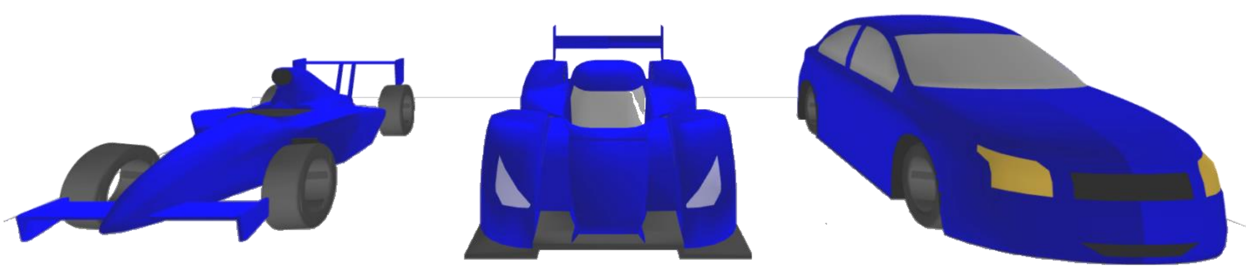
OptimumDynamics

Computational Vehicle Dynamics – Help File



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OPTIMUMG
vehicle dynamics solutions

Welcome

Thank you for purchasing OptimumDynamics, the newest benchmark in computational vehicle dynamic analysis software. This help file contains information regarding the features, functions and general usage of OptimumDynamics.

Feedback

OptimumDynamics is a continually evolving program and we give high regard to any suggestions, comments or complaints that you might have. Please contact us at softwaresupport@optimumg.com and we will endeavor to improve OptimumDynamics based on your feedback. You also have the option to report feedback by selecting 'bug reporting' from the file menu within OptimumDynamics.

Document Overview

The help file can be navigated by clicking on the various section links in the document. At the bottom of each sub-section there is also a link that will bring you back to the beginning of that section. If you are new to OptimumDynamics then you should start by reading through the Getting Started guide.

Getting Started

This section of the help file will help you with the initial installation and opening of OptimumDynamics. The following topics are covered:

Document Overview

Hardware/ Software Requirements

Section	Minimum	Recommended
Operating System	Windows® XP (32/64-bit) Windows® Vista (32/64-bit) Windows® 7 (32/64-bit) Windows® 8 (32/64-bit)	
Processor	Intel® Pentium 4™ Intel® Xeon™ Intel® Core™ AMD® Athlon™ AMD® Opteron™ AMD® Turion™	
Memory (RAM)	1 GB	2 GB
Storage Space	100 MB	
Graphics	Microsoft® DirectX® 9.0c capable card with 32MB RAM	Microsoft® DirectX® 9.0c capable NVIDIA® GeForce® ATI® Radeon® with 128MB RAM
Display Unit	15″ screen 1024 x 768 pixel resolution	19″ screen 1280 x 1024 pixel resolution 21″ screen 1280 x 1200 pixel resolution

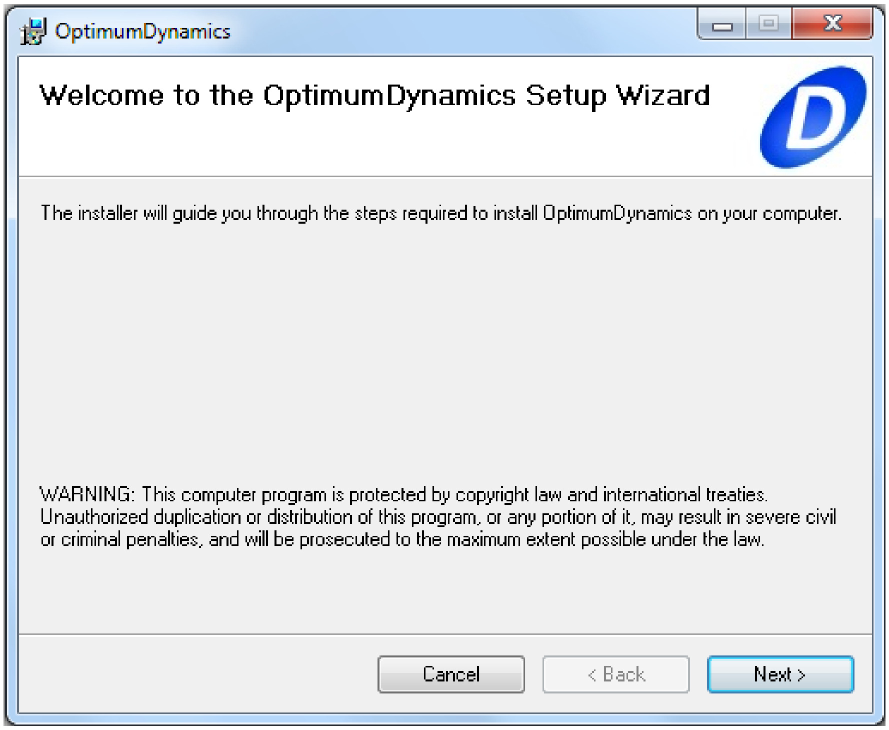
Section	Required
Network	Internet connection for license activation and deactivation
Software Components (Included in Installation)	Microsoft® .NET® Framework 4.0 or higher Microsoft® Windows Installer 3.1 or higher SlimDX Redistributable for .NET 4.0 version 4.0.11.43 or higher for 3D visualization.
Other	Mouse or other pointing device. Microsoft® Excel™ 2010 or higher for import and export of data. Microsoft Office Database Engine 200

Getting Started

Installation

The following procedure should be undertaken to successfully install OptimumDynamics

1. **Run** the OptimumDynamics **Setup** installer. Ensure that you run the **.exe** file and run as an administrator to ensure all components are installed successfully.
2. If a security warning popup box appears click **Run**
3. A setup wizard will open which will guide you through the installation, click **Next**



4. Read through the license agreement and select **I Agree**, click **Next**
5. You may select to create shortcut icons on your desktop or start menu, select **Next**
6. Browse to an installation directory or accept the default location, click **Next**
7. Click **Next** to begin the installation
8. The installation should begin and there will be a progress bar to update progress. If a popup appears asking if you give permission for the program to make changes click **Yes**
9. Once the installer finishes click **Close**
10. The program should now be successfully installed, you can run the program from the start menu or from the icon generated on your desktop.

If you had any issues during installation please contact us at softwaresupport@optimumg.com or by phone at +1 303 752 1562.

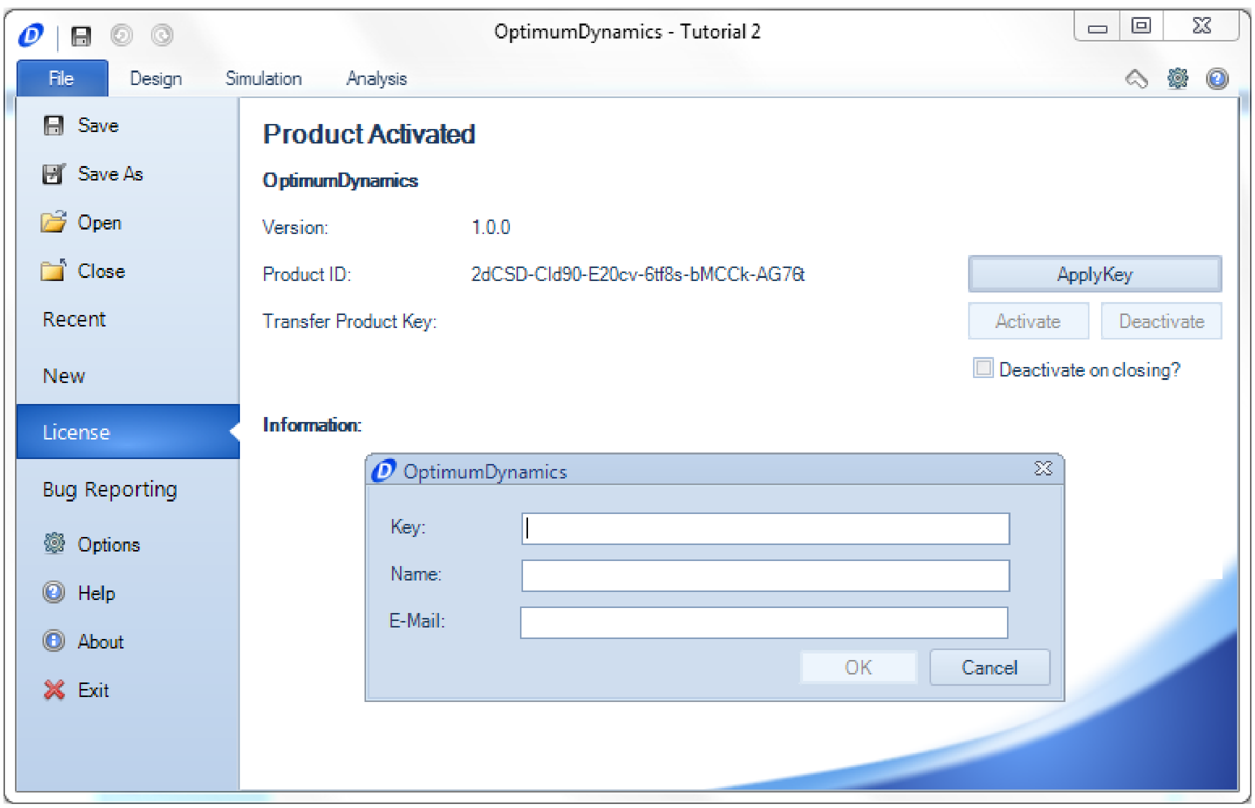
Getting Started

Licensing

Before you can use OptimumDynamics you must enter your licensing information, you should have been given a license key with your purchase of OptimumDynamics. If you wish to purchase or obtain a trial key then please contact us at softwaresupport@optimumg.com

To add your license key

1. **Launch** OptimumDynamics
2. Click on the **File** tab
3. Click on the **License** tab
4. Click on the **ApplyKey** button
5. Enter a **Key**, **Name** and **Email**
6. If the supplied information is correct a **green** check box will appear
7. Click on **OK** to accept



Optimum Dynamics will periodically check your licensing information every 90 days. There is a grace period of 5 uses if the licensing check fails.

Getting Started

Starting a Project

Once you have OptimumDynamics installed and your license applied you are ready to start using the software. The following section describes how to get up and running with a new OptimumDynamics project for the first time:

Launching OptimumDynamics
Project Backstage
Creating a New Project
Opening an Existing Project
Saving a Project
Options Menu
Graphical User Interface (GUI)

Getting Started

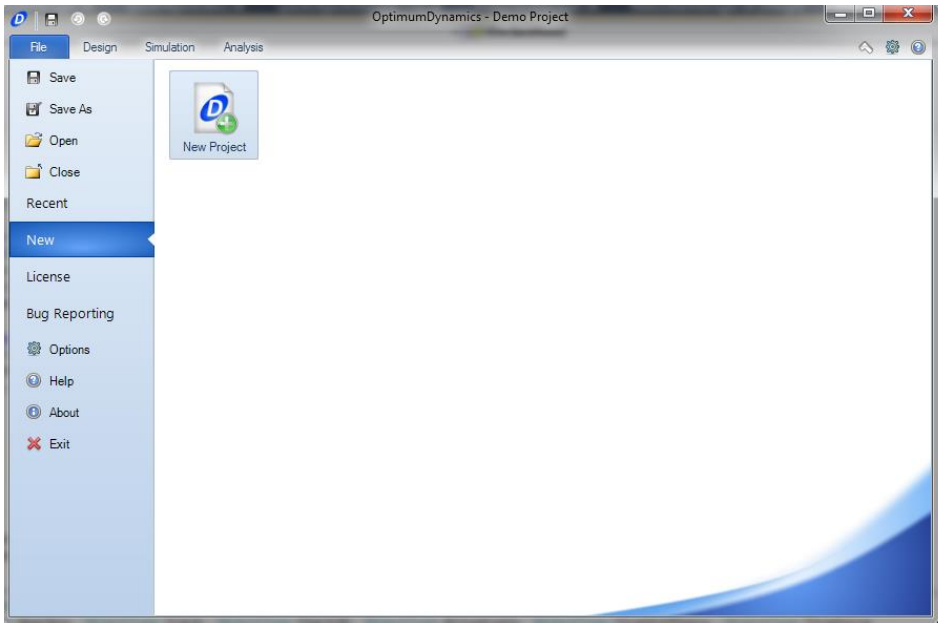
Launching OptimumDynamics

The first step is launching the application. After successful installation you can find the OptimumDynamics executable program in your computer start menu or as an icon on your desktop.

Starting a project

Project Backstage

When opening the software, you will be presented with the following screen. This view is known as the project **backstage** and is used to manage your projects and to change Licensing options. The project settings are also accessible from this screen.



ABOVE – The project backstage

The following functionality is available from the file tab.

Icon	Option	Description
	Save	Saves the current project that is open
	Save As	Saves a new copy of the project with the given filename
	Open	Opens an existing OptimumDynamics project file
	Close	Closes the currently opened project
	Recent	Shows the most recently opened OptimumDynamics project files in order of date last accessed
	New	Creates a new OptimumDynamics project file
	License	Displays current licensing information and allows the application of a license key
	Bug Reporting	Report software issues encountered
	Options	Adjust project settings
	Help	Opens the help file in a separate window
	About	Displays information regarding the current version of OptimumDynamics and contact details
	Exit	Closes the OptimumDynamics program

Starting a project

Creating a New Project

The first time OptimumDynamics is used a new project must be created or alternately an existing project can be loaded. Select the 'New' button to create a new project. You will also be asked to enter a name and select a file location for your project.

1. On the **File** tab, click **New**
2. Select **New Project**
3. You should give the project a relevant **Filename** and select a **Location** to save it
4. Click **Save**

Upon creating a new project, a folder will be created on your hard drive in the selected directory. All the files related to your project will be saved in this project folder. OptimumDynamics separates the project into individual components, this makes importing and exporting between projects much easier. The following file formats are utilized in OptimumDynamics.

Icon	Name	Extension
	Project File	.ODPro
	Aero File	.ODAer
	ARB File	.ODArb
	Brake File	.ODBra
	Bump Stop File	.ODBum
	Chassis File	.ODCha
	Spring Assembly File	.ODSpa
	Drivetrain File	.ODDri
	Gearbox File	.ODGea
	Engine File	.ODEng
	Spring File	.ODSpr
	Suspension File	.ODSus
	Tire Force File	.ODTfo
	Tire Stiffness File	.ODTst
	Tire File	.ODTir

Icon	Name	Extension
	ODVSC	.ODVsc
	Force File	.ODFor
	Acceleration File	.ODAcc
	Simulation File	.ODSim

Icon	Name	Extension
	Result File	.ODRes
	Chart2D File	.OD2dc
	Table File	.ODTab
	Track Map File	.ODCtm

Starting a project

Opening an Existing Project

If you already have an existing OptimumDynamics project than it can be loaded using the open function.

1. On the **File** tab, click **Open**
2. Browse to a **.ODPro** file and click **Open**

Starting a project

Saving a Project

It is important to regularly save your project. An OptimumDynamics project can be saved by either of the following methods.

1. On the **File** tab, click **Save** (Ctrl + S)

To save the project under a new name or in a new directory

1. On the **File** tab, click **Save As** (Ctrl + Shift + S)
2. Browse to the desired location and enter a project file name
3. Click **Save**

Starting a project

Options Menu

If, or when, you wish to change any of the project settings you can do this through the options menu. The most important thing here is the Unit settings; you can adjust from the default units to those you are most comfortable working in. When you are first starting we recommend that you keep the other settings at their default values. You can also reset to the default options at any time.

Setting Tab	Description
Units	This option determines what units are used and displayed in the program. Most standard imperial and metric units can be selected.
Numbers	Here you can select the number of decimal places to be displayed throughout the program.
Coordinate System	This option allows you to select the preferred coordinate system for the car. The default setting is the adapted SAE coordinate system. **This is currently unavailable.**
Document Layout	Here you can select the position layout of the documents within OptimumDynamics.
Document Tab	This option allows you to define default colors for the worksheet tabs in the **Document Manager**.
Simulation Options	Here you can select the default number of steps for the following simulation types • Force Simulation • Acceleration Simulation
Object Names	Select whether you wish to be asked for a file name before creation
File Properties	Here you can choose whether or not to display File properties such as ‘date created’, ‘created by’ etc. in the object documents.
3D Visualization	Here you can select the type of vehicle you would like for visual display.

↑ Starting a project

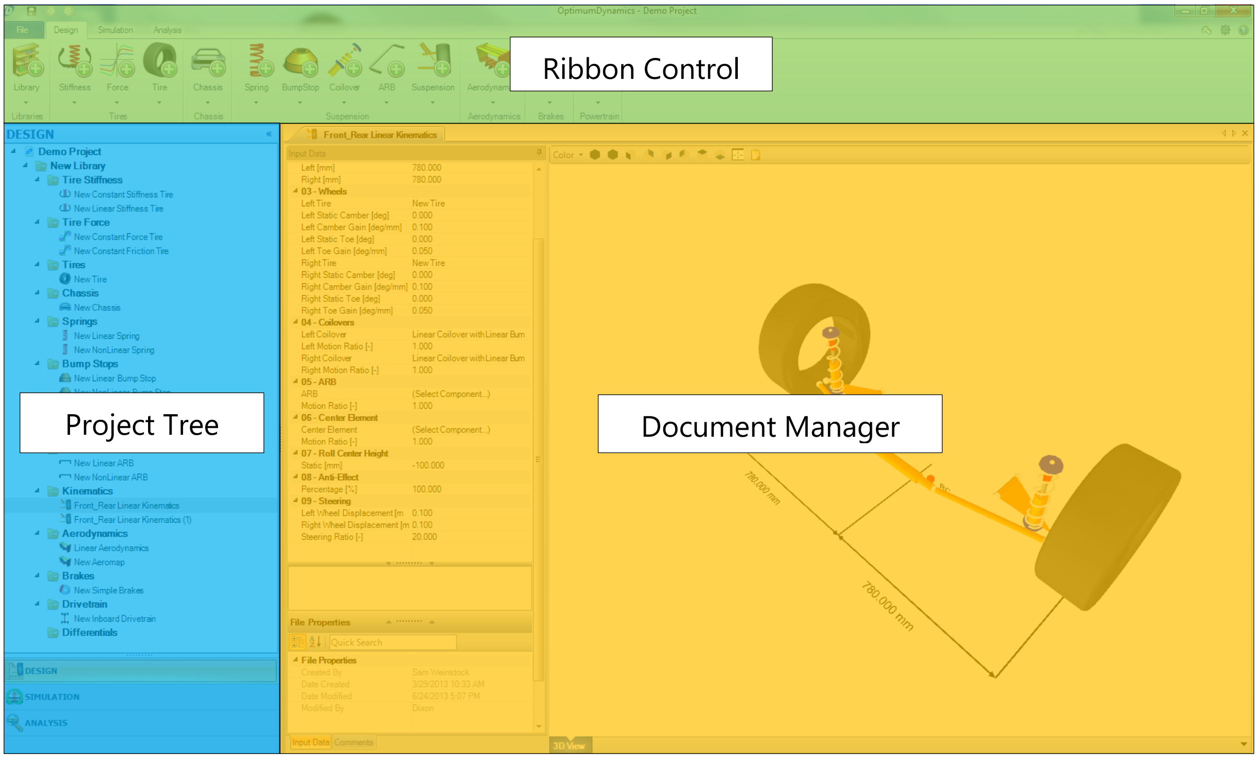
Graphical User Interface (GUI)

With a new project created or an existing project loaded you will leave the project **Backstage** and enter the main program GUI. The Main GUI is organized into the following three sections.

