

## 1. Panthera Software

Cruden's simulation software is collectively known as the Panthera software suite. The Panthera software suite is a comprehensive set of modules and packages that are used to run a simulator. This starts from a free desktop application, Panthera Free, through to complex multi-degree of freedom motion-based simulators with multi-channel projection.

This software controls all elements of the simulator:

- Motion & control loading;
- Visuals;
- Vehicle dynamics (integration);
- Audio;
- Other I/O (Harness loader, vibration actuators etc.);
- HIL tests and controllers;
- Safety.

A typical Cruden simulator setup, including a motion base, is shown below.

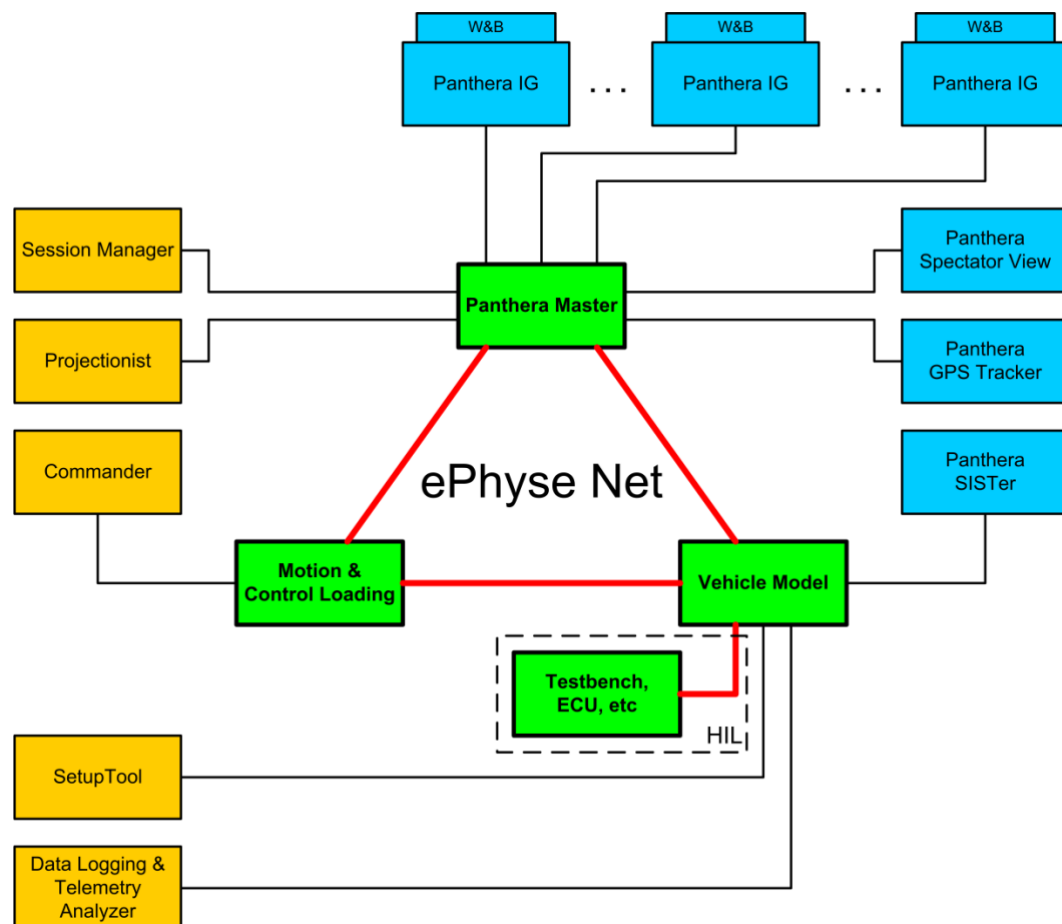


Figure 1-1 Panthera functional overview

The core of a Cruden simulation setup can be seen as a triangle. It consists of three cornerstones, shown in green:

- Panthera Master
- ePhyse & Vehicle Model
- Motion & Control Loading

This architecture has been chosen to maximize the communication rate (i.e. minimize the latency) between the vehicle model on one side and the input from motion and haptic feedback to / from the driver on the other side, whilst keeping transport delays to an absolute minimum.

