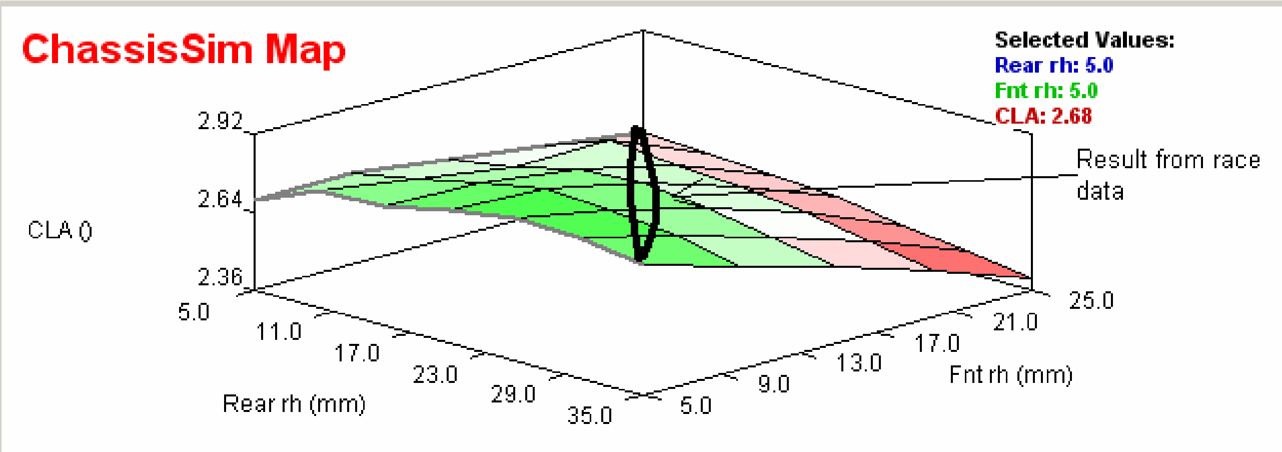
ChassisSim – Creating an aero model.

One of the most powerful features of ChassisSim is its ability to use data to create an aeromap. This has been used to great effect in a number of different formula and is an essential step in modelling your race car.

The purpose of this document is to walk you through step by step what you need to do to create an aeromap and how this can be implemented using ChassisSim.

Step 1 – Generating a thin sliver of the aeromap from race data

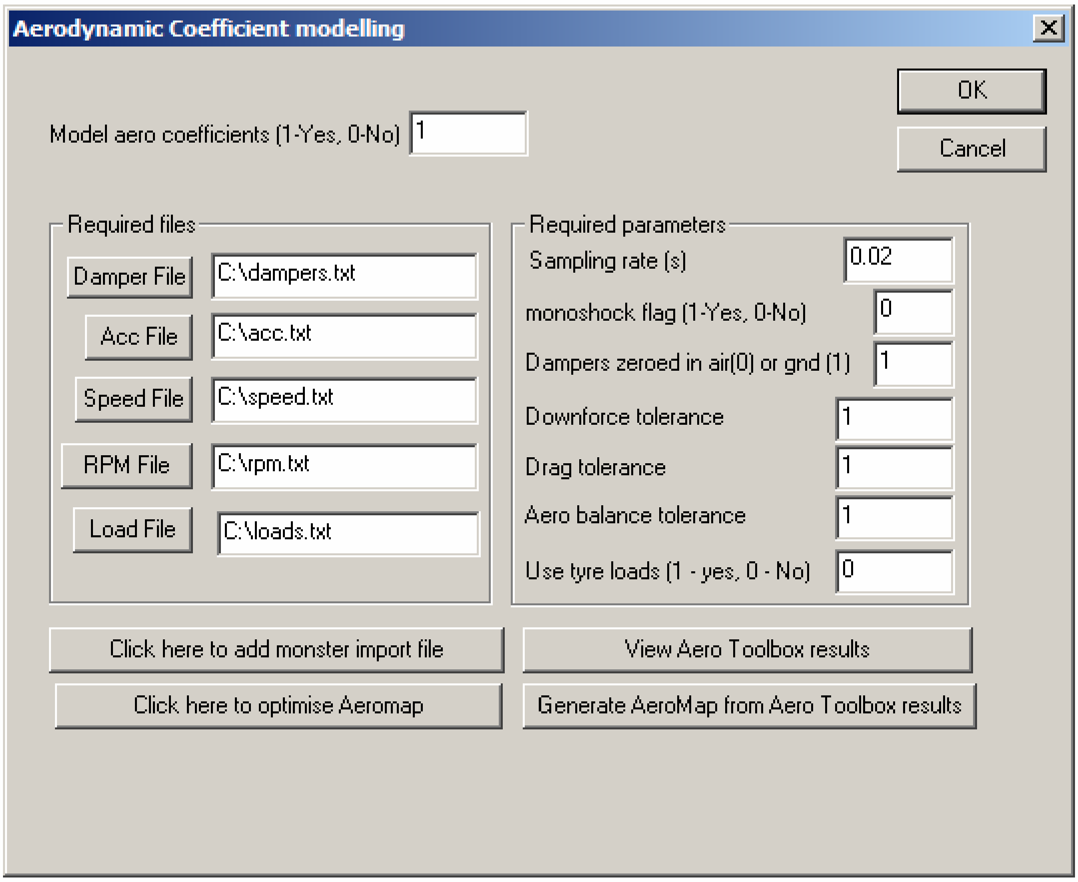
As the car is driven around the circuit it will return a thin sliver of the aeromap. This is illustrated below,