- The **Project Tree** is located on the left of the screen and allows quick display, navigation and manipulation of project files. This is your primary method of navigating through the project. Design components, simulations and results can easily be loaded, created and re-arranged all from within the project tree.

- The **Ribbon Control** is located in the top section of the screen and allows quick access to the software functionality. From the ribbon menu it is simple to add new components, create simulations and develop new analyses.

- The **Document Manager** is where the majority of work is undertaken and allows manipulation of the project files. This is where all the data is input and analysis is taken place. You may have multiple tabbed documents open for quick navigation within the project. Tabs can be re-arranged and displayed side-by-side by dragging the tab and repositioning (see Document Manager). The color of the tabs can also be changed in the options menu.



ABOVE – The general layout of an OptimumDynamics project

OptimumDynamics has been designed to ensure that navigating your project is simple and easy. You can access functionality through the ribbon control or by selecting files in the project tree. You can also use the context sensitive shortcut menu to find additional options. The shortcut menu is found by right clicking on an object, file or area. The majority of the shortcut options are also available directly through the ribbon control.

Starting a project

Detailed Guide

Now that you have started and have been introduced to the software it is time to start building your project. This guide covers the detailed information necessary to achieve this. The main three processes involved with an OptimumDynamics project are.

Vehicle design
Simulation
Analysis

The usual process followed is to begin by fully defining the vehicle you want to investigate. The more accurate and complete the component definitions are the better. After this you will decide what types of simulations need to be conducted and finally the results of these simulations can be analyzed in different reporting formats.

Document Overview

Vehicle design

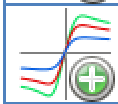
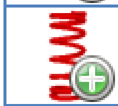
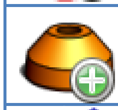
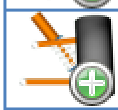
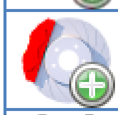
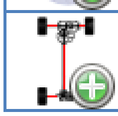
Let's start with building a new vehicle model. The vehicle design covers all of the component detail and assembly. In this part of the project a vehicle is built from its core components into an overall vehicle model that can be used for later simulation and analysis. The following components must be included in an OptimumDynamics vehicle definition if simulation is to be undertaken:

- Tire Stiffness
- Tire Force Model
- Tire
- Chassis
- Spring
- Coil over
- Suspension
- Brakes
- Drivetrain

The following components can also be optionally included:

- Anti-roll Bar (ARB)
- Bump Stop
- Aerodynamics
- Center Element

Fortunately these components can be included in various forms of detail and usually a simpler definition is possible. However, the more information that can be provided will generally lead to a more accurate simulation. Once in the vehicle design tab new components can be defined either from the ribbon menu at the top of the screen or by right-clicking the component folders in the project tree. Begin by working your way across the ribbon menu and creating components and assemblies. Detail information for each object is provided below.

Icon	Ribbon Menu	Option
	**Library**	Library
	**Stiffness**	New Constant Stiffness Tire New Linear Stiffness Tire
	**Force**	New Constant Friction Tire
	**Tire**	New Tire
	**Chassis**	New Chassis
	**Spring**	New Linear Spring New Non-Linear Spring
	**Bump Stop**	New Linear Bump Stop New Non-Linear Bump Stop
	**Coilover**	New Coilover
	**ARB**	New Linear ARB New Non-Linear ARB
	**Suspension**	New Linear Suspension New Non-Linear Suspension
	**Aerodynamics**	New Simple Aerodynamics New Aerodynamics Map
	**Brakes**	New Simple Brakes
	**Drivetrain**	New Inboard Drivetrain

Detailed Guide

Library

The project tree comes pre-filled with a project library that stores the information for each component. Additional libraries can be added, allowing for better content management if there is more than one distinct vehicle in a project.

Vehicle design

Constant Stiffness Tire

The stiffness of the tires on the vehicle is necessary so that the tire deflection can be accounted for. The constant tire stiffness model assumes that the tire vertical stiffness is a constant and unchanging parameter. In addition to this the unloaded radius and the width of the tire must also be specified. The unloaded radius and width can either be measured or identified from the markings on the tire sidewall.

Input Name	Description
Vertical Stiffness	The vertical stiffness of the tire
Unloaded Radius	The outer radius of the tire while under no load
Width	Nominal width of the tire. This is only used for visualization purposes and does not affect the simulation results.

Vehicle design

Constant Friction Tire

The vehicle simulation in OptimumDynamics relies on knowing the actual forces generated at the tire contact patch for each wheel. To achieve this some form of a tire model is required. The constant friction tire is the simplest type of tire model that OptimumDynamics offers. You have to define the constant friction limit of the tire. The coefficient defined describes the maximum combined lateral and longitudinal friction factor. This can be approximated from physical testing by knowing the maximum lateral acceleration of the vehicle.

$$\mu_{friction} = \frac{a_{max\ lateral}}{a_{gravity}}$$

Input Name	Description
Coefficient of Friction	The maximum coefficient of friction of the tire. For this model it is assumed to be a constant value. It is used for determining the combined lateral and longitudinal tire force

Vehicle design

Tire

This is a tire assembly that is composed of a previously defined tire stiffness model and a tire force model. Generally at least two tire assemblies are created representing the front and rear tires of the vehicle. If you wish to investigate the effect of different tires then you can create additional tire assemblies for each of these.

Input Name	Description
Stiffness Model	The tire stiffness model to be used in the tire
Force Model	The tire force model to be used in the tire

Vehicle design

Chassis

The chassis component is used to define the mass distribution of the vehicle. Either the distribution percentage or individual corner weight readings can be used to achieve this. A value for the center of gravity (CG) height is also required to fully define the vehicle chassis. The corner weight readings are often found by placing the vehicle on setup scales. The center of gravity height can either be estimated or determined experimentally.

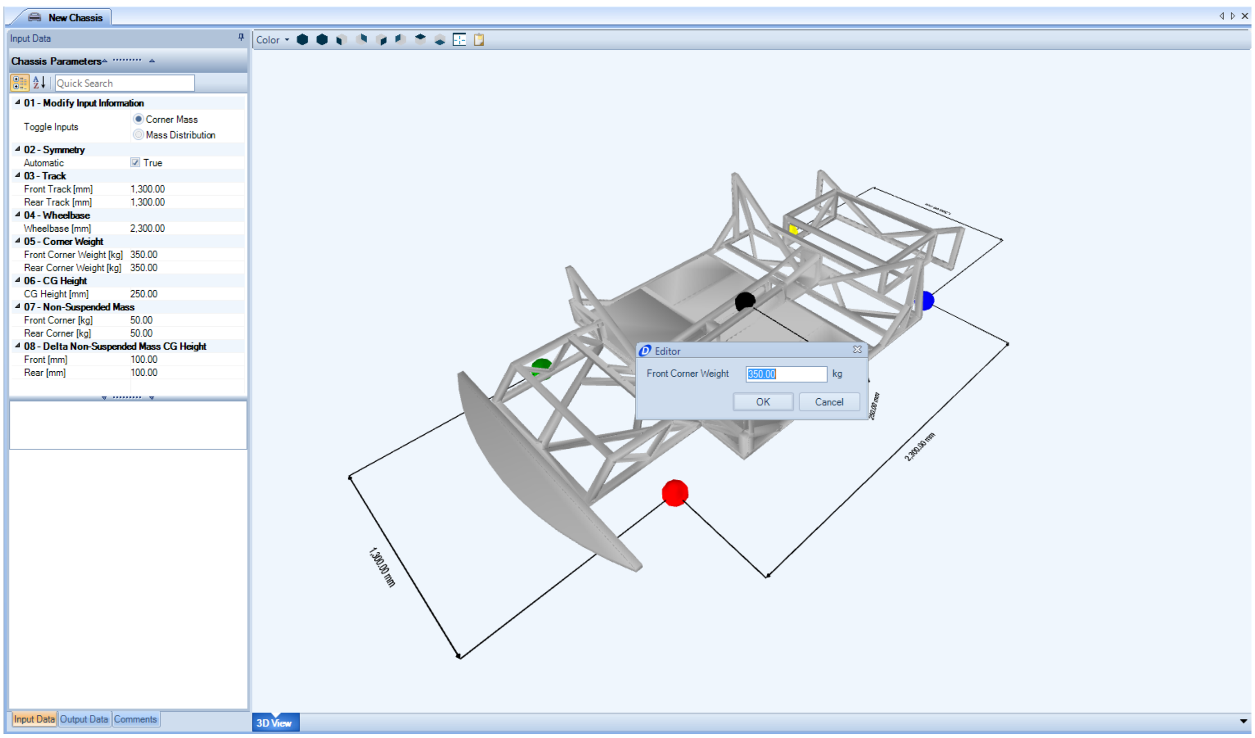
Input Name	Description
Toggle Inputs	Corner Mass – The vehicle longitudinal and lateral CG position is determined based on the measured corner weights Mass Distribution – The vehicle CG longitudinal and lateral position is calculated based on the mass distribution
Symmetry	The vehicle is assumed to be symmetric when this is checked. The left and right side of the vehicle are assumed to be equal in terms of corner weights and the mass distribution is 50:50
Corner Mass [Corner Mass toggled]	Input the weight on each corner of the vehicle if symmetry is unchecked. Input the weight on a single front corner and a single rear corner if checked
Total Mass [Mass Distribution toggled]	The total mass of the vehicle and driver
Mass Distribution [Mass Distribution toggled]	The front to rear % of mass distribution. If symmetry is unchecked then you will also need to enter the left to right % of mass distribution
CG Input	Reference Ride Height – The entered CG height is referenced from the ground plane. The software will re-calculate the CG with respect to the chassis bottom based on the given reference ride heights Chassis Bottom – The entered CG Height is referenced from the bottom plane of the chassis
CG Height	The height of the vehicle CG using the given reference system determined by the CG input toggle
Reference Front Ride Height [Reference Ride Height toggled]	This is the front ride height of the vehicle when the CG height was determined. The front ride height is measured vertically from the front track.
Reference Rear Ride Height [Reference Ride Height toggled]	This is the rear ride height of the vehicle when the CG height was determined. The rear ride height is measured vertically from the rear track.
Non-Suspended Mass	This is the mass of the non-suspended components for that corner or axle depending on your toggled input option.
Delta Non-Suspended Mass	This is the offset of the equivalent CG position of non-suspended components. This offset is positive upwards from the wheel center. This is usually taken to be 0
Front Ride Height	The front ride height in static conditions. This needs to be measured in the same place as that of the Reference Front Ride Height (If selected). This value also corresponds to the front aerodynamic ride height when an aerodynamic map is used in the vehicle setup.
Rear Ride Height	The rear ride height in static conditions. This needs to be measured in the same place as that of the Reference Rear Ride

	Height (If selected). This value also corresponds to the front aerodynamic ride height when an aerodynamic map is used in the vehicle setup.

Another feature of the Chassis object is the 3D visualization. The 3D view displays a generic Chassis with the overall and the equivalent corner masses located and labelled. The size of the spheres change depending on the magnitude of the mass specified.

- Front Left – ● Red
- Front Right – ● Green
- Rear Left – ● Blue
- Rear Right – ● Yellow

The 3D visualization also works as a component editor. By clicking on any of the circles you will bring up the respective property editors.



ABOVE – The chassis 3D view and component editor

Vehicle design

Linear Spring

The vehicle springing is necessary to allow the suspension to operate. Some knowledge of this mechanism is required to determine how much, and in what way the suspension will move when inputs are applied in the simulation.

A linear spring assumes a constant spring rate across the defined operating range. This value is usually given when springs are purchased or it can be determined experimentally.

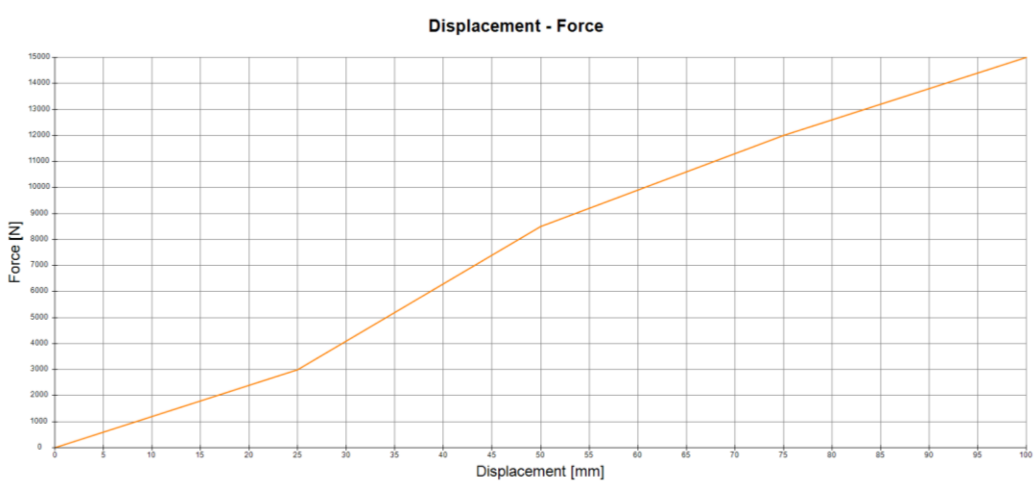
Input Name	Description
Stiffness	The stiffness of the spring
Free Length	The length of the spring under no load
Compressed Length	The minimum length of the spring when fully compressed. This is the length of the spring when binding occurs (the spring can no longer be physically displaced).

Vehicle design

Non-Linear Spring

A non-linear spring model is defined by a set of user defined data points. The data describes the force response of the spring with displacement from its free length. Data should be added that covers the entire possible operating range of the spring from its free length to its compressed length. This data is often determined from physical spring testing.

Input Name	Description
Free Length	The length of the spring under no load
Compressed Length	The minimum length of the spring when fully compressed. This is the length of the spring when binding occurs (the spring can no longer be physically displaced).



LEFT – A nonlinear user defined spring curve

Vehicle design

Linear Bump Stop

Bump stops are a common component seen on dampers. They are used to limit the maximum amount of suspension movement by increasing the effective spring rate when engaged. There are three ways in which bump stop models can be handled in OptimumDynamics.

The first option is to simply leave the bump stop undefined, this is ok if there are either no bump stops in the system or if they do not engage during use.

The second option is too choose a linear bump stop. This works in an identical way to a linear spring where a constant spring rate is assumed over the defined operating range of the bump stop.

Input Name	Description
Stiffness	The stiffness of the bump stop
Free Length	The length of the bump stop under no load
Compressed Length	The minimum length of the bump stop when fully compressed. The bump stop can no longer be physically displaced

Vehicle design

Non-Linear BumpStop

A non-linear bump stop is defined by a set of data points describing the force response with displacement from the bump stop free length. Data should be input that covers the entire possible operating range of the bump stop (from its free length to its compressed length). These curves are often determined from physical testing.

Input Name	Description
Free Length	The length of the bump stop under no load
Compressed Length	The minimum length of the bump stop when fully compressed. The bump stop can no longer be physically displaced

Vehicle design

Coilover

This is an assembly of a previously defined spring and/or bump stop model. In addition to defining the spring and/or bump stop components you will also need to define the corresponding gap or preload.

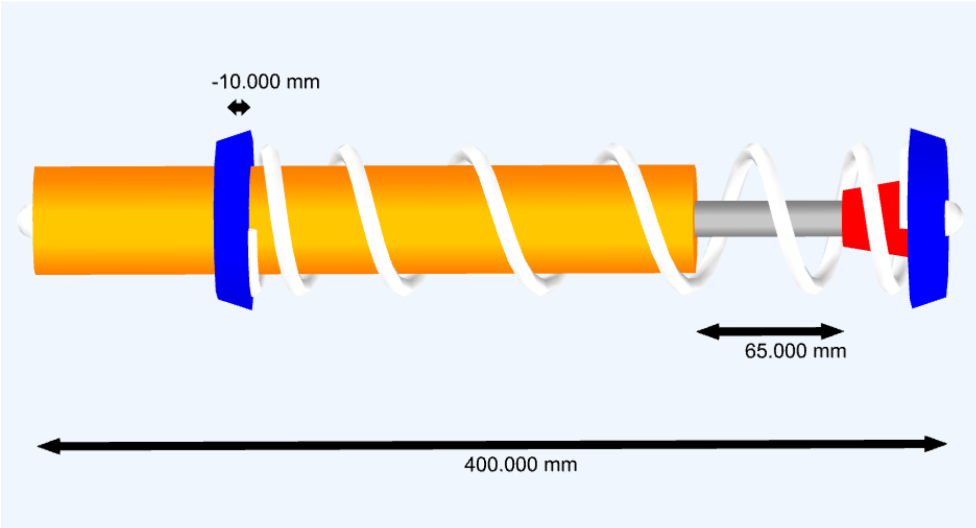
Both the gap and preload are defined with the coilover unattached from the vehicle and fully extended. If the spring rattles loose in the coilover then there will be a positive spring gap. The spring gap describes the distance that the coilover would have to compress before it is in contact with the spring.

If the spring does not rattle loose then there is some static preload and there will be a negative spring gap, you should input a negative value that describes how far the spring is compressed from its free length. If the spring gap is negative then this can also be described by a positive preload force. The preload force corresponds to the force required to compress the spring from its free length to its current length. A similar process is taken for the bump stop. Also note that you cannot define a gap and a preload force as these are equivalent measurements.

It is important that the coilover geometry is also included. This includes the eye to eye length of the coilover when fully extended and the eye to eye length when fully compressed. The free length of the coilover needs to be greater than the free length of the spring you have chosen to install.

The spring and bump stop are considered as springs in parallel when engaged. The engagement point of the bump stop can be defined using the bump stop gap. A negative gap indicates a preload on the bump stop. You can see the overall response of the system in the resulting force vs displacement chart for the coilover.

RIGHT – An example 3D view of a coilover defined in OptimumDynamics



Input Name	Description
Spring	The spring model to be used in the coilover
Spring Gap	The distance between the spring and the coilover mount at full droop. If the spring is loose in the coilover then there is a positive spring gap. If there is static preload on the spring then this should be entered as a negative spring gap
Spring PreLoad	This value represents the preload of the spring. By adjusting this value the spring gap will automatically be set. The preload displacement that is induced by this force cannot exceed the maximum displacement of the spring or coilover
Bump Stop	The bump stop model to be used in the coilover
Bump Stop Gap	The distance between the bump stop and the coilover mount at full droop. This is normally a positive value to indicate that the damper is not preloaded so far as to be touching the bump stop. A negative value here results in a bump stop preload.
Bump Stop PreLoad	This value represents the preload of the bump stop. By adjusting this value the bump stop gap will automatically be set. The preload displacement that is induced by this force cannot exceed the maximum displacement of the bump stop
Free Length	The free length of the damper under no load (eye to eye)
Compressed Length	The minimum length of the coilover when fully compressed. At this point the coilover can no longer be physically displaced

Vehicle design

Linear ARB

The anti-roll bar (ARB) on the vehicle only provides suspension stiffness during vehicle roll and has no effect during heave motion. A linear ARB is assumed to have a constant spring rate over its range of travel. The stiffness of the ARB is taken at the tip of the ARB level arm. This can be calculated knowing the material properties and geometry or it can be evaluated experimentally.

Input Name	Description
Stiffness	The linear stiffness of the tip of the ARB lever arm

Vehicle design

Non-Linear ARB

A non-linear ARB is defined by a set of data points describing the force response with displacement. Data should be input that covers the entire possible operating range of the ARB. These curves are often determined from physical testing.

