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X-PD LAPSIM - VEHICLE LAP SIMULATION TOOLS:

'X-PD LapSIM' is a vehicle simulation toolbox comprising a suite of software components which can be used for the detailed analysis of vehicle performance over a defined vehicle path.

Utilising a comprehensive, non-linear multi-mass vehicle model described by over 200 parameters & characteristic arrays it can be used to simulate and subsequently characterize a road or competition vehicles performance over a defined path in the virtual test environment.. Using the tools described it is, for example, possible to.....

- Analyse new vehicle designs
- Evaluate suspension setup changes
- Establish optimum aerodynamic configurations
- Test the effect of gearbox setup
- Analyse tyre characteristic & performance
- Compare alternative drivetrain/power profiles
- Review effects of environmental variables
- Predict performance at new circuits

The LapSIM software suite utilises four main components;

- **X-PD Vehicle Tool:**
  - The Vehicle Tool is used for construction of the vehicle description and for detailed parameter setting.
- **X-PD Circuit Tool:**
  - The Circuit Tool is used for the construction of the circuit path and geometry to be used in the lap simulation.
- **X-PD LapSIM Solver:**
  - The solver is the heart of the simulation toolbox and is used for implementing the lap solution.
- **X-PD Data Analysis Export:**
  - The Data Export facility allows advanced users to review simulation data in industry standard packages.

X-PD LapSIM Tools Main Components:

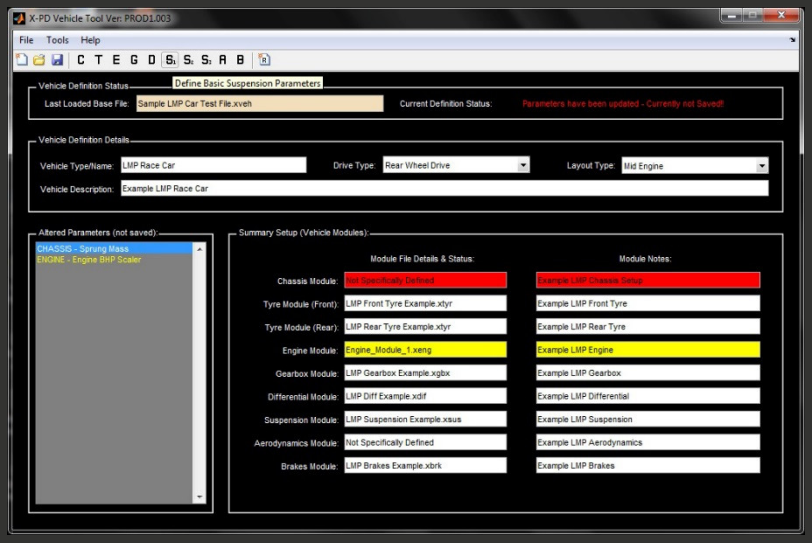
X-PD Vehicle Tool:

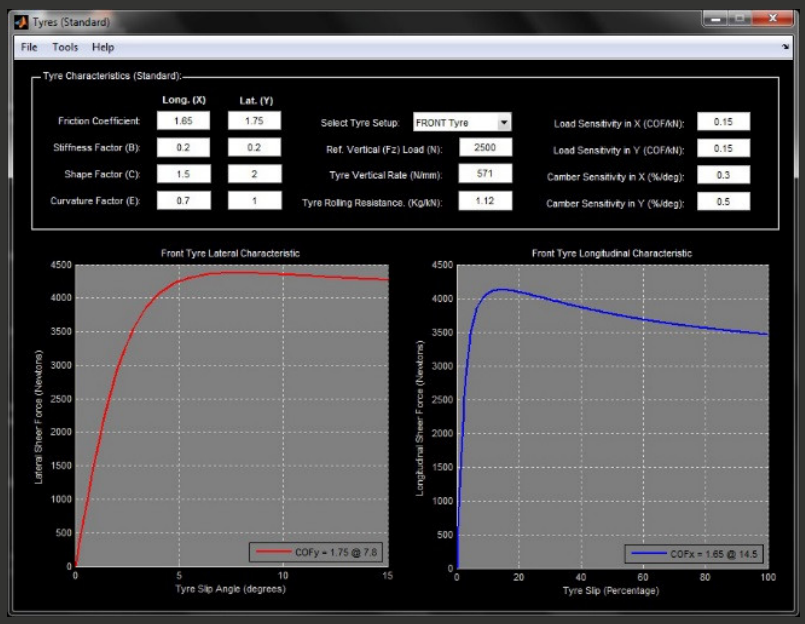
The vehicle tool is used for building the vehicle definition; the software covers all areas of the car including chassis, engine, gearbox, differential, aerodynamics, suspension and brakes.