Around this simulator core, a typical simulator contains various other systems, such as a number of IGs, vehicle engineering tools and interaction with the road. These systems are shown in blue. Finally, various systems in the simulator require a GUI, such that simulation engineers can start, stop and manipulate the simulator. These are shown in yellow. All systems in this figure feature software. This software is collectively known as the Panthera Software Suite. The Panthera software suite consists of various packages and modules, which means that each Panthera installation can be configured individually by only selecting only the modules / licenses required. The following sections describe the modules and license fee in more detail.

## **1.1 Panthera Core – Licence fee € 10,000**

This package contains the base module, Panthera Master, along with Session Manager and other modules and is required for each Cruden Panthera installation.

### **1.1.1 Panthera Master**

Panthera Master is the main module of the simulator system. It runs the simulation, audio, performs several monitoring tasks and interfaces with:

- The motion base, CL, specific I/O;
- IG PC's;
- ePhyse for the integration of the CSVm model.

Besides this, it also incorporates an internal vehicle model. This internal model will be used to enable driving of the simulator for testing and other purposes. The vehicle dynamics properties of this model are not as advanced as e.g. CSVm (Cruden Simulink Vehicle Model, see also Chapter 1.6), but it is a great model for troubleshooting simulator subsystems and is a very practical solution for simulator use cases for which a very detailed and complex vehicle model is not necessary or feasible.

### **1.1.2 Session Manager**

In Session Manager, the operator can set up a simulation by selecting a relevant car, road and enabling the motion system. Additionally, Session Manager provides feedback to the operator regarding the status of the simulator. The main functions and features are described below. More functions are available and are shown to the customer during the training sessions.

- **Session duration**

The operator can select a fixed time to run a session;

- **Selecting a vehicle;**

The operator can select which vehicle to run.

- **Circuit / Test track**

The operator will be able to choose which road or circuit will be driven. A list of all roads / tracks is shown in a pull-down menu.

### 1.1.3 Panthera Pacejka Analyzer

The Pacejka Analyzer allows engineers to visualize and modify tire characteristics through an easy-to-use GUI.