Input Name	Description
Toggle Inputs	Toggle Inputs. You may choose to enter the Non-Linear information based on the following: Displacement – Force: The force response of the ARB as a function of linear displacement Angle – Force: The force response of the ARB as a function of angular rotation. You must also enter the level arm length when using this option
Lever Arm Length	The length of the ARB arm. This is the perpendicular distance from the end of the ARB to the ARB pivot axis. This is used to calculate the relation between angular and linear displacement of the ARB.

Vehicle design

Linear Suspension

The definition of a suspension is important as it describes the layout and motion of the vehicle. When defining a linear model the geometry of the suspension is not known and is instead defined using linear models to represent camber gain, toe gain and motion ratio. In addition to this you will need to define the roll center heights and anti-effects. Generally both a front and rear suspension are defined for the vehicle.

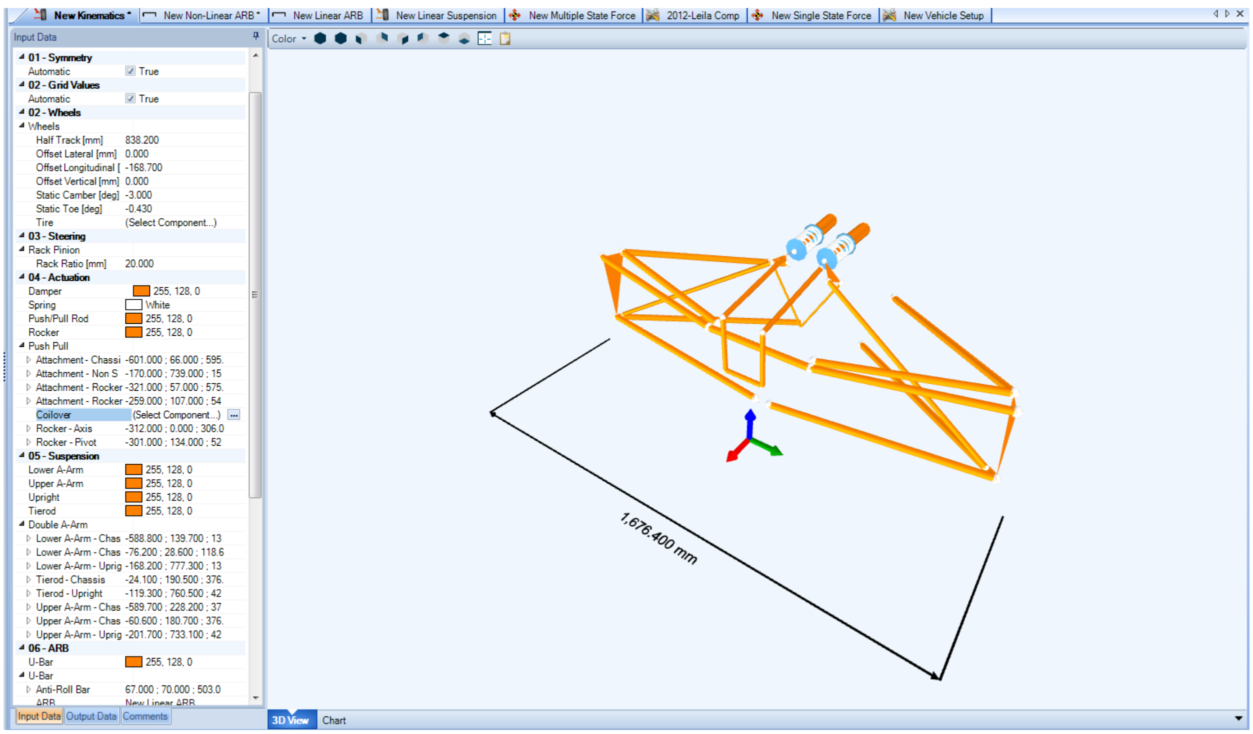
Input Name	Description
Symmetry	The suspension is assumed to be symmetric when this is checked. If the suspension is asymmetric then parameters will need to be defined for both corners of the suspension
Track	The lateral distance between the tire contact patches
Tire	The tire model to be used in the suspension
Static Camber	The static camber angle. A negative value indicates that the top of the tire is leaning inwards towards to the centerline of the chassis.
Camber Gain	The camber change due to suspension movement. A negative value indicates that the camber will become more negative when the vehicle is pushed down.
Static Toe	The static toe angle. A negative number indicates toe-in.
Toe Gain	The toe change due to suspension movement. A negative value indicates that the toe angle will change towards more toe-in when the vehicle is pushed down.
Coilover	The coilover model to be used in the suspension object
Coilover Motion Ratio	This value represents the motion ratio of the coilover (wheel motion/ coilover motion)
ARB [Optional]	The ARB model to be used in the suspension
ARB Motion Ratio [Optional]	This value represents the motion ratio of the ARB (wheel motion/ ARB motion)
Center Element [Optional]	Select a previously defined center element model
Center Element Motion Ratio [Optional]	This value represents the motion ratio of the center element (wheel motion/ center element motion)
Static Roll Center Height	This is the height of the roll center as referenced from the vehicle ground plane (the vehicle is stationary on the ground).
Anti-Effect Percentage	This value represents the percentage of longitudinal weight transfer that will be geometric. The higher this value is the less suspension travel there will be.
Steering – Wheel Displacement	This value is used to determine how far the wheel travels up or down when the steering wheel is turned. A positive value indicates that the inside wheel center will move down
Steering Ratio	This is the ratio of the steering angle to the wheel angle (steering angle / wheel angle)

Non-Linear Suspension

A non-linear model can be described geometrically if you know the 3D location of your vehicles geometry. This requires that you specify the [X, Y, Z] locations and orientation of every suspension component. You will also need to select your Tires, Coilovers and optionally an ARB and Center Element if applicable.

It is also possible to directly import an existing OptimumKinematics file into the project. When using this method the suspension parameters are found by running a full kinematic analysis of the suspension layout.

Detailed information regarding creating a non-linear suspension can be found in Designing a Non-Linear Suspension



ABOVE – A complete 3D geometric definition of a suspension

In the non-linear suspension you can also specify the lookup grid for the kinematics. When a simulation is run with a non-linear suspension the vehicle is first operated geometrically and a lookup table is generated. The grid defines the range for this table and the number of steps. During an actual simulation this lookup table is used for determining new camber, toe etc… If you choose to manually specify the grid then you must ensure that the defined grid will cover the maximum range of suspension motion. You may get an extrapolation or failure error if this is not done.

Input Name	Description
Grid Values – Automatic	When set to true the range of motion of the suspension is automatically calculated. If set to false it is up to you to determine the useable range of motion of the suspension.
Negative Steering	The maximum negative steering allowed by the suspension
Positive Steering	The maximum positive steering allowed by the suspension
Number of Steering Steps	The number of steering steps to calculate between the maximum and minimum set
Wheel Displacement	The maximum positive wheel displacement allowed from the full droop condition (which is determined by coilover free length).
Number of Wheel Displacement	The number of wheel displacement steps to calculate

Vehicle design

Simple Aerodynamics

The option to define the vehicle aerodynamics is possible in OptimumDynamics. This is important for most vehicles as it influences the top speed and the overall vehicle performance. For the simple aerodynamic model the downforce and drag are calculated using the following formulae:

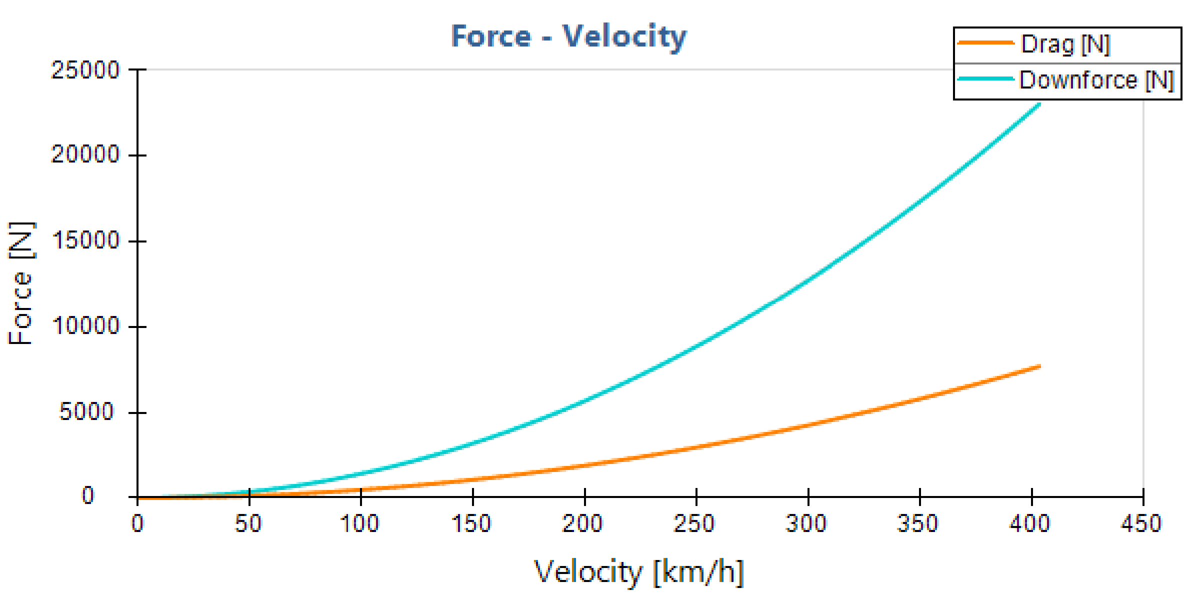
$$F_{downforce} = \frac{1}{2}\rho_{air}v^2 AC_{downforce}$$

$$F_{drag} = \frac{1}{2}\rho_{air}v^2 AC_{drag}$$

Where ρ_{air} is the density of air, v is the vehicle speed, A is the frontal area, $C_{downforce}$ is the coefficient of downforce and C_{drag} is the coefficient of drag. You will need to determine a value for the frontal area of your vehicle and the coefficients for drag and downforce.

You can view the simple aerodynamic map in the adjacent window to determine if the values are correct. Also note that the aerodynamic balance includes the effect of both the downforce and drag forces. So when specifying downforce coefficients or downforce balance, remember that the load transfer effect of the drag is included in this value and is not calculated separately.

Note that the frontal area can also be used as any reference area or set to 1 provided that the coefficients are determined with this in mind.



ABOVE – An example of a simple aerodynamic map

Input Name	Description
Toggle Inputs	You may choose to enter the information as either: • Downforce – Balance – Efficiency [DBE] • Downforce – Drag – Balance [DDB] • Front Downforce – Rear Downforce – Drag [FRD]
Density	The density of air. The default value is 1.2255 kg/m3
Frontal Area	The frontal area of the vehicle. Alternately this is a reference area for the coefficients used.
Downforce Coefficient [DDE or DDD selected]	This value represents the downforce coefficient. A positive number results in downforce
Downforce Balance Front [DDE or DDD selected]	The percentage of the total downforce (including the effect of the drag force) that is reacted by the front axle
Drag Efficiency [DDE or DDD selected]	This is the percentage ratio of downforce over dragforce
Drag Coefficient [DDD or FRD selected]	This value represents the drag coefficient. A positive value results in a dragforce
Front Downforce Coefficient [FRD selected]	The downforce coefficient of the aerodynamics that is reacted by the front axle of the vehicle (including the effect of the drag force)
Rear Downforce Coefficient [FRD selected]	The downforce coefficient of the aerodynamics that is reacted by the rear axle of the vehicle (including the effect of the drag force)

Vehicle design

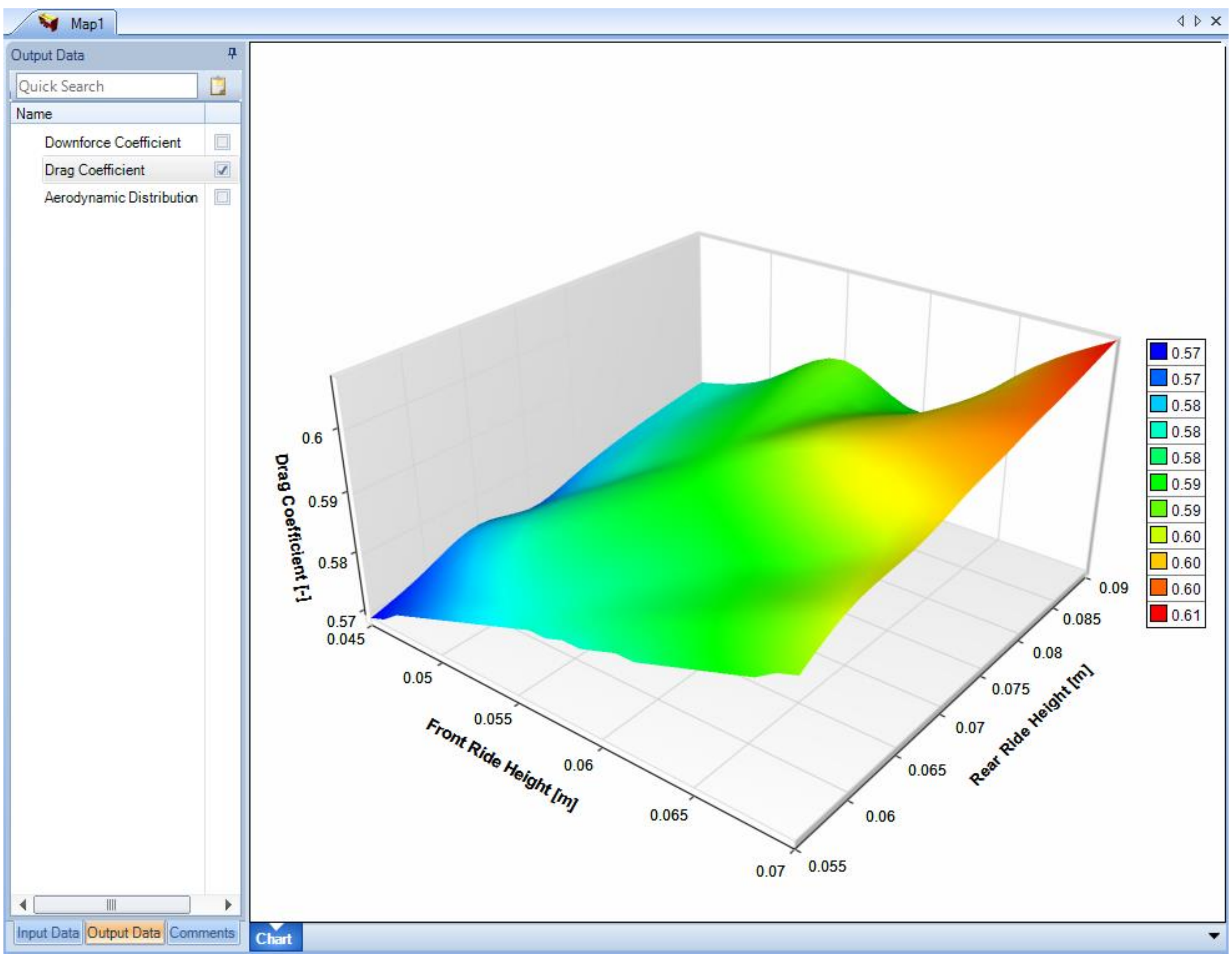
Aerodynamics Map

The vehicle aerodynamics can also be described by defining the downforce, drag and aerodynamic balance as a function of front and rear vehicle ride height. All three parameters should be entered for each combination of front and rear ride height.

Offsets can also be defined for each of the parameters if required. This removes the need to adjust each datapoint individually or having to import a new dataset. The aeromap should be defined for the entire possible range of ride heights as values are not extrapolated in the simulation.

Input Name	Description
Required Inputs	This is how you change between viewing and entering data for downforce, drag and aerodynamic distribution.
Air Density	The density of air. The default value is 1.2255 kg/m3
Frontal Area	The frontal area of the vehicle. Alternately this is a reference area for the coefficients used.
Offset Amount	Offsets every datapoint by the given amount
Offset Multiply	Multiplies every datapoint by the given value.

You can view the aero map as a 3D surface plot. You can either do this from the 'Input Data' tab or from the 'Output Data' tab. By selecting the different checkboxes you can easily visualize the resulting aero map from within OptimumDynamics.



Vehicle design

Simple Brakes

The braking system of the vehicle can be defined simply by the location of the brakes and the distribution of braking force front to rear. The braking distribution is assumed to be constant in this model and does not depend on the hydraulic layout of the actual braking system

Input Name	Description
Brake Location	You can modify whether you have inboard or outboard brakes.
Brake Distribution	This value represents the braking force distribution. For example a value of 70% would indicate that 70% of the braking force comes from the front wheels and 30% comes from the rear wheels. **Note#** This value may not be the same as the brake pressure distribution.

Vehicle design

Inboard Drivetrain

This component describes the drive layout of the vehicle. Three options are currently available including rear-wheel drive (RWD), front-wheel drive (FWD) and all-wheel drive (AWD).

Input Name	Description
Drive Type	FWD – Front Wheel Drive: 100% of the drive torque goes to the front wheels RWD – Rear Wheel Drive: 100% of the drive torque goes to the rear wheels AWD – All Wheel Drive: the drive torque is distributed between the front and rear wheels
Drive Application	Choose between having an inboard or outboard drivetrain
Torque Distribution [AWD Selected]	For an all-wheel drive vehicle this represents the distribution of drive torque that goes to the front wheels

Vehicle design

Simulation

The second stage of an OptimumDynamics project is simulation. In this section a vehicle setup is created based on the previously defined vehicle model. Input motions, forces and accelerations can be defined and/or imported from an Excel/CSV file. Once a vehicle setup and simulation input are defined then a simulation can be undertaken.