Each of these vehicle areas are set out as separate vehicle 'modules' which can be individually saved and loaded into the application.

Once the vehicle has been constructed from its constituent modules it can be saved as an assembled complete vehicle file for use in the LapSIM Solver.

One of the advantages of the modular approach to building the vehicle is the flexibility for file and hence analysis management.





The vehicle definition is comprehensive for advanced users, for example it includes a non-linear tyre model which is based on Pacejkas 'Magic Formula' construction.

Tyre characteristics for both longitudinal and lateral slip are set for the front and rear axles with variable load sensitivity, camber effects and a range of coefficients for describing the nature of the characteristic curves.

The tyre modeling allows the user to either generate a tyre characteristic from scratch in the absence of any manufacturer or measured data or to use a base Pacejka model.

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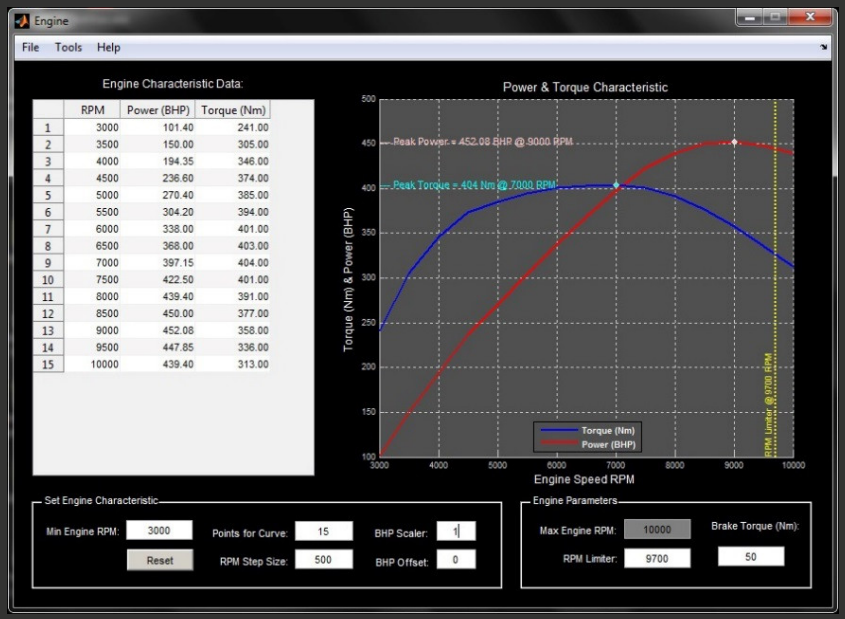
The suspension and steering model is fully configurable to represent a range of layouts and different types of modern vehicle.

Because of the large number of parameters used to define the suspension the definition is split into three sub-modules, these are grouped into one module when loading and saving a suspension system file in the vehicle definition.

Many of the geometry aspects are optionally available as ride height or wheel displacement dependent characteristics to account for substantially non-linear geometries or complex layouts (for example cambers, motion ratios, roll-centre and 'anti' geometry).