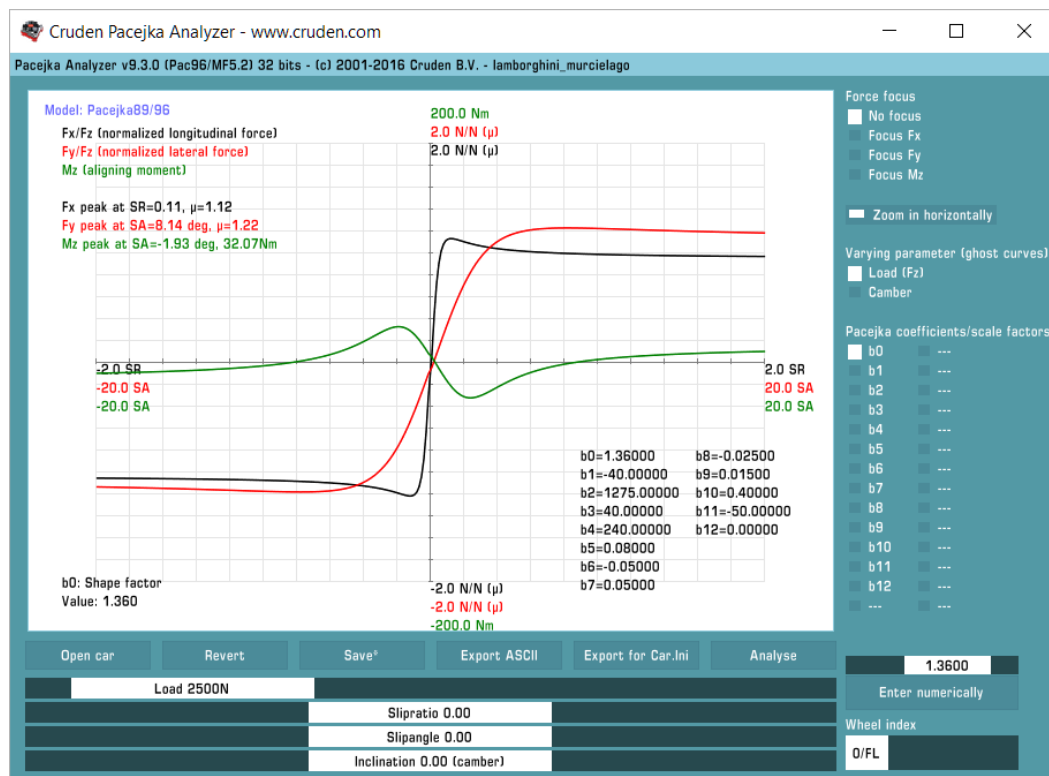


Figure 1-2. Pacejka Analyzer

### 1.1.4 Track Ed

TrackEd is a tool that allows engineers to import a road or track into Panthera. It converts the exported .ASE file into Panthera .DOF files.

Next to importing tracks, it also allows engineers to modify metadata on tracks, change grip levels, draw your own splines, add time lines, grid positions etc.

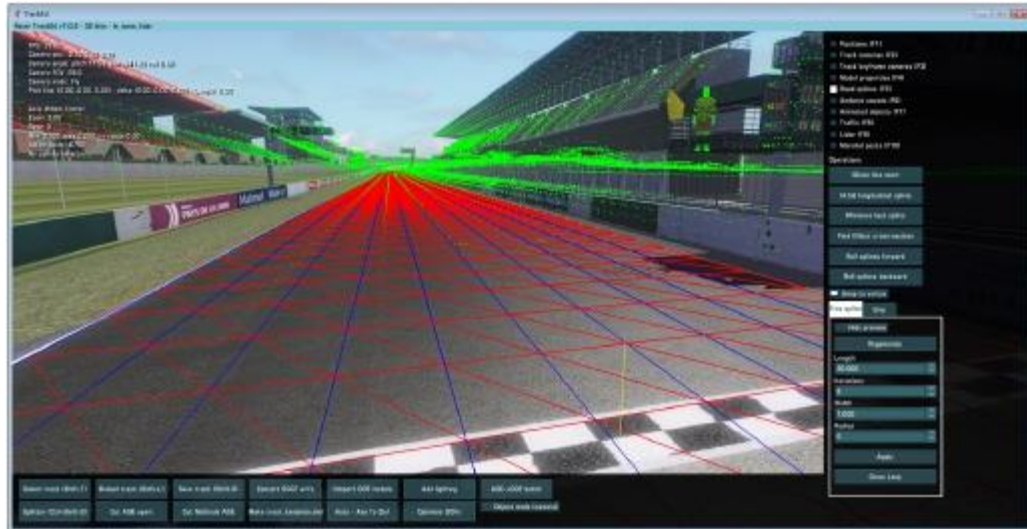


Figure 1-3. TrackEd GUI

## 1.2 Panthera IG – Licence fee € 3,500 per channel

The rendering of the images that are sent to the displays is done by Panthera IG. A separate instance of Panthera runs on each PC to generate images to an output channel (e.g. projector / display). Below is an image of a scenery that is rendered by Panthera IG during a simulation. Panthera can render at resolutions up to WQXGA (2560 x 1600), with frame rates varying from 120 – 300 fps, depending on the scenario. Below are two sample images, which are not offline 'studio' renders.



Figure 1-4. Panthera IG rendering of an endless highway



Figure 1-5. Panthera IG rendering of the Le Mans 24h circuit

### 1.3 Panthera W&B – Licence fee € 3,150 (per channel)

#### 1.3.1 Warping and Blending

The Panthera software includes a post processing step that compensates for the distortion when projecting on an arbitrary shape surface. In the software the virtual world is rendered onto a virtual flat screen; this image is then deformed to compensate for the deformation. The compensation is derived from physical properties of the projectors, the shape of the projection screen as well as the dynamic position of the motion base.

At the same time, an edge blend will be performed to smoothly blend the area where two projections overlap. This results in a seamless image generated by multiple projectors.

#### 1.3.1 Projectionist

The tool that runs the set-up of this W&B is called Projectionist. Below is an image of the GUI to fine tune the warping deformation.