The coordinate system and input definitions can be found in this section

[Coordinate System and Simulation Input Definitions]

The following simulation types and function are possible in OptimumDynamics

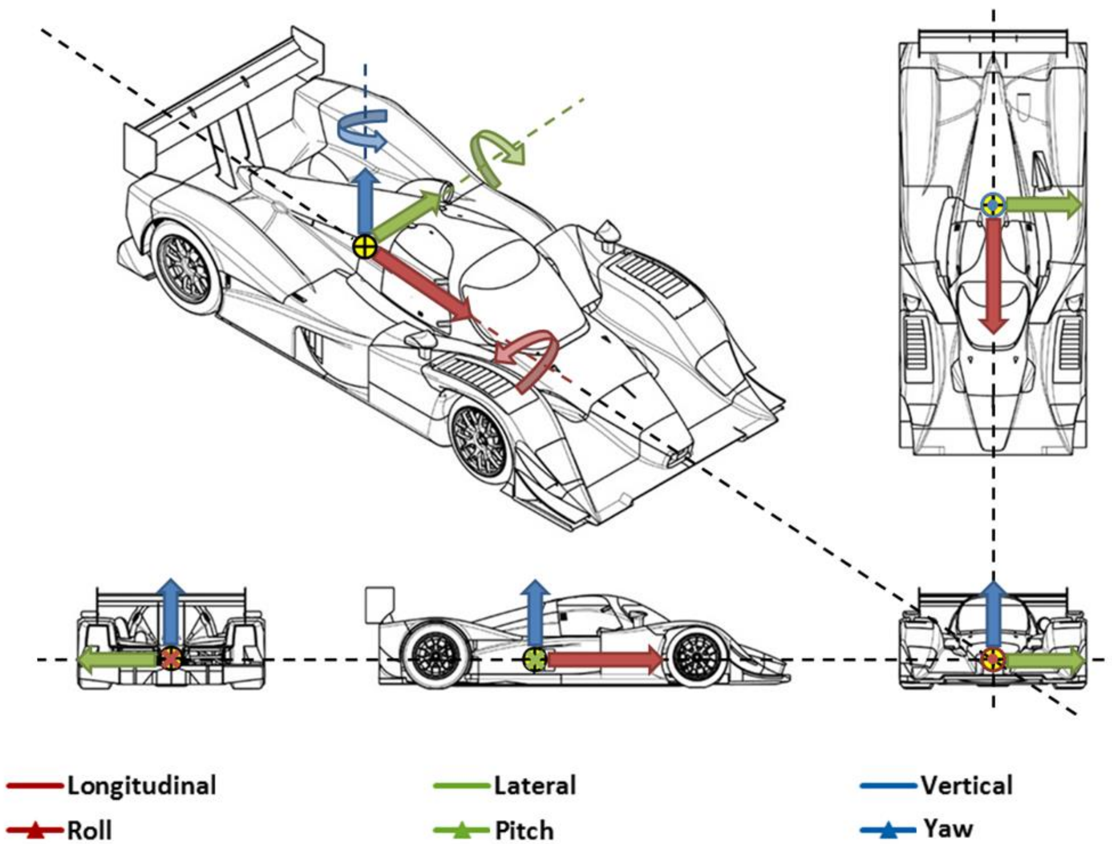
Icon	Ribbon Menu	Option
	**Setup**	New Vehicle Setup
	**Force**	New Single Force New Multiple Force
	**Acceleration**	New Single Acceleration New Multiple Acceleration
	**Simulation**	New Simulation
	**Run**	Run
	**Quick Run**	Quick Run

Detailed Guide

Coordinate System and Simulation Input Definitions

The possible simulation inputs and there definitions are as follows:

Input Name	Description
Steering wheel angle	This is the steering wheel angle in the simulation. A POSITIVE value refers to a LEFT TURN.
Velocity	This is the velocity of the vehicle in the simulation.
Longitudinal force	This is the total longitudinal force applied to the entire vehicle. A POSITIVE value refers to forward ACCELERATION.
Lateral force	This is the total lateral force applied to the entire vehicle. A POSITIVE value refers to a LEFT TURN.
Vertical force	This is the total vertical force applied to the entire vehicle.
Longitudinal acceleration	This is the requested longitudinal acceleration of the vehicle in the simulation. A POSITIVE value refers to forward ACCELERATION.
Lateral acceleration	This is the requested lateral acceleration of the vehicle in the simulation. A POSITIVE value refers to a LEFT TURN.
Vertical acceleration	This is the requested vertical acceleration of the vehicle in the simulation.



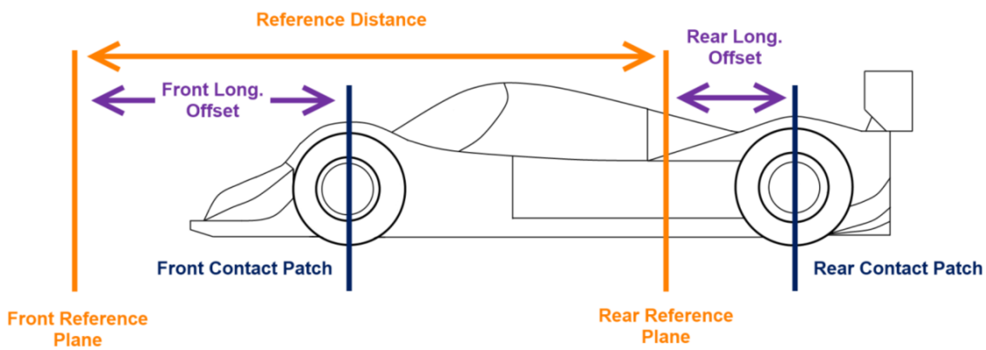
Simulation

Vehicle Setup

The vehicle setup allows you to combine the different components and assemblies that were previously defined into a single vehicle setup. It is also important to give a reference distance between the front and rear suspension.

For a linear suspension the reference distance is simply the vehicle wheelbase. For a non-linear suspension the reference distance is the distance between the front and rear reference planes and is not necessarily the same value as the wheelbase.

RIGHT – Reference distance for a non-linear suspension

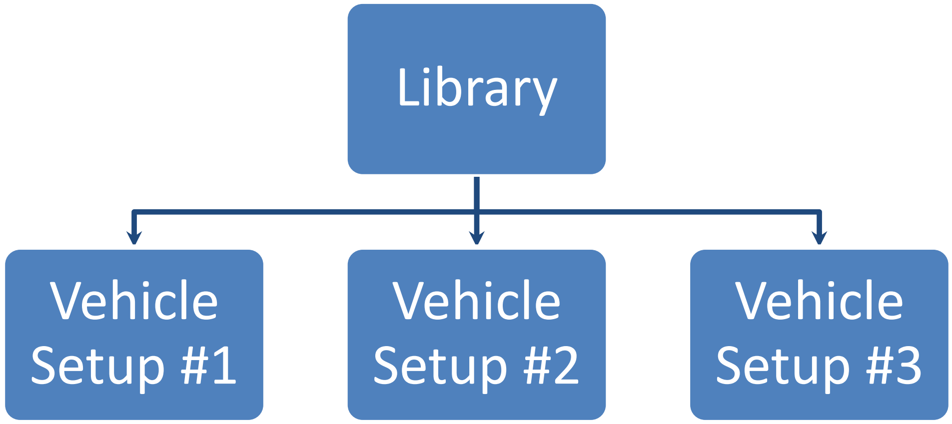


Input Name	Description
Reference Distance	This value represents the distance between the front suspension reference plane and the rear suspension reference plane. For a linear suspension it is equal to the wheelbase

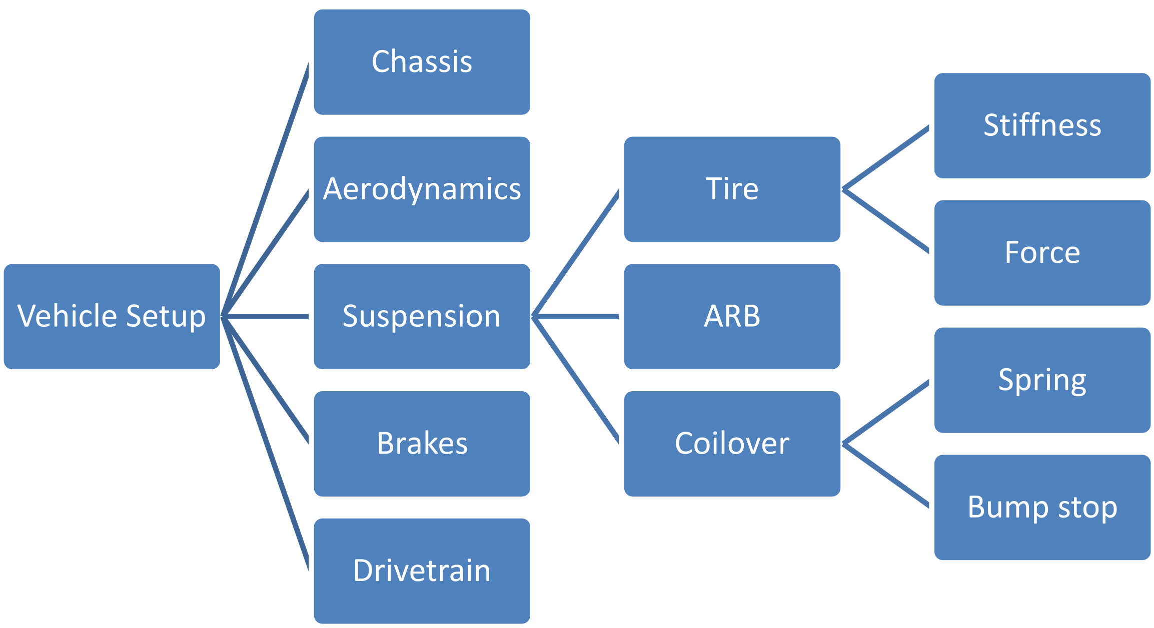
In addition to specifying the reference distance between suspension planes, you must define the vehicle components. You must select a previously defined:

- Chassis
- Aerodynamics (optional)
- Brakes
- Front Suspension
- Rear Suspension
- Drivetrain

Vehicle setups are defined from the components and assemblies in the project library. It is important to note that the components and assemblies defined in the library are not affected by changes in the components in the vehicle setup or vice versa. This is because the vehicle setups are not linked to actual components in the library; they are copied once on creation only. Once loaded, the vehicle setup will **not** automatically update.



If you would like to distribute your vehicle into another project you can export the vehicle setup as a single file. The vehicle setup file contains all of the component information inside it. The vehicle setup can be imported on its own into a project to do simulation and analysis. The below chart shows how the vehicle is described as a hierarchal structure made from sub-assemblies and components that were made as the vehicle design stage.



Simulation

Single Force

The single force type describes a simulation where a single force, steering wheel angle and vehicle velocity is specified. The force is taken to act at the vehicle center of mass. For additional information on defining force inputs see Defining Simulations.

Input Name	Description
Include Gravity	When set to true the gravity is automatically added to the vertical force
Longitudinal Force	This is the total longitudinal force applied to the entire vehicle. A POSITIVE value refers to forward ACCELERATION.
Lateral Force	This is the total lateral force applied to the entire vehicle. A POSITIVE value refers to a LEFT TURN.
Vertical Force	This is the total vertical force applied to the entire vehicle.
Steering Wheel Angle	This is the steering wheel angle in the simulation. A POSITIVE value refers to a LEFT TURN.
Velocity	This is the velocity of the vehicle in the simulation.

Simulation

Multiple Force

This is similar to a single force input except that there is now multiple single force steps defined in the simulation. The option to interpolate between the defined points using a cubic spline is also possible.

Input Name	Description
Cubic Spline	If this is checked then the data points will be interpolated by a cubic spline
Number of Steps	The number of simulation steps
Horizontal Axis Type	The horizontal axis of the simulation plot, this can either be % of completion, distance or time. This is useful if you are playing back actual captured data.
Include Gravity	When set to true the gravity is automatically added to the vertical force

Simulation

Single Acceleration

The single acceleration type describes a simulation where a constant acceleration field is applied to the vehicle. Forces are calculated at the tire contact patch to achieve these accelerations. In addition to this the steering wheel angle and vehicle velocity are also specified. For additional information on defining acceleration inputs see Defining Simulations.

Input Name	Description
Include Gravity	When set to true the gravity is automatically added to the vertical acceleration
Longitudinal Acceleration	This is the requested longitudinal acceleration of the vehicle in the simulation. A POSITIVE value refers to forward ACCELERATION.
Lateral Acceleration	This is the requested lateral acceleration of the vehicle in the simulation. A POSITIVE value refers to a LEFT TURN.
Vertical Acceleration	This is the requested vertical acceleration of the vehicle in the simulation.
Steering Wheel Angle	This is the steering wheel angle in the simulation. A POSITIVE value refers to a LEFT TURN.
Velocity	This is the velocity of the vehicle in the simulation.

Simulation

Multiple Acceleration

This is similar to a single acceleration input except that there is now multiple single acceleration steps defined in the simulation. The option to interpolate between the defined points using a cubic spline is also possible.

Input Name	Description
Cubic Spline	If this is checked then the data points will be interpolated by a cubic spline
Number of Steps	This determines the total number of simulation steps
Horizontal Axis Type	The horizontal axis of the simulation plot, this can either be % of completion, distance or time. This is useful if you are playing back actual captured data.
Include Gravity	When set to true the gravity is automatically added to the vertical acceleration

Simulation

Simulation

You can define a simulation to run. A simulation requires that an input type and a corresponding input file be selected. The simulation definition also requires a vehicle setup that will be used in the simulation.

Input Name	Description
Input Type	The type of simulation that will be run
Vehicle Setup	The vehicle setup to be used in the simulation
Force [Force Toggled]	The force input to be used for the simulation
Acceleration [Acceleration Toggled]	The acceleration input to be used for the simulation

Simulation

Run

Clicking on this button will run a simulation. You must select a previously defined simulation to run and a location and name for the corresponding result file. When running the simulation, a progress bar shows the completion of the simulation. A simulation can be cancelled or stopped at any time. Once the simulation has finished OptimumDynamics will automatically show the Results Tab in the **Document Manager**.

Simulation

Quick Run

Clicking on this button allows you to run a quick run simulation without having to define a simulation beforehand. You need to select a vehicle setup and an input motion, force or acceleration. You also need to input a name for the result file and a location to save it.

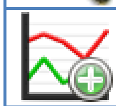
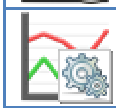
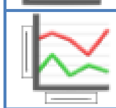
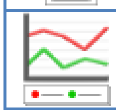
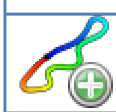
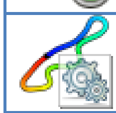
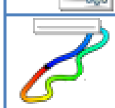
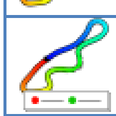
The Quick Run feature is perfect for getting to analysis in a hurry. If you plan on running the same simulation multiple times, it would be beneficial to create an actual simulation file.

The Quick Run feature also allows you to select multiple vehicle setups and/or simulations. By selecting multiple inputs OptimumDynamics will perform a simulation for each combination and a result file will be generated with the vehicle and simulation name for that combination.

Simulation

Analysis

The analysis section of a project provides useful evaluation and visualization tools for analyzing the results of a simulation. Using these tools you are able to investigate all output variables that are calculated during the simulation. The following topics are presented in this section

Icon	Ribbon Menu	Option/ Description
	**Result**	Result
	**Create**	2D Chart
	**Data**	Add/ edit/ remove the series in a chart
	**Title**	Add/ edit the title in a chart
	**Axes**	Add/ edit the axes in a chart
	**Legend**	Add/ edit the legend in a chart
	**Create Table**	Table
	**Create Track Map**	Track Map
	**Data**	Add/ edit/ remove the data in a track map
	**Title**	Add/ edit the title in a track map
	**Legend**	Add/ edit the legend in a track map

Detailed Guide

Result

After a simulation is completed, a result file is created. A preview of the result file can be immediately seen in the **Document Manager** either in table or chart format. The selected channel or channels that are displayed in the preview table or chart is a global setting and will be common for all result files in the project.

By clicking on the result tab result files from other projects can be imported or result files in the current project can be exported. Results can also be exported to an excel CSV file.

Analysis

2D Chart

2D charts allow the graphical plotting of two variables and their relationship to each other. Multiple results can be plotted on one chart, and a secondary axis can also be implemented. Charts are fully customizable using the buttons on the **Ribbon Control Bar** or by clicking inside the **Report Chart** Area.

To create a 2D chart:

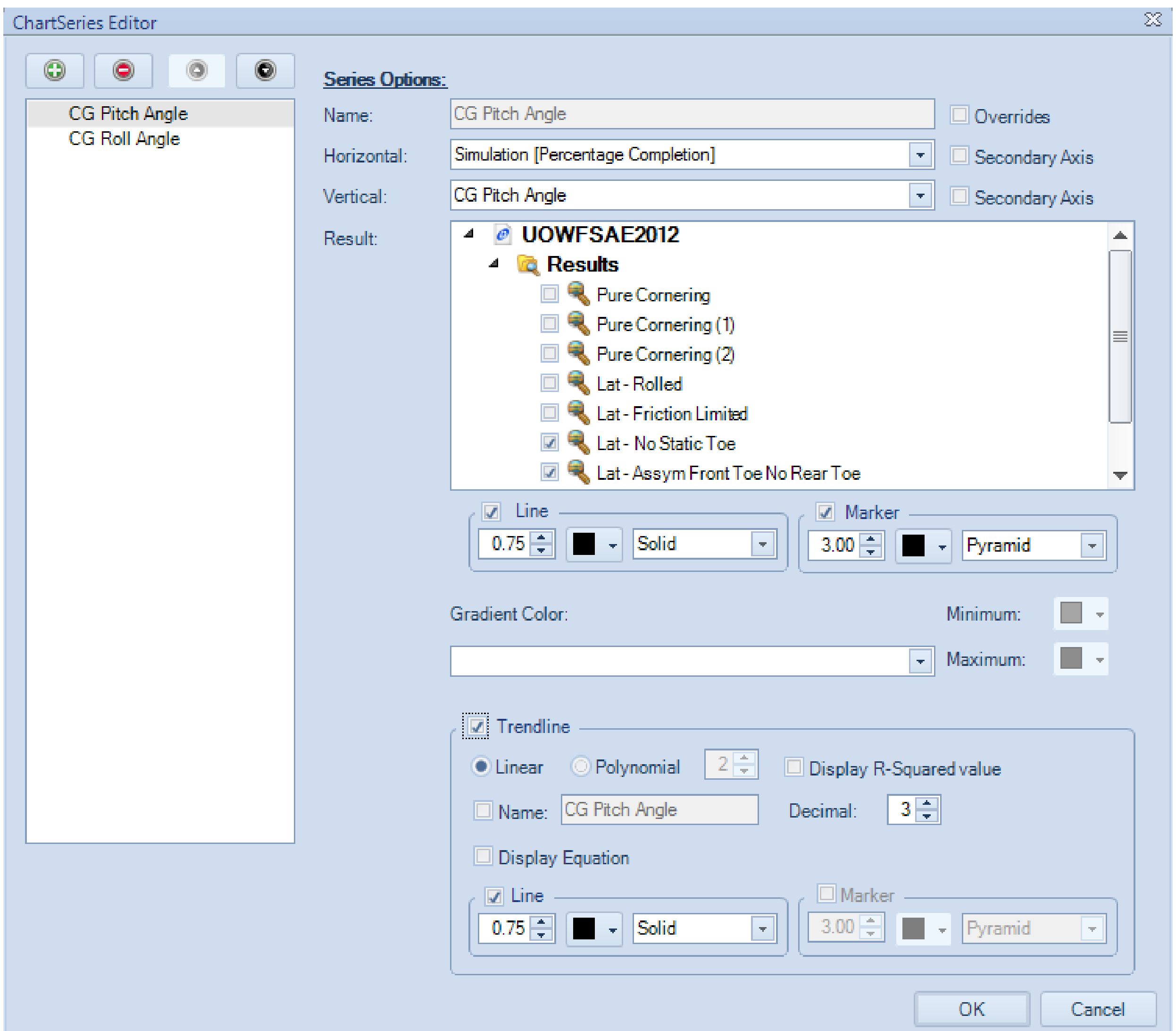
1. Click the **Analysis** section
2. In the ribbon go to the **Charts** group and select **Create** > Select **2D Chart**
3. Enter a name and choose a location for the resulting file

The chart series editor should now be visible. The following options are available for describing the 2D chart. You may also get to the series editor by right clicking in the **Report Chart** area or by selecting the data option from the ribbon menu.