Suspension setup also allows for non-linear bump rubber characteristics, third (heave) spring and bump rubber installations (with the ability to set variable gaps and preload) and suspension compliances.

The engine module allows the definition of the powertrain performance characteristic in a user specified resolution.



The module also allows data to be imported from excel and further adjusted through the user interface.

The software uses the power characteristic vs RPM as an input and calculates the torque produced. The peak power and torque are depicted on the characteristic plot. The rpm limiter and engine braking torque can also be specifically set.

As with all the vehicle modules an engine file can be individually saved and loaded into the vehicle, notes can also be added to all the module files for reference.

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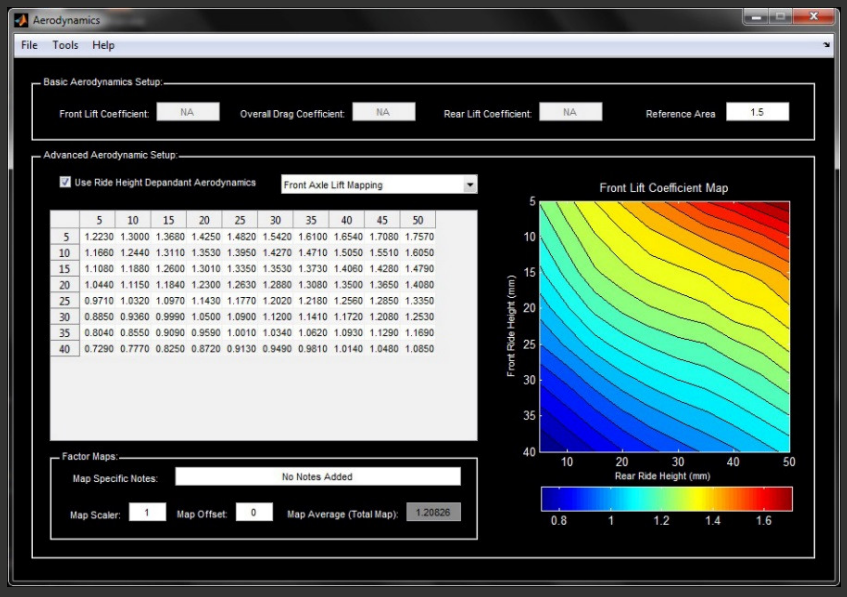
The vehicle gearbox is configurable for number of gears, shift times, final drive and drop ratios, shift rpms in each gear and internal power losses. RPM drops and maximum speeds in each gear are calculated and displayed.

In addition it is possible to implement a CVT if required to take the gearbox performance aspect out of any specific analysis or for special vehicles.

The gearbox module can be loaded with a bespoke ratio list, the user can make up this list of available ratios which can then be selected from the drop down for each gear. Multiple lists can be produced which can then be loaded into any vehicle definition or gearbox module.

The aerodynamics module allows the user to define either a basic set of fixed drag and lift (downforce) coefficients for the vehicle or a set of ride-height dependent aero maps.



	5	10	15	20	25	30	35	40	45	50
5	1.2230	1.3000	1.3680	1.4250	1.4820	1.5420	1.6100	1.6540	1.7080	1.7570
10	1.1660	1.2440	1.3110	1.3530	1.3950	1.4270	1.4710	1.5050	1.5510	1.6050
15	1.1080	1.1880	1.2600	1.3010	1.3350	1.3530	1.3730	1.4060	1.4280	1.4790
20	1.0440	1.1150	1.1840	1.2300	1.2630	1.2880	1.3080	1.3500	1.3650	1.4080
25	0.9710	1.0320	1.0970	1.1430	1.1770	1.2020	1.2180	1.2560	1.2850	1.3350
30	0.8850	0.9360	0.9990	1.0500	1.0900	1.1200	1.1410	1.1720	1.2080	1.2530
35	0.8040	0.8550	0.9090	0.9590	1.0010	1.0340	1.0620	1.0930	1.1290	1.1690
40	0.7290	0.7770	0.8250	0.8720	0.9130	0.9490	0.9810	1.0140	1.0480	1.0850

The maps can be created in user-defined resolution, to suit the available data. Data can also be imported from excel and scaled or offset.