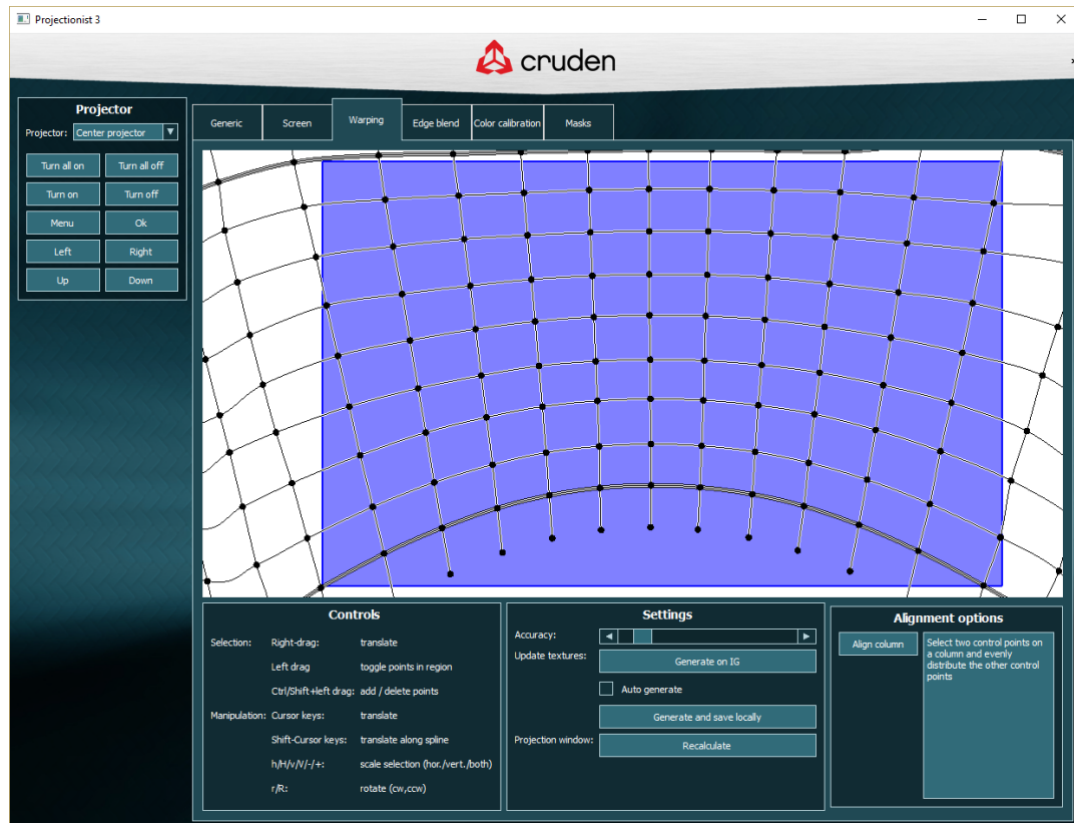


Figure 1-6 Blending and warping fine tuning

#### 1.4 Panthera ePhyse – Licence fee € 19,500 (Soft Real Time) / € 29,500 (Hard Real Time)

ePhyse Net is a generic interface package that enables the use of (custom built) simulation models over a network. This interface can theoretically link any Real-Time code to the simulator environment. This can be a third-party vehicle model, but also Panthera CSVM (see also Chapter 1.6).

The implementation is based on SIMULINK library extensions, through which the model is both timed, as well as linked to Panthera and simulator hardware. In case of third party vehicle models, they run natively, in co-simulation, through their S-functions. In case Panthera CSVM is used, SIMULINK CODER is used to generate and execute the CSVM code.

This is not a deterministic Real-Time approach, but model execution is throttled using the CPU high performance counter. Previous experience shows this approach is robust enough to drive the simulator hardware. Of course, Hard Real-time systems can be integrated using ePhyse as well.

The figure below shows the Simulink implementation of ePhyse. The big block in the middle with the Cruden logo is the vehicle model.