Series Options	Description
Name	This is the name of the series. This can be left as the default name or it can be given a user defined name by checking the Overrides box.
Horizontal	Select what variable is displayed on the horizontal axis. You can also choose whether this should be displayed on the first or secondary axis
Vertical	Select what variable is displayed on the vertical axis. You can also choose whether this should be displayed on the first or secondary axis
Result	Select what result files the series will be plotted for. Each additional result file selected will be another series on the chart
Line	Define the line size, color and type connecting the data points. This can be checked on or off.
Marker	Define the marker size, color and shape of each data point. This can be checked on or off

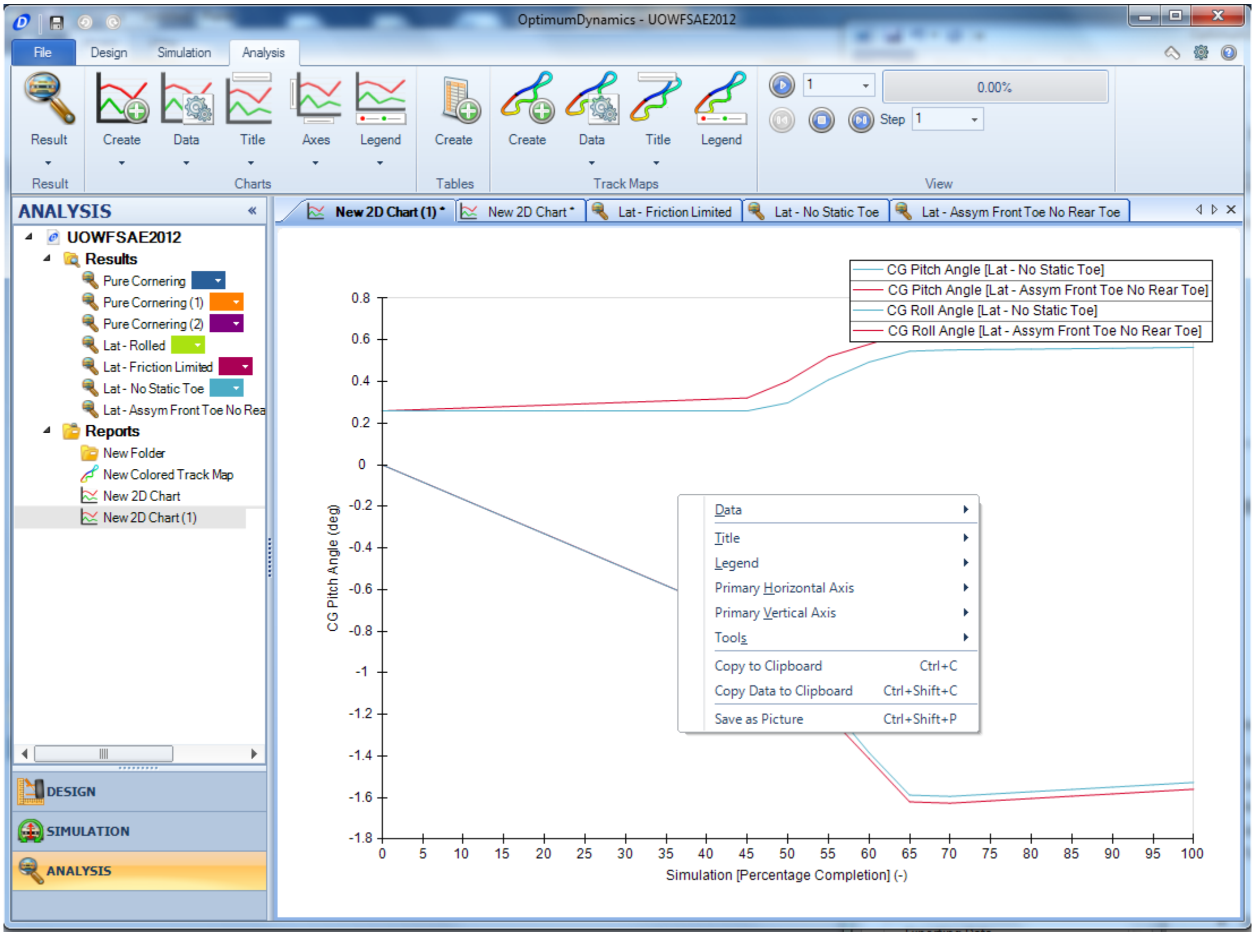
Gradient Color	Gradient color allows you to color a data series based on another output variable. This allows even more information to be displayed on a 2D chart.
Trendline	A Trend-line can be linear or polynomial of the defined order. The R-Squared value can be displayed and is a measure of how well the trendline fits the data. The trendline equation can also be displayed on the chart.

If a chart contains multiple series, it is possible to plot channels against a secondary axis. When graphing a single selected result – the graphed color will be the color selected under 'line options', when multiple results are graphed on the same chart, the graphed color will be that of the color nominated under the results **Project Tree**.



ABOVE - ChartSeries Editor

Each chart can displays results from multiple simulation runs. The selected results can be chosen via the Chart Series editor, via the Data menu option (on the **Ribbon Control Bar**) or by right clicking on the chart. Axis, Title and Legend options are accessible from the **Ribbon Control Bar**.



ABOVE – Shortcut menu for editing 2D charts (right click in the chart area). The same functions can be found in the Charts group in the ribbon menu

Series Options	Description
Data	You can open the series editor from here, add an extra result file to the data or they can clear all result files from the chart.
Title	Select a title font, style, size, color and location by selecting title options
Legend	Choose a location for the legend to display. The legend can also be manually moved by hand
Primary Horizontal Axis	Choose a name, font, style, size and color for the axis. It is also possible to specify the gridline options here.
Primary Vertical Axis	Same as the primary horizontal axis except option refer to the primary vertical axis
Tools	Enable/ Disable the chart zoom and cursor.
Copy to Clipboard	Copy an image of the chart to the clipboard. This can then be pasted into another document or program such as MSWord.
Copy Data to Clipboard	Copies the series names and [X, Y] locations to the clipboard. This can then be pasted into a separate document/ program such as MSExcel.
Save as Picture	Saves the chart as an image with the given name and file type. File formats supported are PNG, JPG, GIF, BMP

A particular area of the chart can be zoomed in on by clicking and holding the left mouse button down and selecting an area of interest. Note that, you need to click and drag down and to the right to zoom. If you drag in any of the other directions you will zoom out. You will notice that a blue square indicates zoom in and a red square indicates zoom out.

The X,Y locations of points of interest can be determined by enabling the **Cursor** option from the tools menu (accessed by right-clicking in the chart area). Simply place the cursor over the interested point and the coordinates will be displayed in the bottom left of the chart area. Note that the values are referring to the primary axis only.

Charts are useful for visualizing the overall trends and behavior of important parameters during a simulation. This behavior can be easily compared with other result files by visual inspection.

Analysis

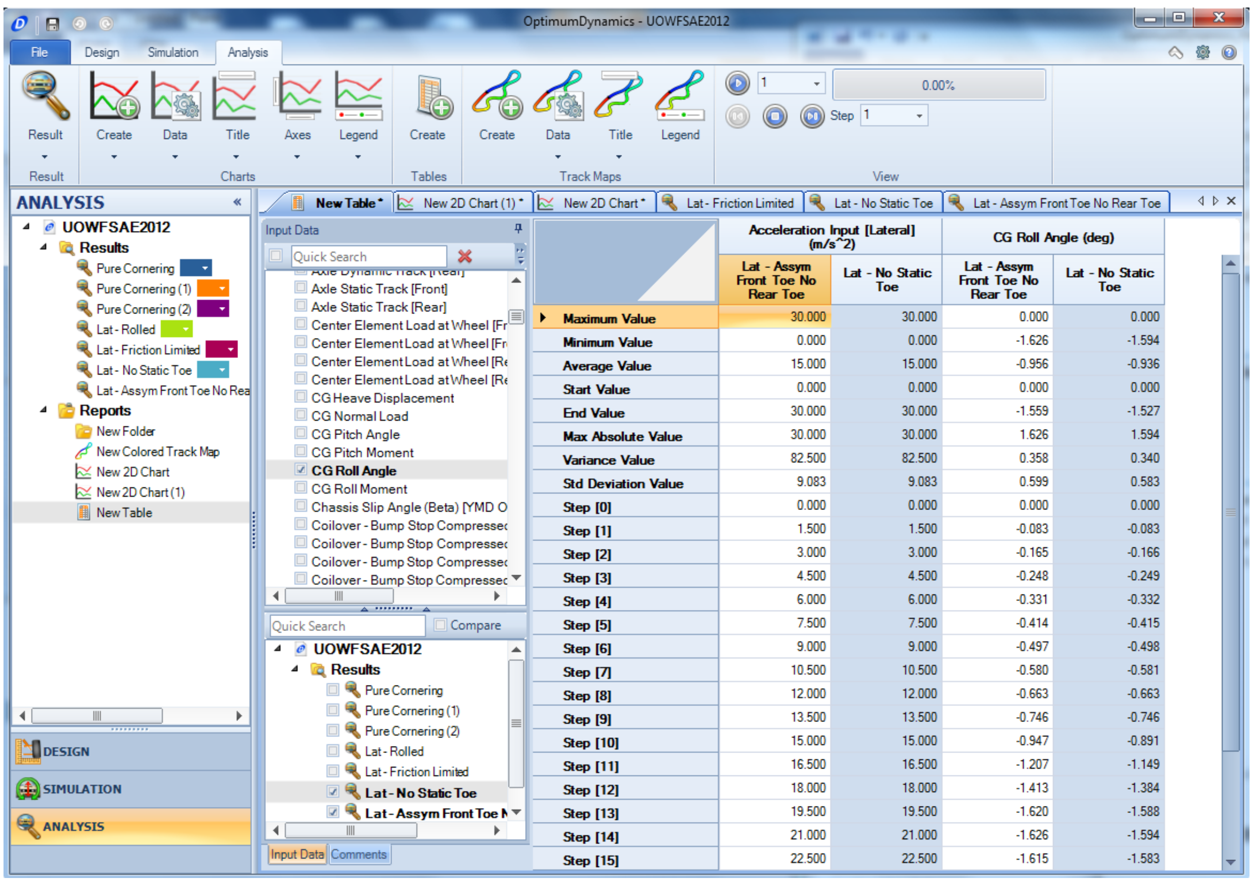
Table

Report Tables allow the tabular display of multiple channels across multiple runs next to each other. Channels for display are chosen through the **Reports Input Data** pane and results are chosen through the Results Input Data pane. Table data can be readily copied to the clipboard (Ctrl + C) for further analysis in external programs if required.

Selecting a channel and a simulation result will display the information in the **Document Manager**. Values for each result will be displayed for each selected channel.

The values shown in a table report can be readily copied to the clipboard, for further processing in Excel or MATLAB®.

Tables are useful for investigating the exact values of parameters during a simulation. The values can be easily compared against other result files by looking across the tables row.



Adding a table will allow you to see the numerical values at each step in the simulation. Tables also include the following calculated values:

Series Options	Description
Maximum Value	The maximum value in the column of data
Minimum Value	The minimum value in the column of data
Average Value	The average value in the column of data
Start Value	The first value in the column of data
End Value	The final value in the column of data
Maximum Absolute Value	The maximum absolute value in the column of data

Analysis

Track Map

One of the most useful visualization tools OptimumDynamics offers is the track map. In the track map you can easily see what the vehicle is doing at different positions during the simulation. Track maps become even more useful when you plot the same track for a different simulation. The result is offset from the track and it is easy to see the changes that have occurred.

To create a track map:

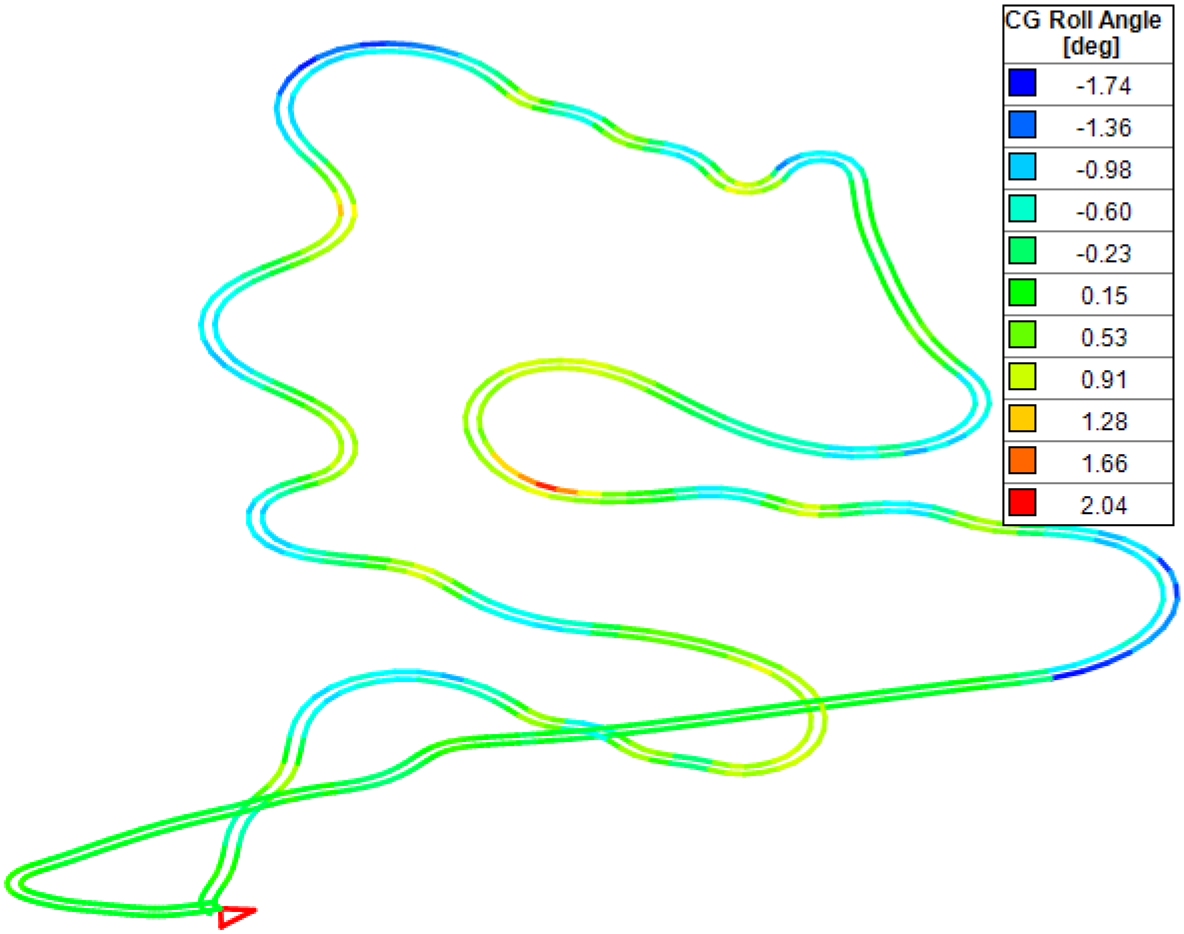
1. Click the **Analysis** section
2. In the ribbon go to the **Track Maps** group and select **Create**
3. **Enter** a name for the report and **select** a location to save
4. Select the result file/s to plot and a variable to color the map by

It is important to note that certain requirements must be fulfilled before a result file can be turned into a track map. The simulation/ result file must have the following channels:

- Distance or time
- Lateral acceleration
- Longitudinal acceleration
- Velocity

Without these channels a track map cannot be created. Specifically simulations that have been defined as a percentage of simulation completion cannot have track maps generated.

One more important thing to note is that only results that have been run on the same simulation can be overlaid. You cannot have two different tracks displayed at the same time. You will notice that when one result is selected the other non-valid ones will become greyed out. This is to indicate that they are not compatible with the selected result file.



ABOVE – A track map demonstrating the side by side comparison of two different simulations.

Analysis

Result Playback

ABOVE - Playback Controls

The playback controls can be found on the **Ribbon Control Bar** when in the analysis section. These controls allow you to visually replay the result file. The playback speed and the step size can be adjusted, and individual frames can be navigated through. Selecting the progress bar directly will allow you to either skip or pan to a specific stage of the motion completion.

Analysis

Output Variable Definitions

The following output variables can be displayed in OptimumDynamics result and report files. The definitions of each of these are also provided and can be seen within the software when viewing result files only. Depending on the type of simulation and vehicle setup are used some of these variables are not accessible.

Output Variables	Definition
Acceleration Input [Lateral]	The applied lateral acceleration in the simulation
Acceleration Input [Longitudinal]	The applied longitudinal acceleration in the simulation.
Acceleration Input [Vertical]	The applied vertical acceleration in the simulation.
Aerodynamic Downforce	The total aerodynamic downforce generated by the vehicle. A negative value means that the vehicle generates lift.
Aerodynamic Downforce [Axle]	The aerodynamic downforce reacted by the axle. A negative value means that the vehicle generates lift.
Aerodynamic Downforce Coefficient	The aerodynamic downforce coefficient. A positive number results in downforce.
Aerodynamic Downforce Distribution	This value represents the percentage of the downforce that is reacted by the front axle.
Aerodynamic Downforce Utilization	The ratio between the current and the maximum aerodynamic downforce coefficient.
Aerodynamic Dragforce	The total aerodynamic dragforce generated by the vehicle. A positive value represents a force in the direction opposite to the vehicle velocity.
Aerodynamic Dragforce Coefficient	The aerodynamic drag coefficient. A positive value results in a dragforce.

Aerodynamic Efficiency	The ratio of aerodynamic downforce / aerodynamic dragforce.
Aerodynamic Pitch Moment	The pitch moment due to the aerodynamic forces (inlcudes downforce and drag effects).
Air Density	The density of air.
All Wheels On Ground	This channel is set '1' when all wheels are in contact with the ground, and '0' when at least one wheel has no normal load on it.
Anti-Effect [Axle]	This describes the effect of kinematic linkages in the system. An anti-effect of 100% indicates that the slope of the side view instant center passes through the vehicle center of mass and there will be minimal spring deflection. An anti-effect of 0% indicates that the side view instant center is on the ground plane and there will be minimal geometric support of the vehicle body.
ARB Displacement [Axle]	The difference in linear displacement between the left and right side of the anti-roll bar.
ARB Force [Axle]	The force at the tip of the ARB arm.
ARB Linear Stiffness [Axle]	The current linear stiffness of the anti-roll bar.
ARB Motion Ratio [Corner]	This is equal to the ratio of wheel displacement over ARB linear displacement.
ARB Motion Ratio [Axle]	This is equal to the ratio of wheel displacement over ARB linear displacement.
ARB Wheel Rate [Corner]	Instantaneous wheel rate of ARB
Axle Normal Load [Axle]	The sum of the axle's tire vertical load.
Axle Rotational Speed	The rotational speed of the driven axle
Bump Stop Displacement [Corner, Axle]	The distance that the Bump Stop has been compressed from its free length. A positive value represents Bump Stop compression.
Bump Stop Force [Corner, Axle]	The force generated due to Bump Stop displacement.
Bump Stop Free Length [Corner, Axle]	The length of the Bump Stop under no load.
Bump Stop Gap [Corner, Axle]	The current distance the coilover must compress before the bump stop is engaged. If this value is negative the bump stop is compressed.
Bump Stop Gap Full-Droop [Corner, Axle]	The static bump stop gap of the coilover as measured at full droop.
Bump Stop Preload Displacement [Corner, Axle]	The displacement of the bump stop due to preload.
Bump Stop Preload Force [Corner, Axle]	The force due to the bump stop preload.
Bump Stop Stiffness [Corner, Axle]	The instantaneous stiffness of the Bump Stop.
Camber Angle [Corner]	The camber angle of the tire. A negative value means the top of the tire leans towards the center of the vehicle.
Camber Gain Heave [Corner]	The camber gain in heave for the corner. A negative value represents an increase in negative camber.
Center Element Motion Ratio [Corner]	This is the ratio of wheel displacement over center element displacement.