Maps for front axle, rear axle and overall drag as well as individual data points are editable for fine tuning a specific map.

The map itself is displayed both in terms of data point values and as a graphical 'carpet'. Notes can be added to the maps and the module as a whole for reference purposes.

In addition to those examples described the vehicle tool also has modules for chassis (masses, lengths, relevant inertia etc), braking system and differential.

The software has a straightforward interface with visual indications for the state of both the whole vehicle definition (if saved, what parameters have changed etc.) and the individual sub-modules (if saved into the whole vehicle file, as individual modules, if they have been changed etc).

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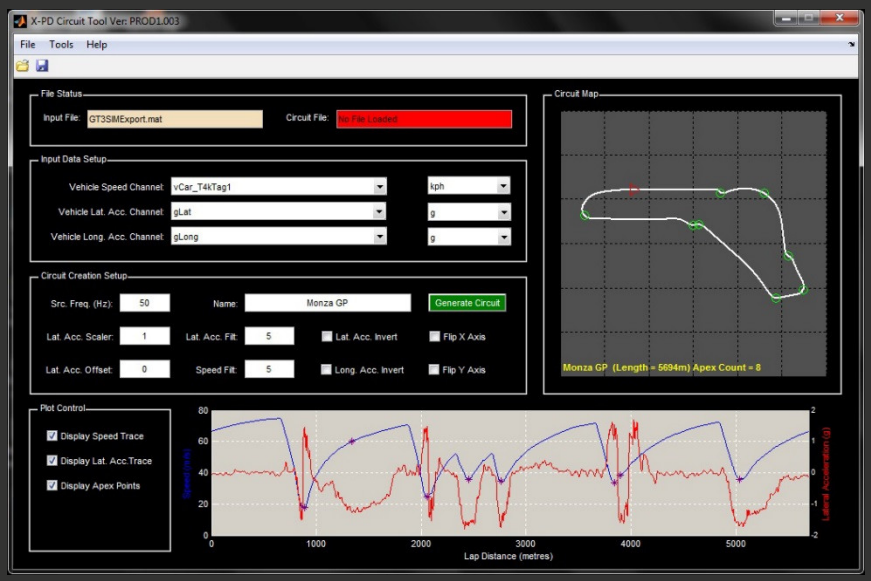
X-PD Circuit Tool:

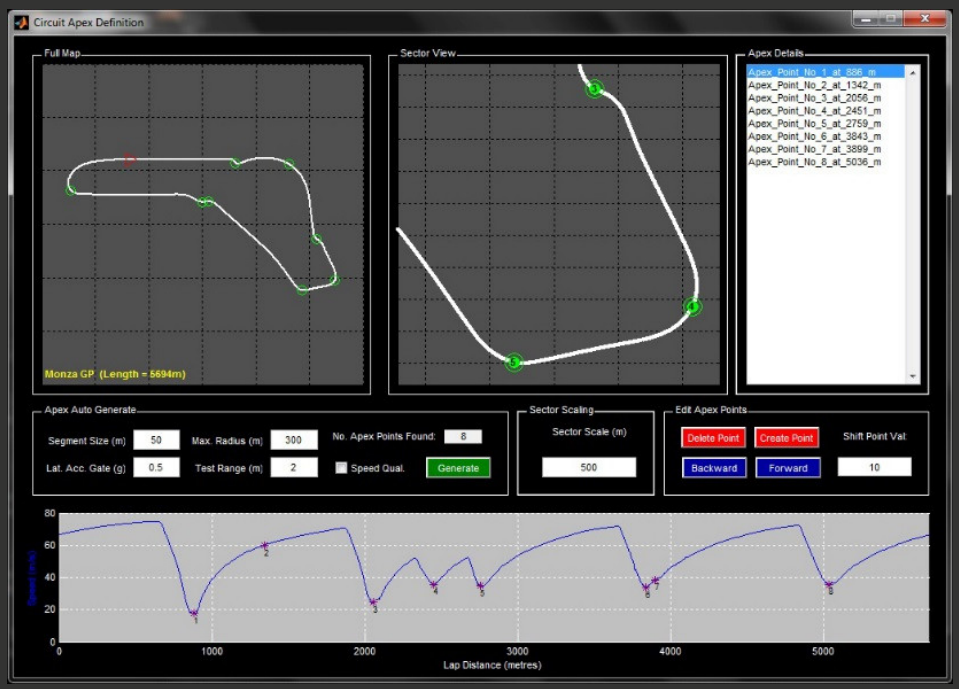
The Circuit Tool facilitates the production of path profiles for use in the solver.