Unfortunately it is very difficult to determine the whole aeromap from this thin sliver. Mathematically it is impossible. However if you put enough of these thin slivers together an aeromap can be generated. Fortunately with the ChassisSim aero toolbox you can do both.

To generate this sliver you need the monster file and you need to load the car file that represents the setup that the monster file came from. To access what you need to do is Select Simulate->AeroModelling. This will bring up the following dialog.

ABN 3517 202 936 9
ChassisSim Technologies™
9 Harriet Street Marrickville
NSW 2204 Australia
Danny Nowlan, Director mobile: +61 425 219 375



Click on the tab that says import the monster import file. If it has loads click on the checkbox first and then import the monster file. Indicate if you want to use loads, indicate if the loads and dampers are zeroed on the ground, and click to 1 to model the aero coefficients. Also if the car is a monoshock – but you are importing the monster file – ensure the monoshock flag is set to 0. Then click OK

Once you have clicked on OK the ChassisSim simulation window should start. When it is finished the average C_LA, C_DA and aero balance will be displayed for this data as well as the standard deviations for this data. This will also generate a file called aero_analysis_results.dat. This will be in the same directory as the car file. Its format will be,

Front ride height (m), Rear ride height (m) C_LA, C_DA, aero balance/100

This is an ascii file.

Rename this file to an appropriate name such as aero_analysis_results_run1.dat. Congratulations you have just deduced the sliver of the aeromap for this run.

ABN 3517 202 936 9
ChassisSim Technologies™
9 Harriet Street Marrickville
NSW 2204 Australia
Danny Nowlan, Director mobile: +61 425 219 375

Aero test procedure

As we discussed before we need a number of these thin slivers and some wing sweeps to construct an aeromap. However the test matrix you need to perform is not as complicated as you would think. An example of the test matrix you need to perform is shown below in Table 1

Table – 1 Aero test procedure for a Sportscar

Run No	Setup
1	frh_0 and rrh_0 + baseline rear wing
2	frh_0 and rrh_0 + d_rrh + baseline rear wing
3	frh_0 and rrh_0 + 2*d_rrh + baseline rear wing
4	frh_0 and rrh_0 + 3*d_rrh + baseline rear wing
5	frh_0 – d_rrh and rrh_0 + baseline rear wing
6	frh_0 + d_rrh and rrh_0 + baseline rear wing
7	frh_0 and rrh_0 + baseline rear wing
8	frh_0 and rrh_0 + baseline rear wing + 2 holes
9	frh_0 and rrh_0 + baseline rear wing + 3 holes

Just to clarify the nomenclature we have,

frh_0 = Baseline front ride height as specified in the starting setup.
rrh_0 = Baseline front ride height as specified in the starting setup.
d_rrh = delta rear ride height.
d_frh = delta front ride height.

The delta's you choose will depend on what the race car. For example for an open wheeler/Sportscar these might only be in the order of 2mm. For a touring car these deltas might be in the order of 5mm. As a rough rule of thumb choose the delta where you know it will have an effect on the car. The goal of tests 1 – 6 is to establish the pitch sensitivity map. The goal of tests 7 – 9 is to asses the variation in downforce levels.

Also bear in mind if the aero configurations vary considerably, for example the difference between high, medium and low downforce packages on say an F3 car, the tests in Table 1 will have to be repeated. However I will say if you get stuck you can stretch the results from one configuration. It's not ideal but it will get you by. Also make sure the baseline you choose represents your current running configuration. This way you are modelling what you are running.