Chassis Heave Displacement	The vertical displacement of the center of gravity from its position when the suspension is in full droop.
Chassis Pitch Angle	The pitch angle of the chassis. It includes the suspension and tire displacement.
Chassis Roll Angle	The roll angle of the chassis. It includes the suspension and tire displacement.
CoilOver Displacement [Corner, Axle]	The total axial displacement of the coilover from its free length. This does not include the effect of the installation mount displacement. A positive value represents a compression.
CoilOver Force [Corner, Axle]	The force generated due to coilover displacement. This includes the effect of the bump stop and spring
CoilOver Motion Ratio [Corner]	This is the ratio of wheel displacement over coilover displacement.
CoilOver Preload Force [Corner, Axle]	The total static preload force acting on the CoilOver. It is the combined preload force due to the spring, bump stop and damper gas. This force has to overcome for the CoilOver to displace.
Coilover Stiffness [Corner, Axle]	The effective stiffness of the coilover as a whole.
Contact Patch Location X [Corner]	The position of the tire contact patch from the vehicles center of gravity.
Contact Patch Location Y [Corner]	The position of the tire contact patch from the vehicles center of gravity.
Contact Patch Location Z [Corner]	The position of the tire contact patch from the ground.
Differential Input Torque	Torque delivered to the differential after gearing.
Elastic Force [Corner]	This is the elastic portion of the total vertical force that acts between the vehicle body and the unsprung body. It is due to the deflection of the elastic elements that connect the vehicle body and the corner unsprung bodies.
Elastic Force Ratio [Corner]	This is the ratio of the elastic force over the total vertical force that acts between the vehicle body and the unsprung body.
Front View Instant Center Location X [Corner]	The point where the instant axis (between the wheel and the chassis) crosses the lateral axle plane.
Front View Instant Center Location Y [Corner]	The point where the instant axis (between the wheel and the chassis) crosses the lateral axle plane.
Front View Instant Center Location Z [Corner]	The point where the instant axis (between the wheel and the chassis) crosses the lateral axle plane.
Frontal Area	The frontal area of the vehicle used in the calculations for the aerodynamic model.
Geometric Force [Corner]	This is the geometric portion of the total vertical force that acts between the vehicle body and the unsprung body. It is due to the direct kinematic connection between the vehicle body and the corner unsprung bodies. Geometric Force does not cause deflection of the elastic elements that connect vehicle body and the corner unsprung bodies.

Geometric Force Ratio [Corner]	This is the ratio of the geometric force over the total vertical force that acts between the vehicle body and the unsprung body.
Lateral Load Transfer Distribution	The ratio of front lateral load transfer to the total lateral load transfer due to all external inputs. If negligible or no load transfer is occurring, the solver will return NaN.
Lateral Velocity	Lateral Velocity of the Chassis in Chassis x-y coordinates
Load Distribution [Cross]	The sum of the front left and rear right tire normal load divided by the total tire normal load.
Load Distribution [Axle]	The sum of the front left and front right tire normal load divided by the total tire normal load.
Load Distribution [Left]	The sum of the front left and rear left tire normal load divided by the total tire normal load.
Longitudinal Velocity	Longitudinal Velocity of the Chassis in Chassis x-y coordinates
Non-Suspended Mass [Corner]	The static non-suspended mass of the corner.
Resultant Lateral Acceleration	The resultant achieved lateral acceleration of the vehicle.
Resultant Longitudinal Acceleration	The resultant achieved longitudinal acceleration of the vehicle.
Resultant Vertical Acceleration	The resultant achieved vertical acceleration of the vehicle.
Ride Height [Axle]	The vertical displacement of the vehicle as measured at the front/rear track.
Roll Angle [Axle]	The roll angle of the vehicle chassis about the longitudinal axis. This is the sum of the tire and suspension roll angle.
Roll Center Height [Axle]	The geometric roll center height at the front/ rear plane of the vehicle.
Side View Instant Center Location X [Corner]	The point where the instant axis (between the wheel and the chassis) crosses the longitudinal axle plane.
Side View Instant Center Location Y [Corner]	The point where the instant axis (between the wheel and the chassis) crosses the longitudinal axle plane.
Side View Instant Center Location Z [Corner]	The point where the instant axis (between the wheel and the chassis) crosses the longitudinal axle plane.
Simulation Input [Steering]	This is the applied steering wheel angle for the simulation.
Simulation Input [Velocity]	The input velocity for the simulation.
Solver Converged	A value of '1' means a successful solution for the vehicle was found based on the given simulation inputs. A value of '0' means a valid solution for the vehicle was not possible.
Solver Convergence Error	The sum of convergence errors.
Solver Time To Solve (Iteration)	The time taken to solve the particular iteration.
Solver Total Iterations	The total number of iterations required to reach a solution.
Spring Displacement [Corner, Axle]	The distance that the Spring has been compressed from its free length. A positive value represents Spring compression.
Spring Force [Corner, Axle]	The force generated due to Spring displacement.
Spring Free Length [Corner, Axle]	The length of the Spring under no load.

Spring Gap [Corner, Axle]	The current distance the coilover must compress before the spring is engaged. If this value is negative the spring is compressed.
Spring Gap Full-Droop [Corner, Axle]	The static spring gap of the coilover as measured at full droop.
Spring Preload Displacement [Corner, Axle]	The displacement of the spring due to static preload.
Spring Preload Force [Corner, Axle]	The force due to the spring preload.
Spring Stiffness [Corner, Axle]	The instantaneous stiffness of the Spring.
Spring Wheel Rate [Corner]	Instantaneous Spring Wheel Rate
Static Camber Angle [Corner]	The static camber angle of the corner as measured on a setup pad.
Static Corner Force [Corner]	The static corner force.
Static Ride Height [Axle]	The ride height in the static vehicle position.
Static Roll Center Height [Axle]	The roll center height in the static vehicle position.
Static Suspended CG Location X	The static position of the vehicle suspended center of gravity.
Static Suspended CG Location Y	The static position of the vehicle suspended center of gravity.
Static Suspended CG Location Z	The static position of the vehicle suspended center of gravity.
Static Toe Angle [Corner]	The toe angle of the tire in the static vehicle position.
Static Total Non-Suspended Mass CG Location X	The position of the total non-suspended mass center of gravity from the total vehicle center of gravity in the static vehicle position.
Static Total Non-Suspended Mass CG Location Y	The position of the total non-suspended mass center of gravity from the total vehicle center of gravity in the static vehicle position.
Static Total Non-Suspended Mass CG Location Z	The position of the total non-suspended mass center of gravity in the static vehicle position.
Static Track Width [Axle]	The lateral distance between the tire contact patches in the static vehicle position.
Static Weight Distribution [Cross]	The sum of the front left and rear right weight divided by the total weight.
Static Weight Distribution [Axle]	The sum of the front left and front right weight divided by the total weight.
Static Weight Distribution [Left]	The sum of the front left and rear left weight divided by the total weight.
Static Wheelbase [Left]	The longitudinal distance between the tire contact patches in the static vehicle position.
Static Wheelbase Average	The average wheelbase of the vehicle in the static position.
Steered Angle [Axle]	This is the steering angle before the rack.
Suspended CG Location X	The suspended mass center of gravity.
Suspended CG Location Y	The suspended mass center of gravity.
Suspended CG Location Z	The suspended mass center of gravity.

Suspended Mass	The suspended mass of the vehicle.
Suspension Displacement [Corner]	Relative displacement between the wheel and the chassis.
Suspension Pitch Angle [Left]	The pitch angle due to the suspension movement only. This does not include the pitch angle due to the tire deflection.
Suspension Roll Angle [Axle]	The roll angle due to suspension movement only. This does not include the roll angle due to tire deflection.
Tire Deflection [Corner]	The vertical displacement between the contact patch and wheel center.
Tire Force X [Corner]	The X components of the force generated at the tire contact patch.
Tire Force Y [Corner]	The Y components of the force generated at the tire contact patch.
Tire Force Z [Corner]	The Z components of the force generated at the tire contact patch.
Tire Heave	The contribution to the total vehicle heave displacement that is due to tire deflection.
Tire Lateral Friction Coefficient [Corner]	The lateral coefficient of friction of the tire.
Tire Loaded Radius [Corner]	The vertical distance from wheel center to ground.
Tire Longitudinal Friction Coefficient [Corner]	The longitudinal coefficient of friction of the tire.

Analysis

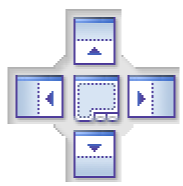
Additional Information

The following sections are presented

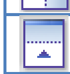
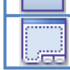
Document Overview

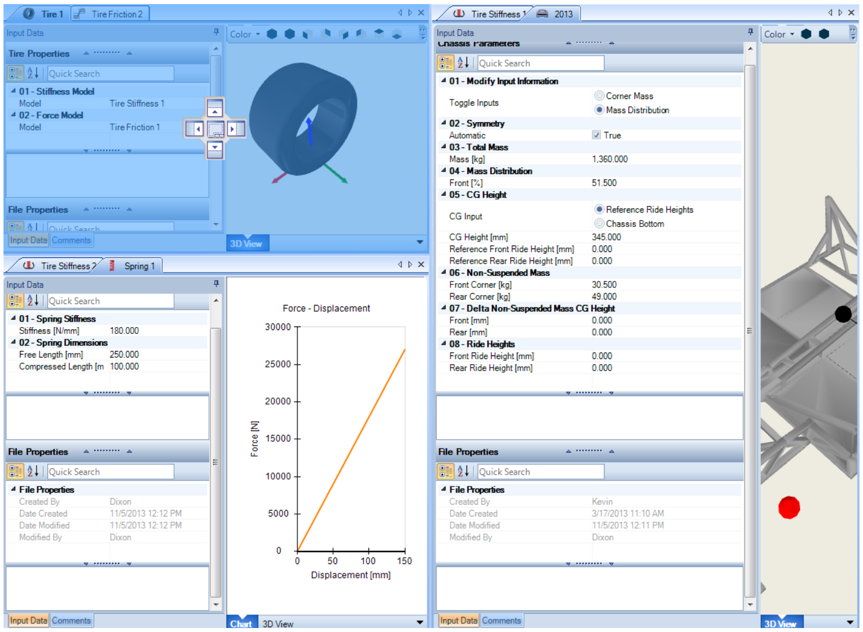
Document Manager / Workspace

It is possible to easily re-configure and arrange the worktabs in the document manager. More than one worktab can be open at a time. To achieve this click on a worktab and drag, you will notice the following menu will appear



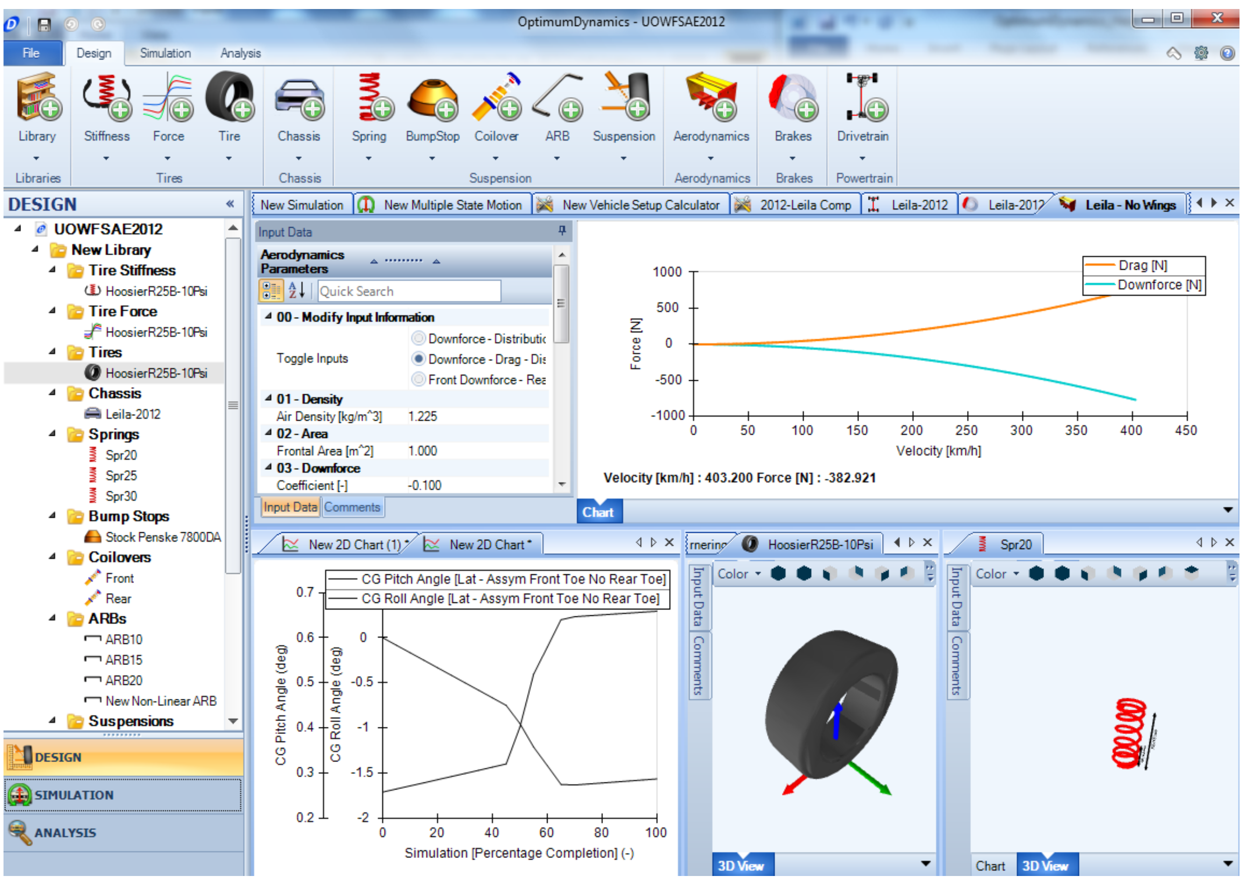
Continue to drag the worktab and hover over one of these menu icons. The worktab will be re-arranged according to which option was selected

Icon	Description
	Places the document in the right section of the current view
	Places the document in the top section of the current view
	Places the document in the left section of the current view
	Places the document in the bottom section of the current view
	Places the document in the current view



LEFT – A project using the work tab manager

BELOW – A project taking advantage of the document manager



Additional Information

Importing/ Exporting Data

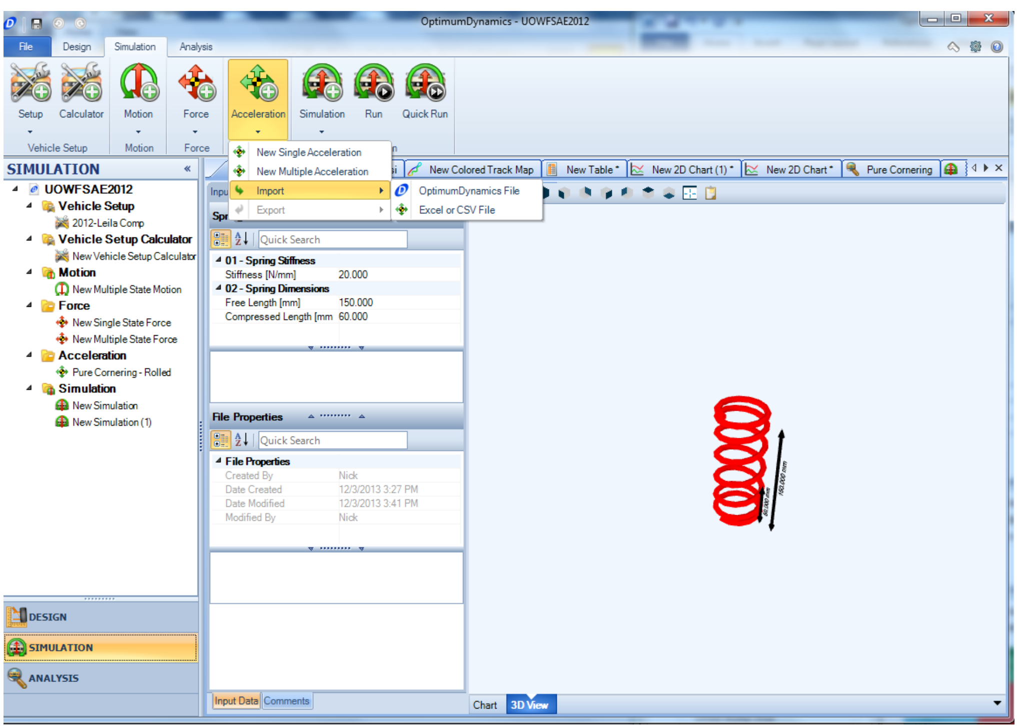
Use the Import and Export features to save and reuse your vehicle setups. You will notice that when it is time to Export the vehicle setup you have two options for the file type:

- OptimumDynamics File
- Binary File

The default .O2Veh setup files that can be found inside your project directory, (located on your hard drive) only contain information on which suspension files are in use, and the corresponding reference distance.

To import a vehicle setup you simply highlight **Setup** from the **Design Tree**, click on the **Import** button located on the **Ribbon Control Bar**, select the file that you would like to import and click Open when you are finished.

All objects in OptimumDynamics can be imported or exported as single files. This makes merging projects or distributing information easier between multiple users and/or projects. The import/ export option can be found in all of the ribbon menu pull-downs or by right-clicking on the relevant folder/ file in the project tree.



ABOVE – An example of an import/ export menu for an acceleration input. For this particular item the data can be imported from either a OptimumDynamics file or from an Excel/ CSV file.

All objects in OptimumDynamics can be exported from within the program

1. In the project tree right click an object
2. Select **Export**
3. Select **OptimumDynamics** File
4. Choose a file location and a file name
5. Click **Save**

Alternately

1. In the project tree left click an object
2. Select the corresponding object tab from the ribbon menu
3. Select **Export**
4. Select **OptimumDynamics** File
5. Choose a file location and a file name
6. Click **Save**

An entire library of vehicle design components can be exported easily in this way also.