Typically an input file is produced from an export of measured on-car data (either a MATLAB or CSV export can be used); from this the basic circuit path profile is generated.

The process is largely automated based on a number of user defined parameters which allow an accurate representation of the path to be produced.



The resultant path (circuit) file, once complete, can be saved for direct use in the LapSIM solver and re-opened for editing if required.



The Circuit Tool de-constructs the imported data and re-constructs a file which is suitable for use with the simulation algorithm. In doing so it breaks the path down into discrete sections over which the solution algorithm works.

The path (circuit) file can then be used with any vehicle file created with the Vehicle Tool; therefore the circuit is useable for any other vehicle type or alternate setup.

The sections are defined by apex points and hence this is an important part of path construction, the points can be generated automatically based on a set of user defined variables and subsequently edited, added or deleted as required.

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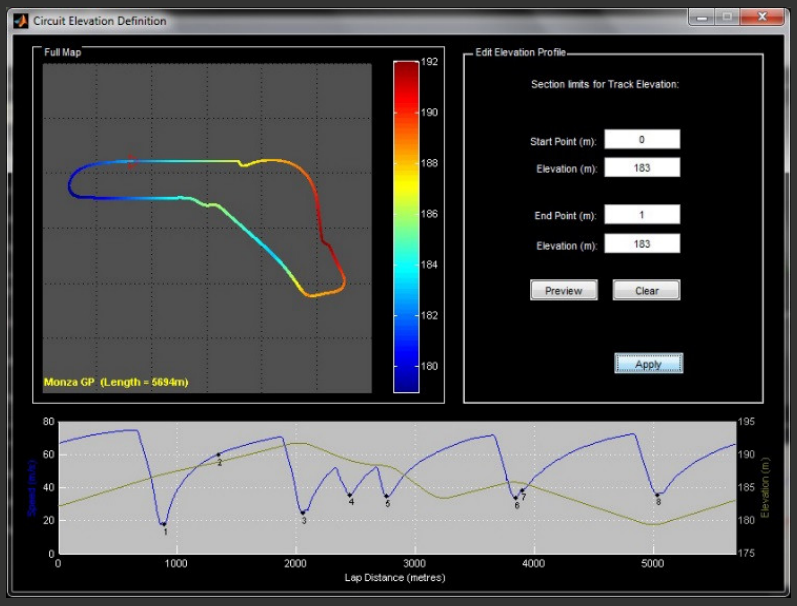
For licensed users the Circuit Tool also allows the definition of the path geometry (specifically elevation & camber) and local grip (Coefficient Of Friction) levels.

Specifying these characteristics is done using built-in editing tools, where it is possible to accurately model these variables.

A path geometry and grip variation is inherently difficult to accurately measure & replicate, however the software provides the tools to do this with a high level of detail if the required information is available.

The Circuit Tool (like the Vehicle Tool) can be used independently of the other software components to produce path files/definitions for use in the solver.