Generating the Pitch sensitivity map

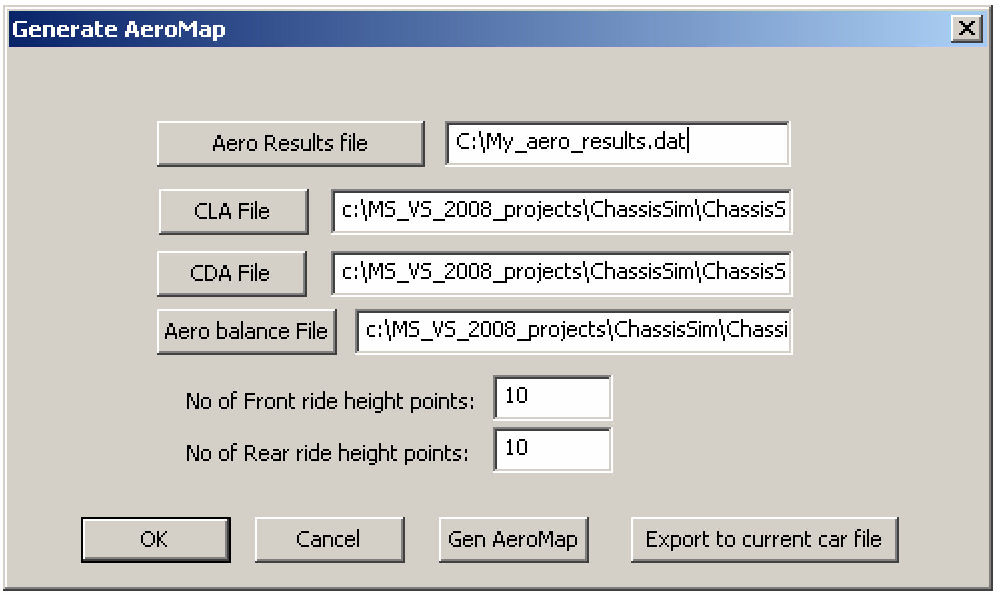
Taking our test procedure in Table – 1 all we need to do is to run the aero toolbox to generate a thin sliver of the aeromap from Tests 1 – 6. Once we have this we are now in a position to generate the aeromap. Also it goes without saying that each time you run the tests, you

ABN 3517 202 936 9
ChassisSim Technologies™
9 Harriet Street Marrickville
NSW 2204 Australia
Danny Nowlan, Director mobile: +61 425 219 375

change the ride heights and rename the aero_analysis_results.dat file! I speak from experience on this one.

Once you have generated these files the next step is to generate these in a larger aero_analysis_results file that combine all the results. All you do is create a blank notepad file and simply copy and paste the results of all the runs into this file and save it. You can call it what you want but for this illustration let's call it My_aero_results.txt.

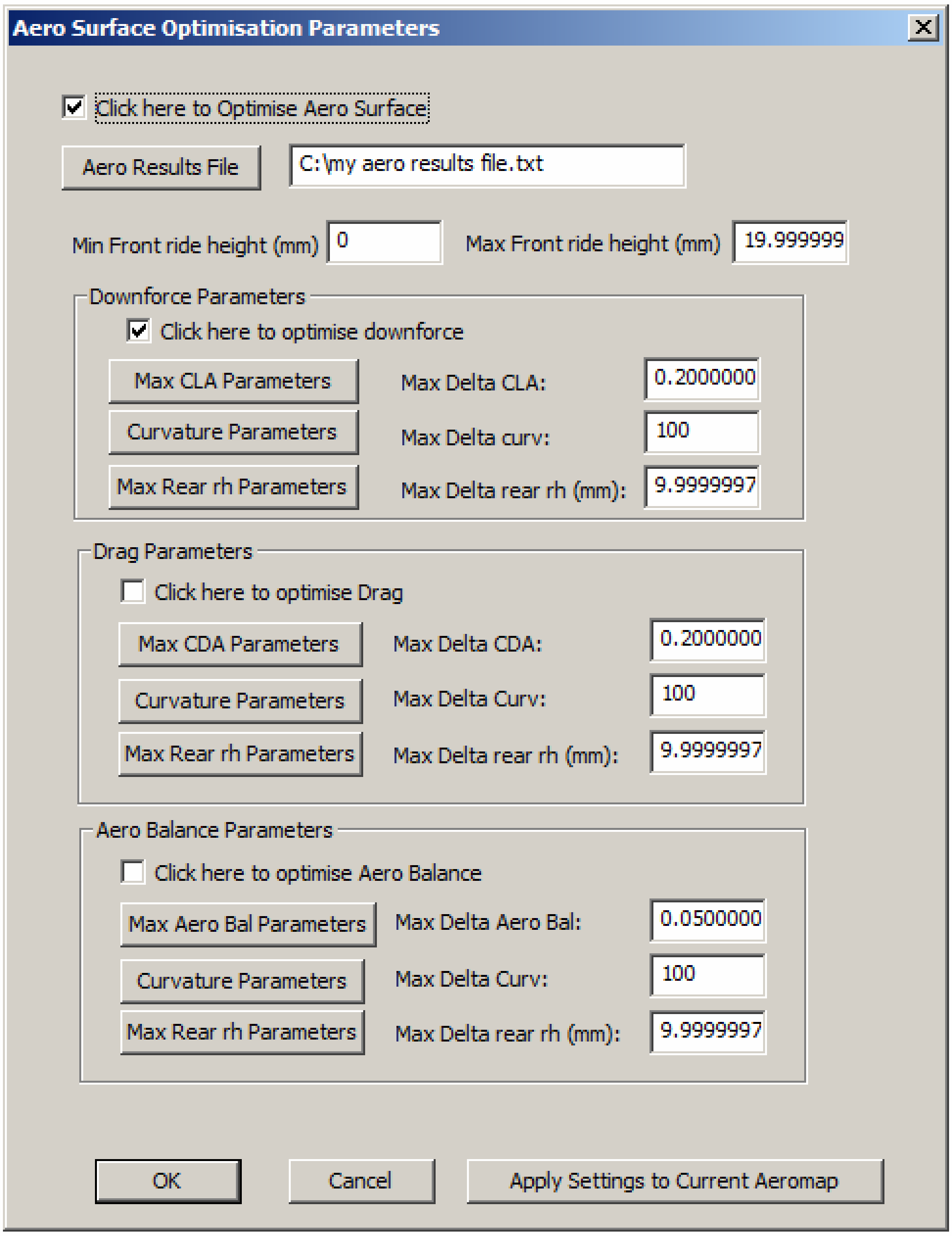
Once you have this file you are ready to create the aeromap and o do this you have two options. The first option is to click on the tab that says Generate AeroMap from Aero Toolbox results. This will bring up the following dialog,



You have the option to generate separate C_LA, C_DA and aero balance files for your inspection. This will show you the ride heights and the results. However you can't import these straight into the aeromaping dialog when you edit the aeromaps. These have been supplied for sanity checking. However you can export this straight to the current car file by clicking on the tab that says Export to current car. When you click on this will update the car file with all aspects of the generated aeromap. This is the ideal method when you are confident in your race data.

The other option is to use the Aero surface optimisation feature. To activate click on the tab that says Click here to optimise Aeromap. This will display the following dialog overleaf.

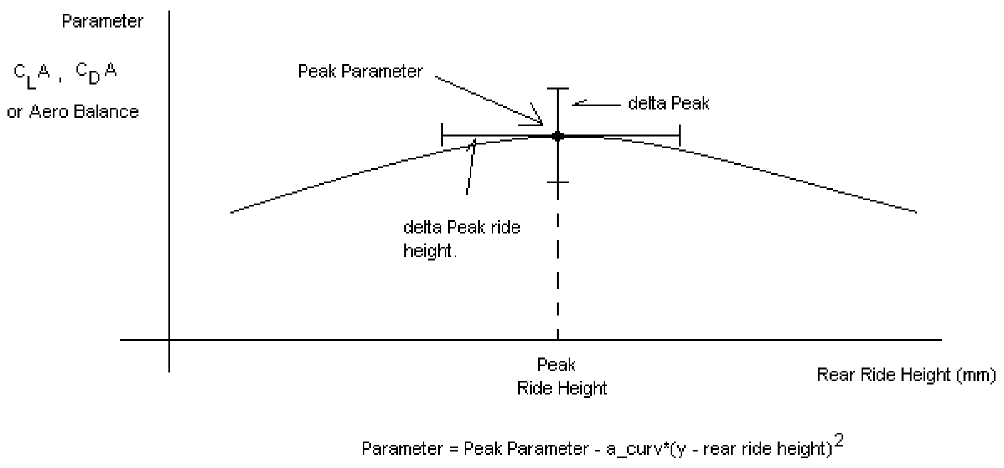
ABN 3517 202 936 9
ChassisSim Technologies™
9 Harriet Street Marrickville
NSW 2204 Australia
Danny Nowlan, Director mobile: +61 425 219 375



The way this works is it treats the aeromap by splitting it up into front ride height slices. For each slice it is optimising the following equation,

The crux of this technique is illustrated in the figure below,

ABN 3517 202 936 9
ChassisSim Technologies™
9 Harriet Street Marrickville
NSW 2204 Australia
Danny Nowlan, Director mobile: +61 425 219 375



As can be seen what we are doing is breaking up the aeromap into front ride height sections. For each of these front ride height sections the following Parameter curve applies. What it says is at any given front ride height, the parameter whether it be drag, downforce or drag is given by whatever the peak value is at that front ride height minus the curvature value multiplied by the difference between the current rear ride height and the ride height at which the peak occurs. The bigger the curvature value is the more it drops off and vice versa.

It is the user's job to enter the appropriate values for their race car. The peak is controlled in the Max CLA Parameters, or CDA Parameters or Aero Balance Parameters Tab depending on what they are editing.. This brings up a 2D graphic where the user clicks on the control and edits the values. The same applies for the curvature values and the peak ride height values. The appropriate delta values are written in the edit controls next to the tab. As can also be seen the user can select which map they want to select.

Then the user specifies the front ride height bounds they wish the map fitted from. To optimise the aeromap click, on the appropriate tab. They then select OK. To start the optimisation the user clicks on the Start button on the main window or Simulate->Simulate. Click on Start simulation and go get a coffee. When it is completed the following files will be produced in the same directory as the car file,
CLA_table.txt - Downforce results.
CDA_table.txt - Drag results.
AB_table.txt - Aero balance results.
These can be viewed in Standard mode, by clicking on the front wing and clicking on the relevant map and using the tab Import file on the 3D map viewer.

Here are some general pointers about what technique to use,

- If you have no idea about what the aeromap looks, the aero surface optimisation will give you a good initial picture.

- If you are confident in your experimental results the 2nd order surface fit will give you very good correlation very quickly.

Obviously these results will vary from car to car but these are good pointers to get you going. It also goes without saying to double check the results.

Once you are happy with these results note the maximum C_LA, C_DA of this map, click on the rear wing and enter these values in the rear wing. Also ensure the aero balance offset is set to 0.

Quantifying different wing levels

Once the aeromap has been created our goal is to quantify the different aero levels. The first step in this process is to note the maximum C_LA, C_DA of the current map, and the average C_LA, C_DA and average aero balance returned by running the aero toolbox in step 1. This is important because it will form our baseline. To clarify our nomenclature let's call the maximum C_LA, C_DA of our baseline map C_LA_{MAX}_bline and C_DA_{MAX}_bline respectively. We'll call the results returned by the aero toolbox C_LA_bline, C_DA_bline and ab_bline.

So to quantify a wing change simply take the monster file from say Step 7 and run it through the aero toolbox. This will return the average values of downforce, drag and aero balance for this configuration. For illustration let's call this C_LA_new, C_DA_new and ab_new. So the values that will be applied for the rear wing are the following,

$$C_L A_{MAX}\_new = C_L A_{MAX}\_bline + (C_L A\_new - C_L A\_bline)$$
$$C_D A_{MAX}\_new = C_D A_{MAX}\_bline + (C_D A\_new - C_D A\_bline)$$
$$ab\_offset = (ab\_new - ab\_bline)/100$$

The values in this equation are what you enter in the rear wing of ChassisSim. It is highly advised that you enter this in an excel spread sheet for quick reference. It should look something like Table – 2

Table-2 – Example Database of what you enter in ChassisSim

Wing configuration	C_LA_{MAX}	C_DA_{MAX}	Ab_offset
Baseline	3.7	1.2	0
Rear wing + 2holes	3.72	1.22	-0.02
Rear wing + 3 holes	3.73	1.23	-0.04

ABN 3517 202 936 9
ChassisSim Technologies™
9 Harriet Street Marrickville
NSW 2204 Australia
Danny Nowlan, Director mobile: +61 425 219 375

Conclusion

As can be seen generating an aeromap is not as intimidating as you would think. The building block is understanding the aero toolbox returns a thin sliver of the aeromap. Once this is understood the next step is to define the aero test matrix and perform the test. Remember if the aero configurations are significantly different the ride height and wing sweeps will need to be repeated. However if resources are tight then the baseline results can be extended.

The next step in the process is to construct the pitch sensitivity map. This is taken from the ride height results, running the aero toolbox for each of these files, and combining all the results into a big file. Lastly the aeromap can be deduced using the 2D polynomial fit or the aero surface fitting. The maximum value of these maps should be noted.

To finish the process off you run the aero toolbox for each of the wing changes. These are then compared to the baseline and the changes you need to put into ChassisSim can be readily quantified. Once you are at this point you have an aeromap that can be used in anger.

ABN 3517 202 936 9
ChassisSim Technologies™
9 Harriet Street Marrickville
NSW 2204 Australia
Danny Nowlan, Director mobile: +61 425 219 375