Data can be imported from previously saved OptimumDynamics files or from other projects

1. Select the corresponding object tab from the ribbon menu
2. Select **Import**
3. Browse to the relevant **OptimumDynamics** File
4. Select **Open**

Alternately

1. **Right click** the corresponding object folder from the project tree
2. Select **Import**
3. Browse to the relevant **OptimumDynamics** File
4. Select **Open**

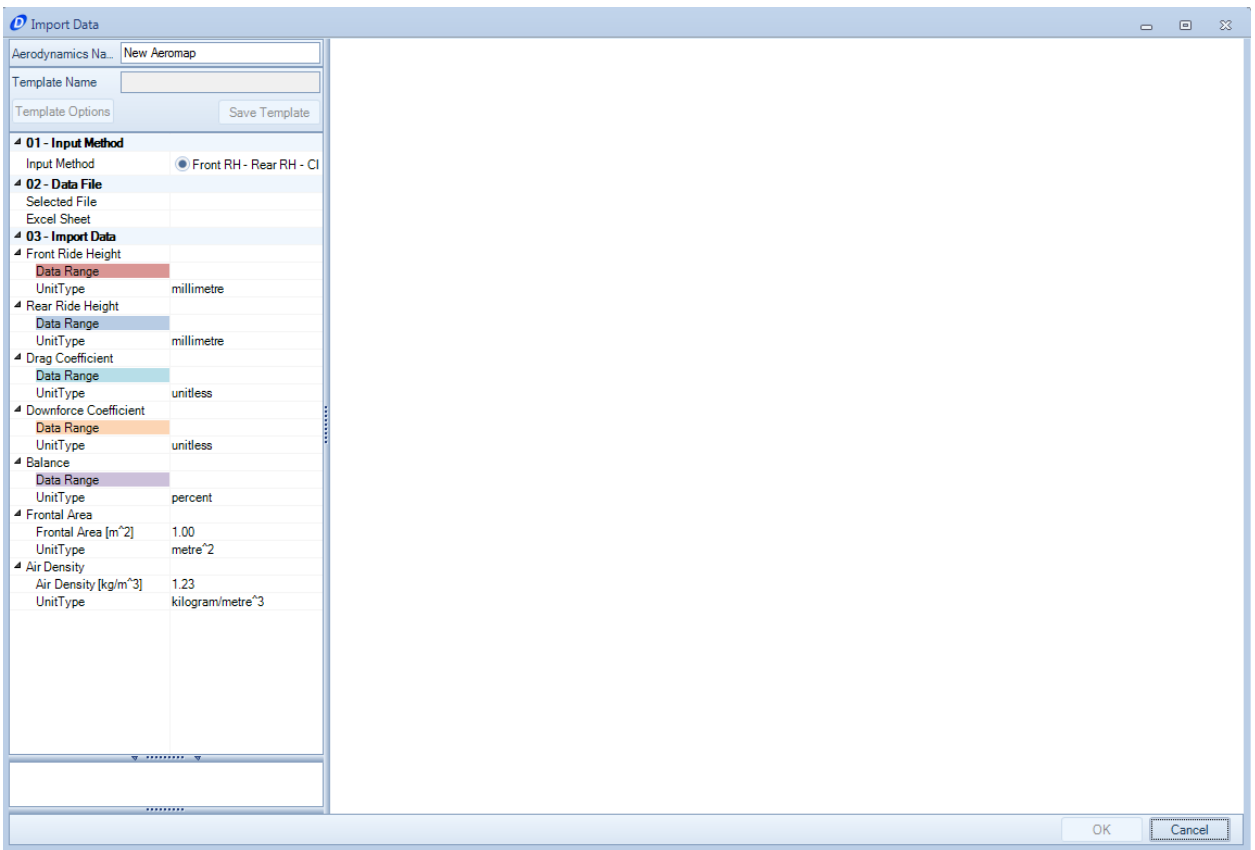
Data can be imported from an external Excel/ CSV file in the definition of the following vehicle design components:

- Spring
- Bump Stop
- ARBs
- Aerodynamics

Data from an external Excel/CSV file can also be used for defining:

- Force input
- Acceleration input

A similar importing process is followed for all of these components. A detailed example is given for importing an aerodynamic map.

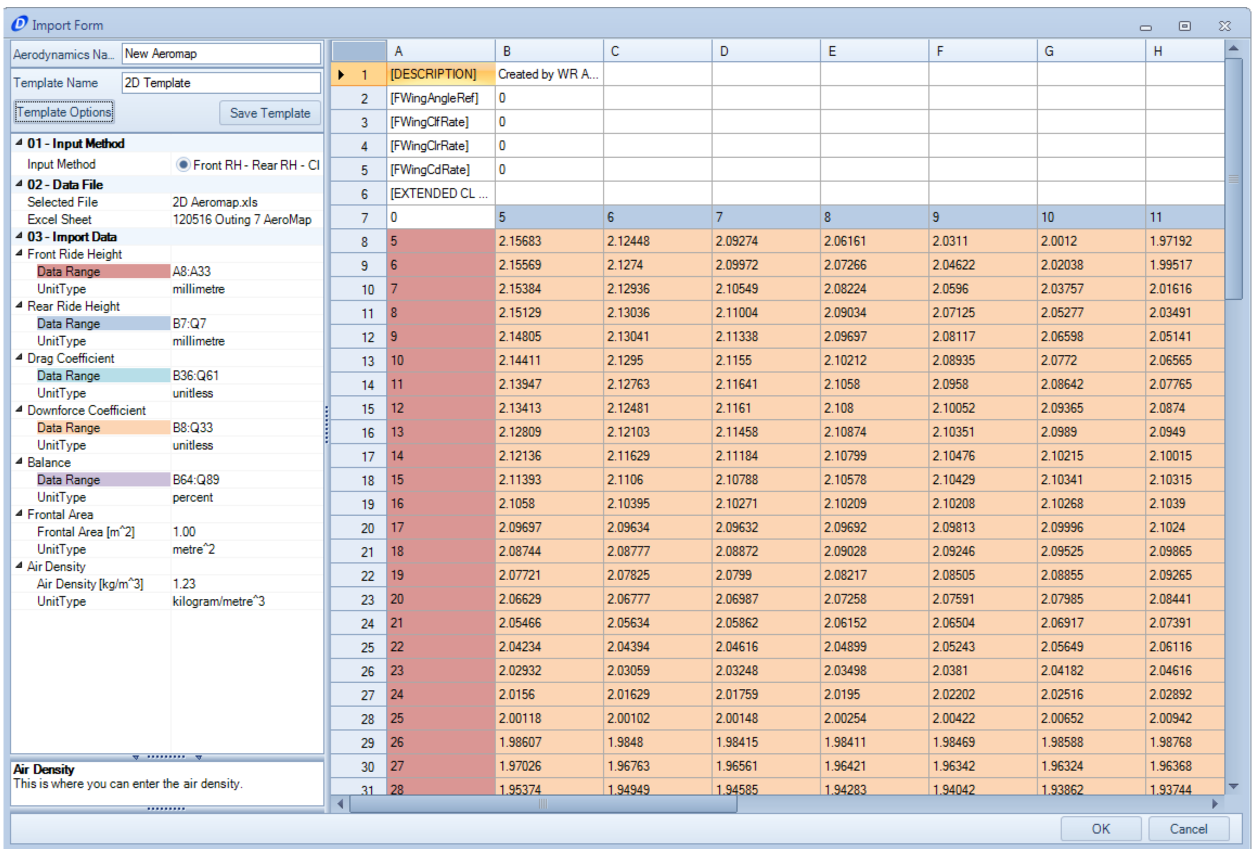


ABOVE – The Import Data screen for an aeromap

Looking at the Inputs that are required:

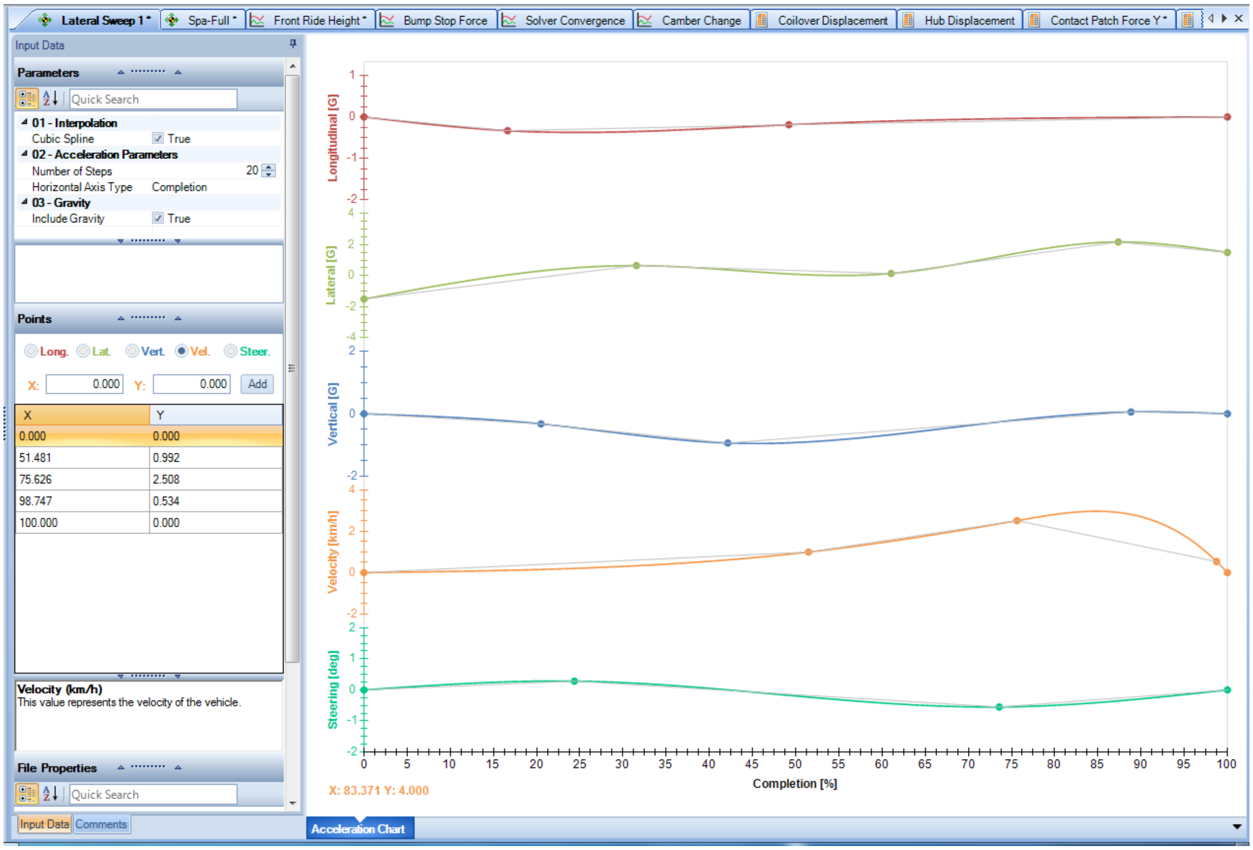
Input Name	Description
Input Method	For some objects it will be possible to enter information in multiple different ways. You can select the method that matches the dataset being imported.
Data File	In this section the Excel/CSV file location should be selected. The relevant worksheet containing the data should also be selected.
Import Data	For each of the required input ranges a column of data should be selected. The units that the data is presented in should also be selected here. Any other relevant information also needs to be entered here before the import is allowed.

Upon selecting all of the necessary data the form will now appear in full:



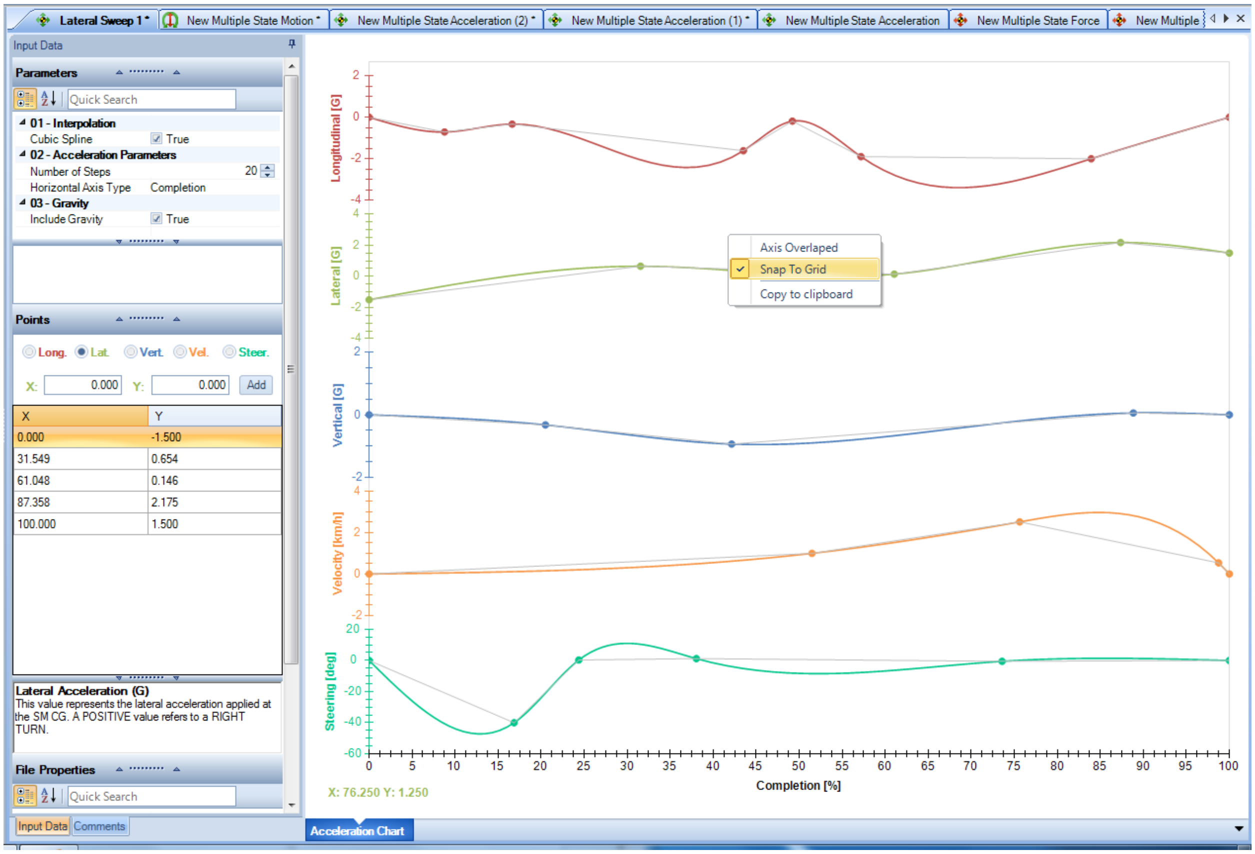
At this point, now that you have selected the data you can save this template for later use so that you don't have to keep manually selecting the data every time you want to import information. Once you click 'OK' the object will be created and added to your library.

Additional Information



ABOVE – An example of a multiple input acceleration profile

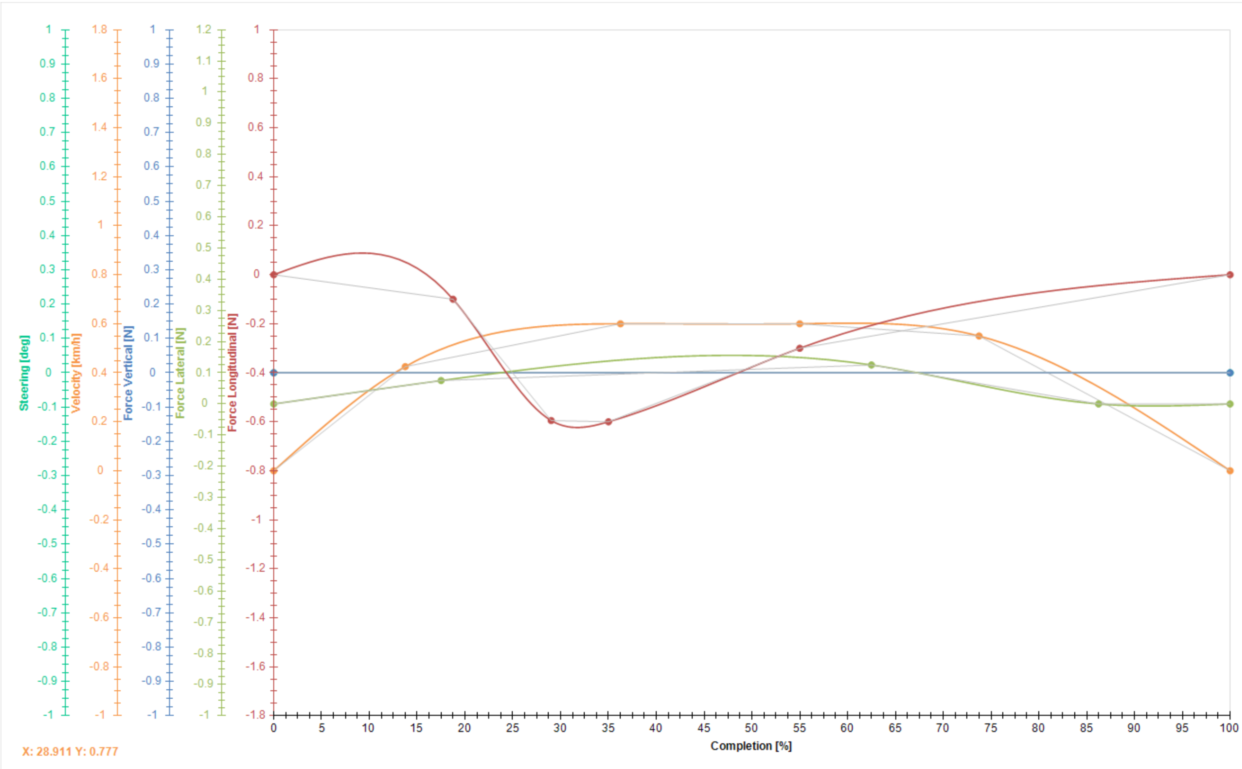
Points can also be added by clicking on the plot area. Click once to make the plot active. Click a second time and the datapoint will be added and can be adjusted to exact values in the data input area. The [X, Y] position is shown in the bottom left.



ABOVE – Snap to grid option for defining multiple input types

There is also the option to snap newly created points to the grid positions:

1. **Right Click** inside the charting window
2. **Select** 'Snap To Grid'



ABOVE – A multiple motion input type showing the display for the axis overlapped option

It can also be helpful to overlay all of the plots in a single chart. This can be achieved by

1. **Right Click** inside the charting window
2. **Select** 'Axis Overlapped'

It is also possible to manually zoom in/out of the plots using the mouse wheel.

Additional Information

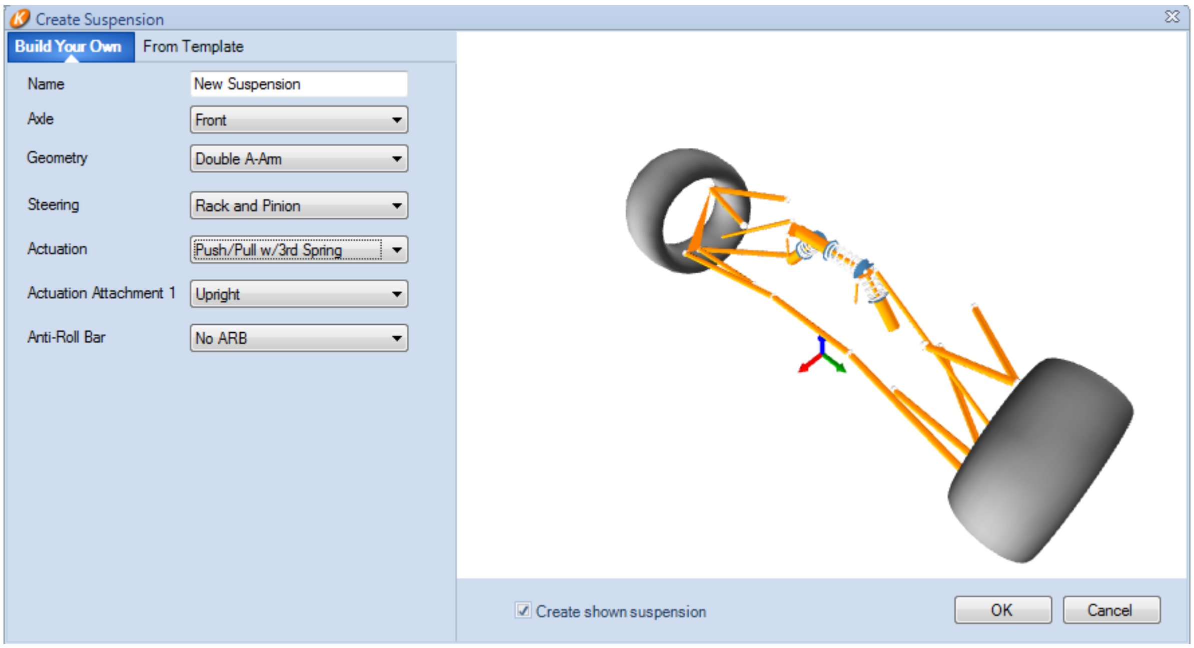
Designing a Non-Linear Suspension

If you are familiar with OptimumKinematics then you should have no issues with designing or importing a 3D geometric suspension design. For those unfamiliar with the process the following sections describe in additional detail what is required.