X-PD LapSIM Solver:

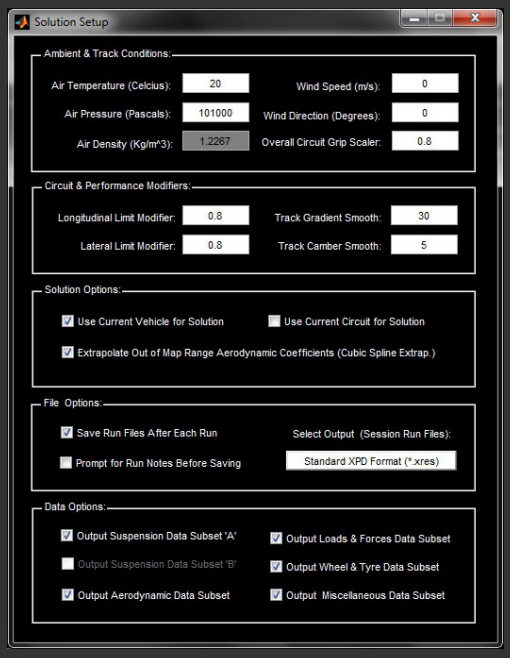
The solver is the tool for running the lap simulations, the interface allows the user to select a vehicle and circuit file for the simulation or (optionally) the 'current' vehicle and/or circuit (those applications must be running on the local machine for this functionality). This means that the solver can be used alongside the vehicle and circuit tools or in isolation with the required files only.

Running alongside the vehicle and/or circuit tools the vehicle or path parameters can be easily adjusted and the simulation re-run quickly without the need to generate and save completely new vehicle or path (circuit) files.

once executed a progress window is displayed showing relevant information regarding the status of the solution, when the simulation has completed a basic set of results are displayed to the user in the main window of the solver.

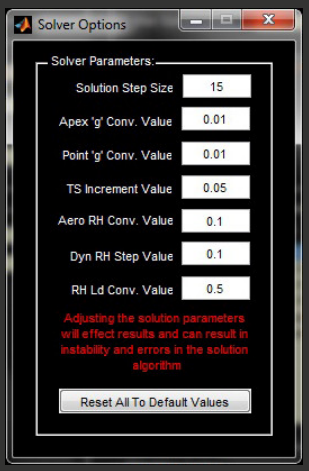
This set of results includes information on the lap time, maximum speed, average speed and the simulations execution time.

In addition a trace of simulation data is displayed as an overlay with the actual data which was used to produce the path profile originally, allowing for a quick check of correct simulation execution.



The '*Solver Options*' and '*Solution Setup*' menus allow the user to specify simulation parameters for convergence and resolution as well as ambient conditions, overall track grip levels, performance parameters (extent to which the peak tyre performance is utilised) etc. Here the user also has options on how the software saves data files for post processing and what data is to be output to those files.

A run history for the session is displayed in the main window with the main results also shown, the solver can save individual run files and/or session files containing the results data as required.



The simulation algorithm uses a numerical approach for its solution and the accuracy levels are tuned using adjustable iteration and convergence parameters.

While these parameters are accessible to the user in the solver options they should be adjusted with caution as they can affect the simulation results. It is advisable not to adjust them between simulation runs so as to limit resolution errors to an analysis results.

The underlying algorithm utilises the user specified vehicle parameter values and characteristic arrays contained in the vehicle definition in a detailed vehicle model which is the basis of the solution.

The solution algorithm itself is iterative around the lap over a user defined step size (increments of distance), allowing a choice between a high resolution and level of absolute accuracy (short steps) or a more efficient (and rapid) simulation speed (larger distance increments between calculations). The algorithm does also dynamically adjust resolution to capture high frequency events when they occur to achieve the best compromise.

Typically (with normal step sizes) the simulation runs much faster than real-time even with complex setups and hence results are rapidly available, iterations of setup can be run through efficiently once the base model has been setup.