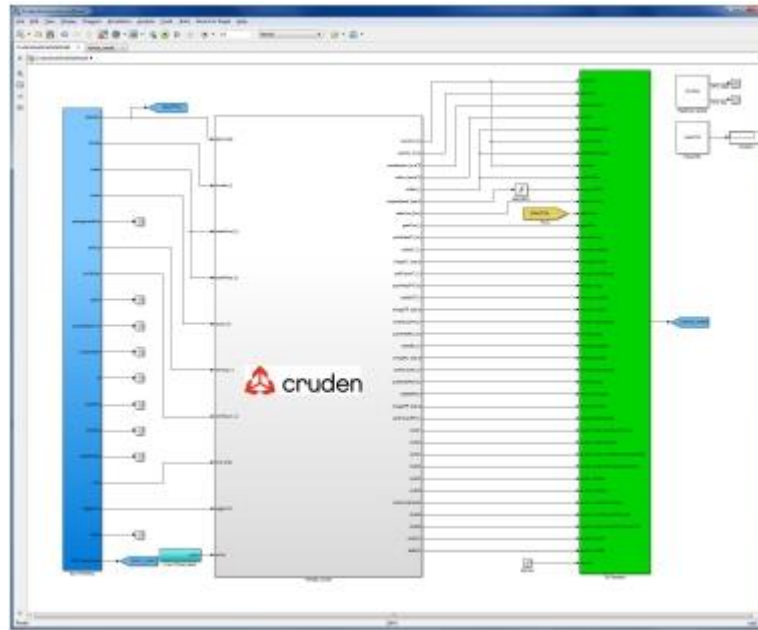


Figure 1-7 ePhyse architecture

### 1.5 3<sup>rd</sup> Party Vehicle Dynamics packages integration – Licence fee € 12,500

Integrating dedicated vehicle dynamics package supplied by a third party, such as VI-CarRealTime, IPG Carmaker, CarSim, SIMPACK, VeDYNA, dSPACE ASM, AVL VSM, Dymola etc. is very simple and straightforward through the ePhyse module of Panthera.

Potential users for this vehicle modeling solution would be customers who have very detailed vehicle data available and wish to simulate a passenger car in the utmost detail, potentially including software or hardware ECU's and other controllers used in the real car.

To run 3rd party vehicle dynamics in a simulation, licenses for MATLAB, SIMULINK and various toolboxes are required.

If the vehicle model is based in Simulink, Set-up Tool can be used in combination with such models. If this is not the case, Set-up Tool cannot be used, but modifications must be made using the third party's frontend.

### 1.6 Panthera CSVm – Licence fee € 19,500

Cruden Simulink Vehicle Model (CSVm) is a vehicle model created in Matlab Simulink. This highly detailed custom vehicle model has been developed and validated in close cooperation with our motorsports clients. The model itself is open and can be modified by customers. The parameters that go into this model reside in a separate ASCII file and can be adjusted by the engineer operating the simulator using the Set-up Tool or directly in the ASCII-file.

This vehicle model runs Pacejka 6.1 based tire models, which are capable of handling temperature and pressure dependencies and also support dynamic rolling radii. Aerodynamic forces are implemented through aero maps and suspension and steering-systems are modeled by their physical components. The user can easily understand, modify or replace building blocks due to the model's open architecture.

The model is built using blocks from standard Simulink, Simscape Multibody and Simscape Driveline, which has been extended by custom S-functions. The modular setup and extensive parameterization allow for straightforward adaption to racing cars as well as other vehicle types. CSVSM has many features, such as a multi-point skid plate, which can be used to simulate bottoming of the race car, as well as calculating ride-height. Items such as KERS and DRS can easily be added by the customer, thus enabling full control at the customer end.

Cars with uniball joints, without too many bushings, can be simulated extremely realistically with this model. These cars are not capable of colliding with objects during the simulation. CSVSM is considered a very suitable tool for customers who wish to do vehicle engineering in motorsports.

MATLAB Simulink, Simscape Multibody and Simscape Driveline licenses are needed to run the system.