Additional Information

Creating a suspension

After a non-linear suspension has been added to the project you will be presented with the following screen that is used to define the particular suspension type that is being created.



ABOVE - Creating a Suspension

OptimumKinematics has many premade front and rear suspension setups to choose from. Within the suspension setups you maintain the ability to modify any of the existing setups or create a suspension setup from scratch. The following options are available to specify the suspension type and combination when made from scratch.

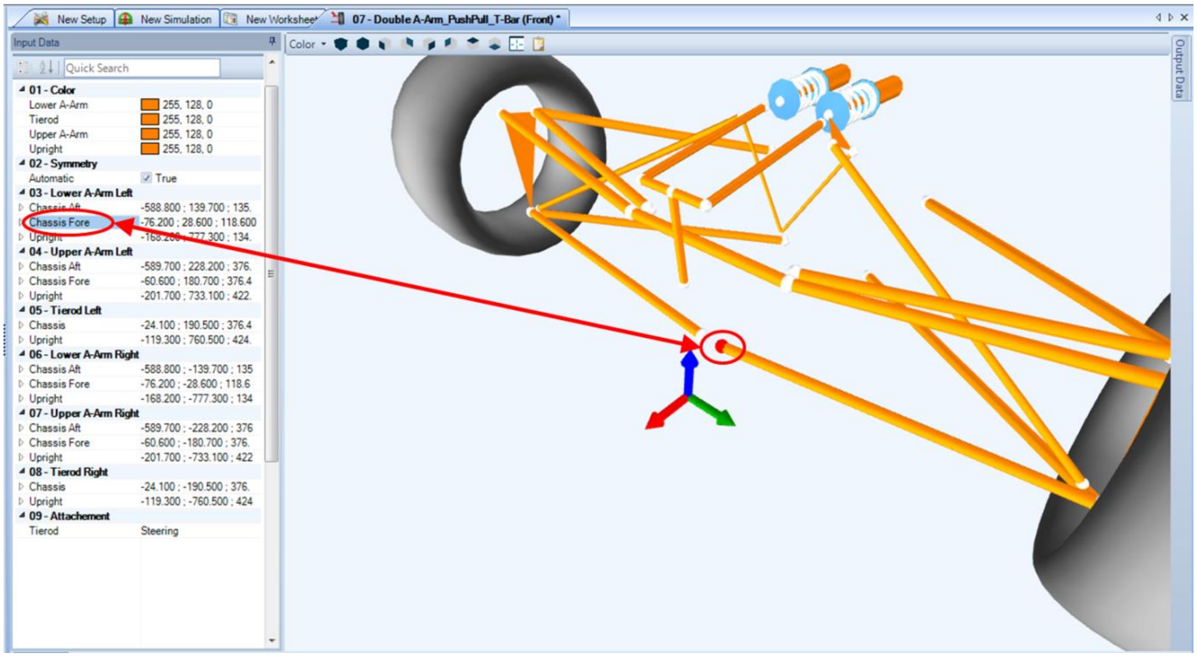
Input Name	Description
Axle	Is the suspension design for the front or rear of the vehicle?
Geometry	The type of suspension geometry, including • Double A-Arm • MacPherson • Live Axle, 2 A-Arms **[Rear Only]** • Five Links **[Rear Only]** • MacPherson Pivot Arm **[Front Only]** • Live Axle, 2 Trailing Arms with Panhard Bar **[Rear Only]** • Live Axle, 4 Trailing Arms with Watts Linkage **[Rear Only]**
Steering	The type of steering system **[Front Only]** • Rack and Pinion • Recirculating Ball
Actuation	The type of actuation system including: • Direct CoilOver • Separate Springs/Dampers • Push/Pull • Torsion Bar • MonoShock Rotational • MonoShock Slider • Push/Pull w/ 3rd Spring
Number of Coilovers	Select the number of coilovers (Usually this is just 1)
Actuation Attachment	The attachment point for the actuation system • Upright • Lower A-Arm • Upper A-Arm • Chassis **[Rear Only]** • Axle **[Rear Only]**
Anti-Roll Bar	Select the type of ARB • U-Bar. • U-Bar Rocker. • T-Bar. • T-Bar w/ 3rd Spring

Designing a Non-Linear Suspension

Input Data

After a suspension has been created, additional suspension parameters can be entered in the Suspension Input Data pane. This pane defines all of the input parameters for a given suspension, including the location of the end points for all suspension members, steering geometry properties, wheel and rim information and any non-suspension reference points of your choice, such as center of gravity or lowest bodywork points.

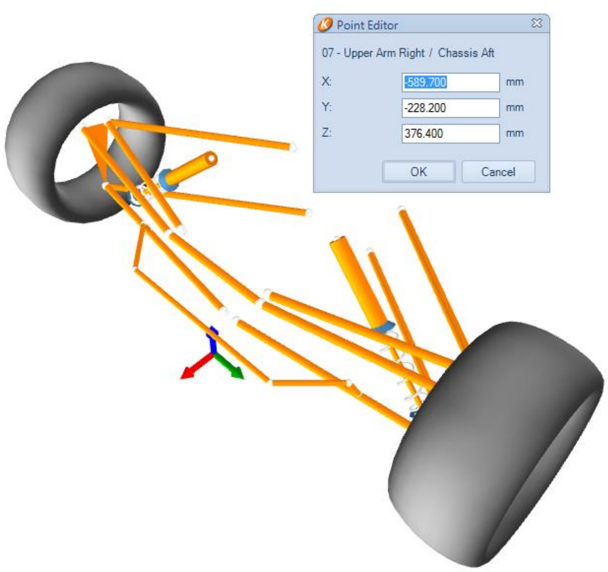
The following figure shows how points are highlighted in 'red' in the 3D Visualization when you select a point in the Input Data window.



ABOVE - Highlighting points in the visualization window

The location of each point can either be given as a list of semicolon (;) separated x, y, z points (IE – x,y,z) or the input item may be expanded and each x, y, z point entered individually. The values for all points should reflect their location when the car is at static.

NOTE - If you hold down the 'CTRL' key and click and hold on a point you are able to drag it in the 3D visualization window. While dragging the point you can also notice that the coordinates in the Input Window will be instantaneously changing with your mouse movement.



Alternatively, a suspension point may be double clicked upon in the 3d visualization window – allowing the x, y, z coordinates to be adjusted directly from the visualization pane. The following figure shows this pane.

LEFT – The 3D View Point Editor

Designing a Non-Linear Suspension

Output Data

After the information on the input tab has been completed, the corresponding information regarding the newly create suspension is available under the output tab.

Output channels can be quickly sorted through, via the quick search box. Search results will be displayed if a channel contains the search string anywhere inside the channel name.

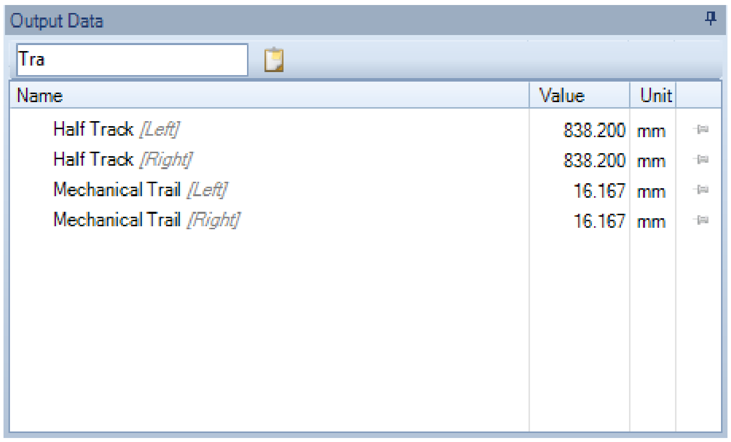


Figure 1 Output Data (Quick Search)

Output items of interest may be 'pinned' to the top of the list, ensuring that they are easier to find at all times.

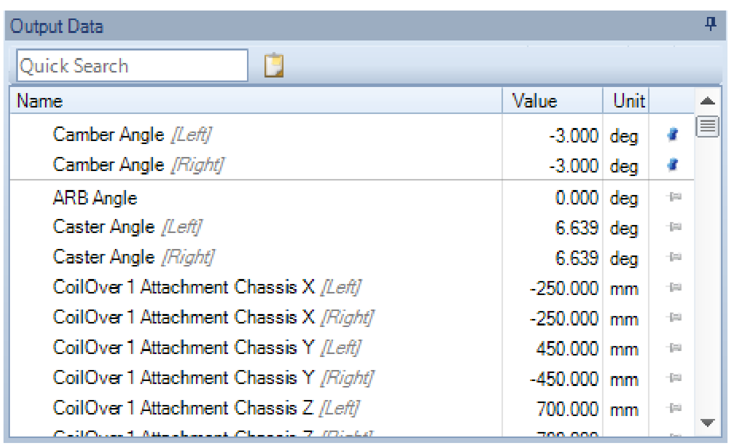


Figure 2 Output Data (Pinned)

Designing a Non-Linear Suspension

Modify Suspension

Modifying suspension geometry allows you to ensure that the geometry created matches that of your car.

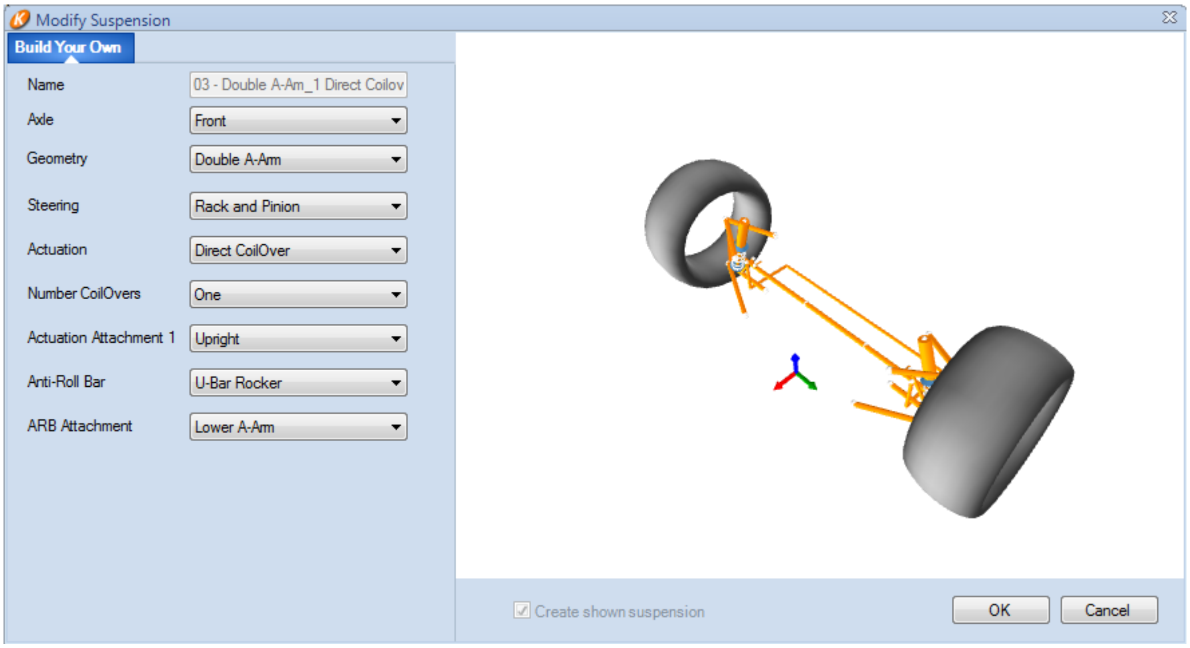


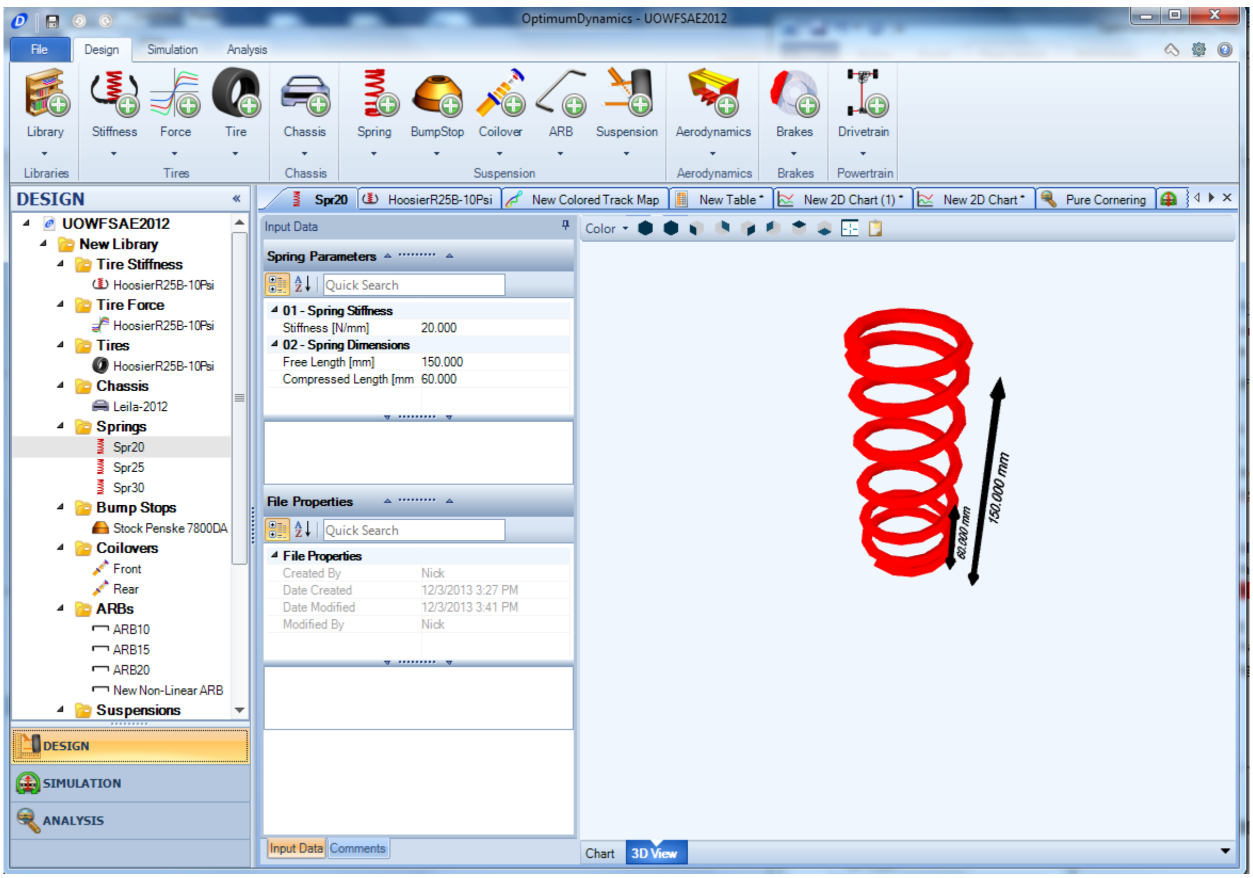
Figure 3 Modifying a Suspension

Additional Information

3D Visualization (3D View)

At multiple points during the design, simulation and analysis process a 3D visualization is possible. This is possible for the following:

- Design - Tire Stiffness
- Design - Tires
- Design - Chassis
- Design - Springs
- Design - Bump Stops
- Design - Coilovers
- Design - Suspensions
- Design - Brakes
- Design - Drivetrain
- Simulation - Vehicle Setup
- Results – Result Files



ABOVE – The 3D View is selectable in the bottom left of the graphic display area

The 3D view is selectable in the **document manager** and will enable the display of a 3D visualization of the object. The following shortcuts are possible for navigating the object.

Shortcut Key	Description
Left Click + Drag	Rotates the view
Middle Click + Drag	Zooms the view
Mouse Wheel	Zooms the view
Right Click + Drag	Pans the view
Right Click	Opens the shortcut menu

The following visualization options are accessible from the mini-toolbar at the top of the visualization window or from the 3D view shortcut menu (click the right mouse button in the window)

Input Name	Description
Background Color	Select a background color for the 3D view
Projection	You can change between parallel and perspective projection
Predefined Views	You can switch to a predefined viewing position: • Isometric • Left • Top • Front • Right • Bottom • Back
Fill Mode	You can specify between point fill, wireframe or solid fill
Copy To Clipboard	Copies an image of the visualization area to the clipboard
Fit To Window	Fits the suspension zoom level to fill the visualization window

Designing a Non-Linear Suspension

Importing and Exporting

Suspension configurations can be imported and exported from the **Ribbon Control Bar**. Both OptimumKinematics projects and Excel files can be imported – allowing OptimumK v1 files to be imported into OptimumKinematics through excel file exports from v1.

Designing a Non-Linear Suspension

Creating a Vehicle Setup

Once you have the suspension setup of your choice the next step is to create a vehicle setup. With **Setup** highlighted within the **Design Tree** you are able to **Create** a new vehicle setup.

Designing a Non-Linear Suspension

Frequently Asked Questions (FAQ)

Additional Information

My simulation does not converge!

There are a few common reasons for a simulation to not converge correctly. Firstly you should check that the solver actually is failing by viewing the result file and selecting Solver Converged. This output channel is a true or false value describing whether or not each simulation step has failed. The solver will indicate after the simulation is complete if any step have not converged you will be notified.

Another common reason for a simulation to have convergence issues is when unrealistic acceleration or force inputs are requested. Although the solver should still converge on a solution it may have issues if the inputs are simply too excessive. The non-convergence is either due to the tires not being able to provide enough force to reach the requested acceleration or the vehicle may be flipping over at the requested acceleration. If this is occurring you need to either revise your simulation inputs or the vehicle setup being used.

Frequently Asked Questions (FAQ)

My acceleration output does not match my acceleration input?

This happens when the grip limit of the tires has been exceeded or in extreme cases where the simulation hasn't converged (sees above). In the case of tire limit grip the solver is able to converge on a valid solution where the vehicle is not able to meet the requested simulation inputs. To solve this problem you either need to request smaller input forces/accelerations or have a higher friction limit for the tire.

This problem often occurs when you try and run imported real world data. The data is often scattered with high acceleration peaks that do not represent reality. You can try smoothing the data if this is the case.

Frequently Asked Questions (FAQ)

What does this "coilover out of range" mean?

This error message often occurs when a simulation is being run. It's simply stating that the solver is guessing a position that is outside the valid coilover range. The solver will move on to a better guess when this one is found to be unsuccessful.

Frequently Asked Questions (FAQ)

Why do I get errors when running a full kinematics model?

The full kinematic models can sometimes be a little bit tricky to setup. There are a few issues that may be preventing a successful simulation. The first thing that you should do is check that each suspension is being calculated correctly. Try loading the suspension component by double clicking on it in the file explorer. Then click on the chart tab at the bottom of the window. If the suspension setup is valid you should see a 2D or 3D chart describing the suspension properties. If this does not occur then you do have a problem in the full vehicle kinematics.

To solve this problem you need to ensure that there were no coordinate input errors when defining point locations. You can see this visually as well in the 3D view where any large errors should be obvious.

Ensure that the coilover has the correct dimensions. The coilover must be able to reach the suspension position that was defined in the kinematics model.

Frequently Asked Questions (FAQ)

What coordinate system is being used in OptimumDynamics?

Please refer to Coordinate System and Simulation Input Definitions for an explanation of the coordinate system and direction being used in OptimumDynamics.

Frequently Asked Questions (FAQ)