The modeling and simulation components of all the LapSIM software tools are highly modular and therefore it is possible to develop and implement a bespoke application to suit a customer's individual/specific needs.

For example; Should specific areas of sensitive information need to be hidden within the software or in encrypted module files (sensitive vehicle parameters, such as engine, tyre or aerodynamic characteristics) this can be accommodated, X-PD has experience in providing tailored simulation solutions which fit the customer's requirement for distribution or internal use where restrictions on information flow are required.

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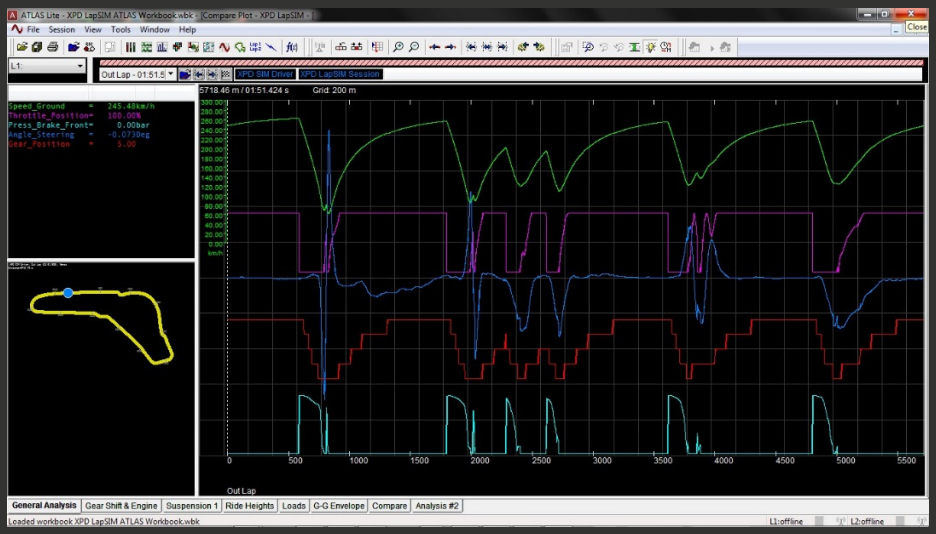
X-PD Data Analysis Export & Post Processing:

The data export features allow the extraction of simulation data in a number of formats suitable for analysis in the third party software of choice.

The results files generated by the solver contain all the relevant information relating to the simulation, including the circuit and vehicle file names, lap distance, lap times etc. as well as the data channels themselves.

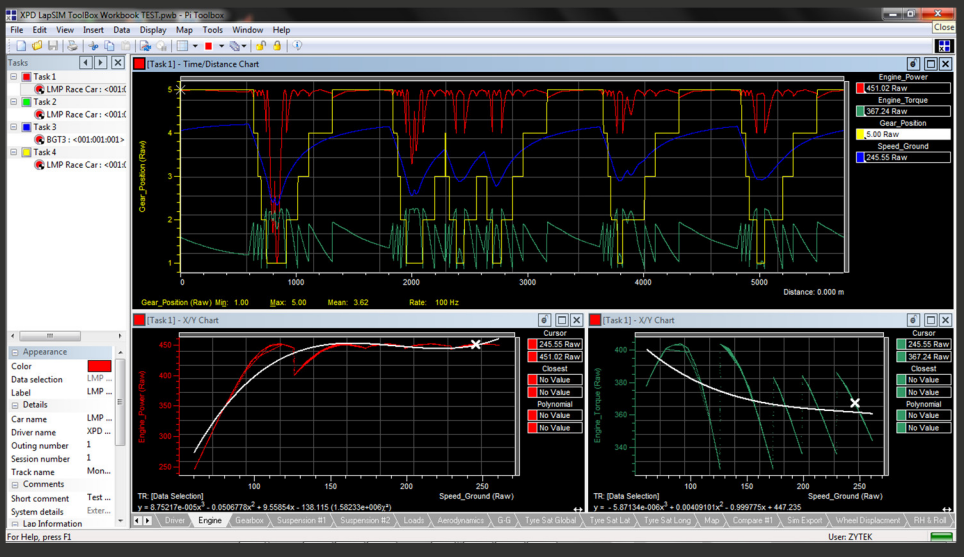
The data generated by the simulation comprehensively describes the vehicle as it traverses a single lap, vehicle speed, g's, loads, displacements etc. are generated as data channels as if created by an on-board vehicle data logging system.