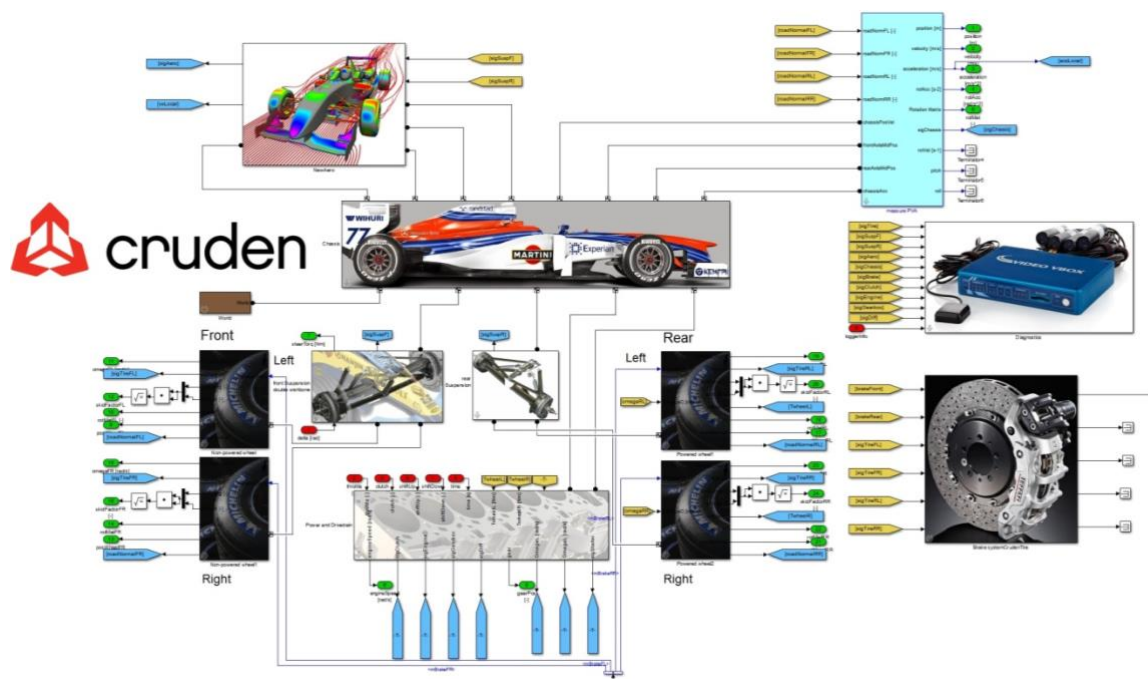


Figure 1-8 CSVSM schematic

## 1.7 Panthera CSVSM-Lite – Licence fee € 0

The 'light' version of the Cruden Simulink Vehicle Model (CSVSM-Lite) is a vehicle model created in Matlab Simulink. This vehicle model can also be modified by customers. The parameters that go into this model reside in a separate ASCII file and can be modified by customers.

CSVSM-Lite is a simplified multibody model, which can run 'soft real-time' in Simulink without compilation on a typical high-performance PC. The main simplification consists of refraining from rocker-pushrod actuated suspension geometry, avoiding also T-bar roll stabilizers. This results in a double wishbone suspension with spring-damper directly connecting to the wheel carrier to the chassis. A mass-less U-bar is included for roll-stabilization. Such a suspension layout, inspired by computational efficiency in Simscape Multibody, is highly uncommon in modern vehicle engineering applications.

The customer is invited to use this model as proof of principle for the ePhyse communication architecture and the possibilities of multi-body modeling in Simscape Multibody. Given the uncommon



suspension layout of this model may have limited engineering contribution, but the open software platform still allows the user to tailor this model to his needs. Pursuing this approach, the user could soon encounter the strict constraint of real-time computational speed. Cruden then advises to transfer to CSVM.

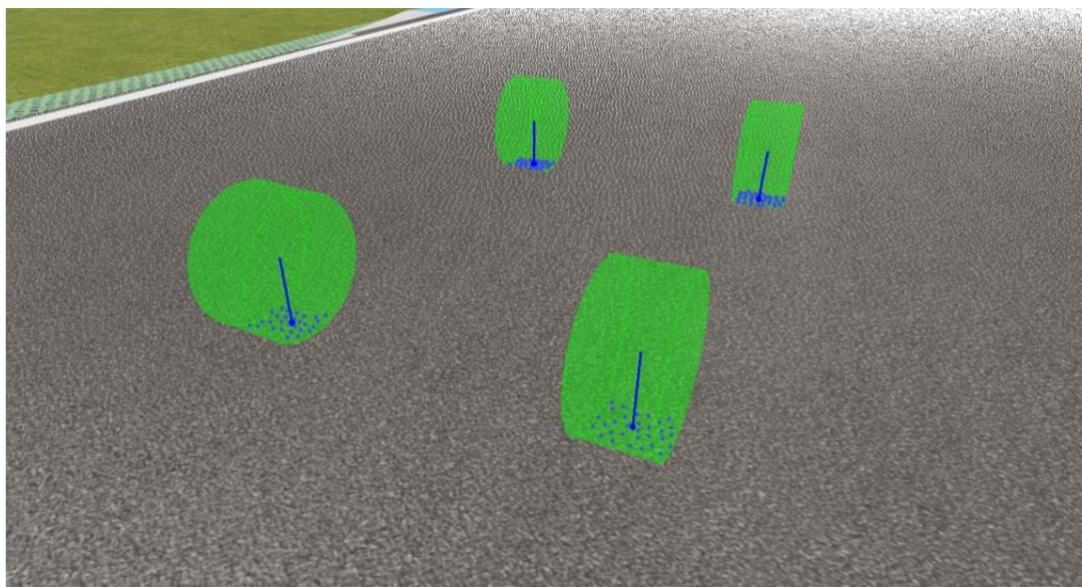
CSVM-Lite is provided free of charge, as an example of a multi-body vehicle model and the integration thereof. Typically, Cruden integrates CSVM-Lite using the ePhyse environment. To modify and/or run CSVM-Lite in a simulation, licenses for Matlab, Simulink and various toolboxes are required.

Set-up Tool can be used in combination with this model.

### 1.8 SISTer – Licence fee € 10,000

Cruden has developed a separate module for tire road interaction: Server for Interaction with Surfaces and Terrains, or SISTer. With this module, interaction between the car (tire, skid plate, etc) and the road (Lidar triangles, Lidar points, OpenCRG, etc.) is handled in a separate thread, at a very high data rate.

This can be done either by multisampling with up to 49 intersection queries per wheel or skid plate, or by driving directly on a dense point set with a spatial density down to 10 mm. This is done at a frequency of 1000 Hz or higher. This method provides highly improved input to the tire model, resulting in detailed and precise forces and moments plus road-normal calculations, without additional computational costs to the vehicle model. The interaction between the vehicle model and Panthera SISTer has a latency of less than 2 ms and uses a predictive algorithm to compensate for these delays.



*Figure 1-9 Image of tire-road interface with SISTer*

### 1.9 Panthera Control loading – Licence fee € 1,250

This module handles the interface of the Panthera software to the control loading force feedback steering system.

## 1.10 Panthera Motion – Licence fee € 5,000

### 1.10.1 Motion interface

The interface to the motion system, including all the safety features is handled by this module.

### 1.10.2 Platform tracking

The Panthera software tracks the motion platform and adjusts the projected images depending on the platform position and orientation.

## 1.11 Panthera Motorsport Engineering – Licence fee € 6,500

Included in the delivery is the Panthera Motorsport Engineering Package. This package includes Data Logging and a Set-up Tool

### 1.11.1 Set-up Tool

This module is used to adjust the setup of the vehicle. Using this tool, setups can be created, saved and loaded.

Set-up Tool has a comprehensive visual feedback that has a full display of parameters. A sample screenshot is shown below. Additionally, Set-up Tool enables live adjustment of various car parameters, i.e. the vehicle set-up can be changed on the fly, whilst the driver is driving the simulator. This saves valuable time as the simulator does not have to be re-set each time a change is being made.

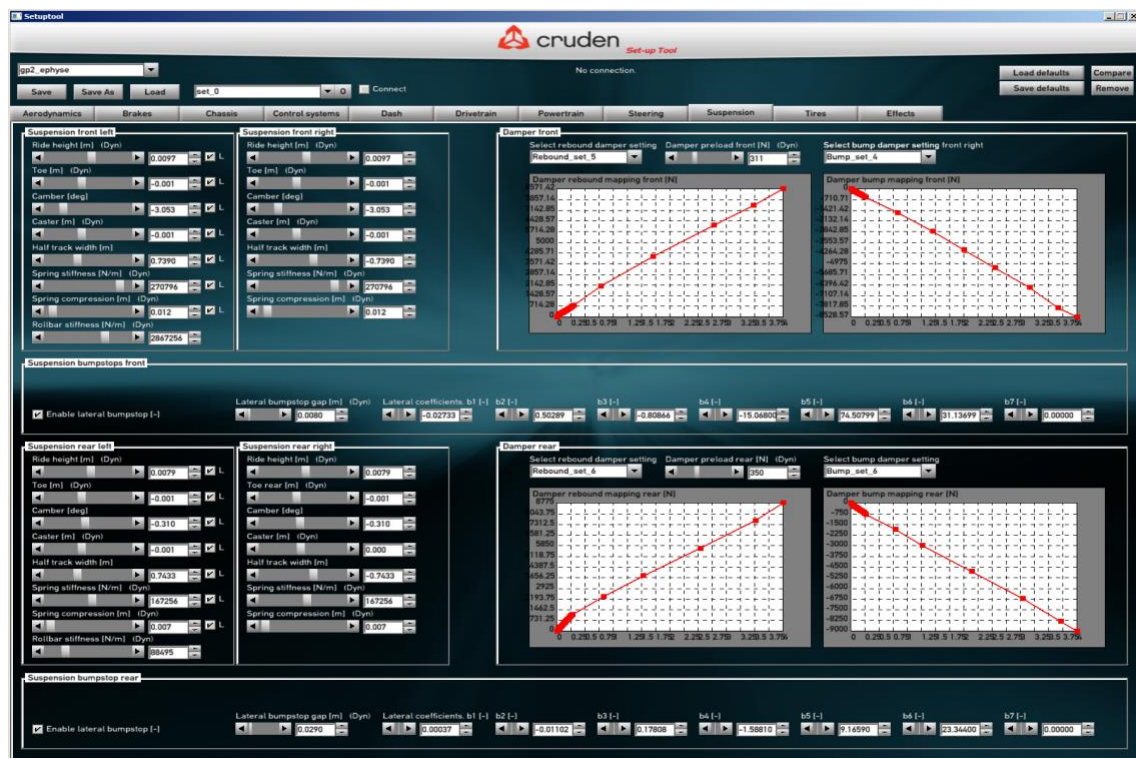


Figure 1-10 Set-up Tool

### 1.11.2 Data logging

Data logging is a SL-block that writes real-time vehicle data to a Cruden proprietary file format. This data can subsequently be converted to either Matlab or ASCII, but can also be read, analyzed and/or post-processed by Panthera's Telemetry Analyzer.

### 1.12 Panthera Spectator view – Licence fee € 3,500

This TV like coverage enables engineers, spectators and/or visitors to follow the vehicle from different angles or through in car camera coverage. Below is a screen shot of such view.



*Figure 1-11 Spectator view of a Land Rover on a UK road*



*Figure 1-12 Spectator view of an F3 car on Moscow Raceway*

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### **1.13 Panthera Public Content – Annual licence fee € 8,950**

Cars and tracks that have been created by Cruden (often generated from laser scanned data) identify themselves as 'official Cruden content' during loading. By contrast, content that was generated by others has no such identification. On a simulation setup, only 'official Cruden content' can be used that is explicitly mentioned in the license. Other content, whether from Cruden or from third parties, cannot be used.

A Public Content License enables the user to utilize additional content in the simulator software, which is not labeled as 'official Cruden content'. Such content could be generated by a third party, or downloaded from the internet. With such a license and the associated tools, the user can generate (compile) content from source material by himself. This will allow the customer to build and/or import his own tracks for use on the simulators. Note that a Public Content License does not include source material for content (typically 3ds files). It only enables the user to compile and run content from source material.

### **1.14 Panthera ADAS - Licence fee € 17,500**

The Panthera ADAS module enables an engineer to develop and evaluate ADAS controllers using MATLAB Simulink, with a driver in the loop. Through the integration with Panthera, the MATLAB Simulink model of the ADAS controller receives information about the objects around the car via so called Ideal Sensor inputs. These ideal sensors can be configured by the user to match what will be available on the real car. The signals generated are based on the fact that Panthera controls the virtual environment and knows what is happening around the car.

With this concept of ideal sensors, the development and testing with a driver in the loop can be focused on the decisions making algorithms and the way in which the ADAS controller assists the driver in preventing accidents.

For the simulation of traffic and the interaction between the traffic cars and the ego car, the Panthera ADAS module can be interfaced with existing traffic simulation tools like Vires and Prescan.





Figure 1-13 Panthera ADAS Ideal Sensor concept