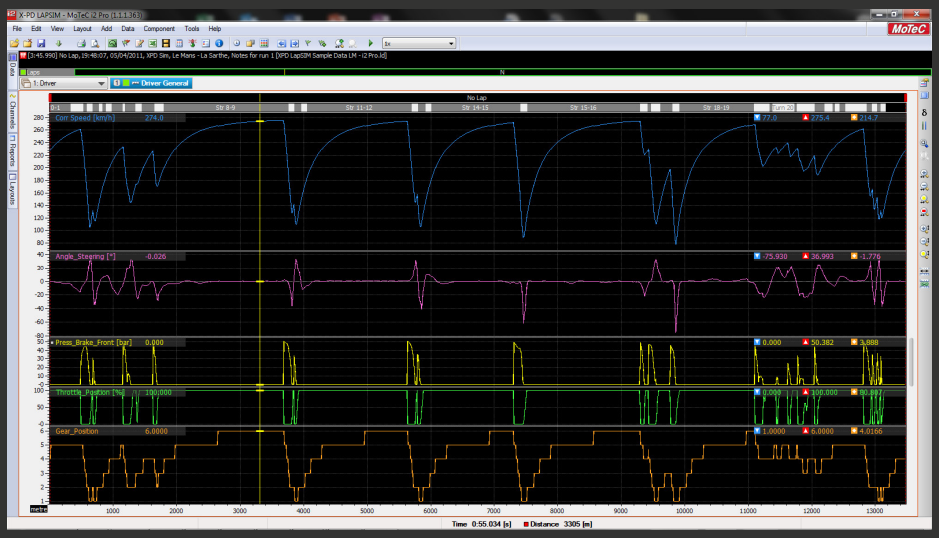
With the multiple output format capability the user is able to choose the post-processing tool most suitable to their needs and/or budget.

Rather than implementing a new data analysis package the flexibility to output data formats suitable for importing/opening directly in industry standard analysis packages is provided.

For example; It is possible to export data to a formats suitable for analysis in tools such as Motec I2 Pro, MES ATLAS and Cosworth Electronics PI Toolbox as well as more general data processing and analysis software such as MATLAB. This gives users ultimate flexibility in how they use the information and data produced by the simulation.



This flexibility allows the user to perform analysis of data as required including directly comparing simulation results with track data, in the preferred analysis environment.



This export/import capability is subject to the user having the appropriate licenses for the third party software.

By facilitating analysis with existing software tools commonly used in the industry the trackside/test engineer is able to integrate the LapSIM system into their engineering processes easily, making the system a highly effective tool

In addition to the ease of integration the export capability provides, the user inherently benefits from the powerful features of the leading data analysis packages into which he has already invested valuable resource.

This range of features makes the software flexible and effective for use in both trackside engineering optimisation and more detailed workshop/office based design, analysis and simulation tasks.

NOTES:

Data Analysis screenshots are of X-PD LapSIM generated data displayed within Motec I2 Pro, McLaren Electronic Systems ATLAS & Cosworth Electronics Pi Toolbox.

For Pi Toolbox and MES ATLAS a valid license/dongle is required for those third party analysis tools in order to display data produced by X-PD LapSIM Solver.

For Motec I2 Pro generated *.ld files the Motec API license is required – please contact X-PD for further information and licensing details.

DISCLAIMER: