Automotive Simulation Models (ASM)

ASM Vehicle Dynamics

- Vehicle Dynamics Simulation
- Car, Truck and Trailer Simulation
- Brake Hydraulics and Pneumatics Simulation

Embedded Success   **dSPACE**

The vehicle graphics used in this brochure are by courtesy of Maserati, Scania, and Volkswagen.

Content

Virtual Test Driving

Efficient Vehicle Controller Development

How can you test new control software long before your vehicle is even ready? How can you speed up the development of ever more complex electronic systems? Simulation is the answer to many questions. With off-the-shelf simulation models and ready-to-use roads and maneuvers you go through virtual test drives easily. In a passenger car, in a truck, with or without a trailer. At your desk. The advantages are clear:

Testing is quick and convenient and the savings are much higher in comparison to test beds or prototype cars.

Truck simulation for critical situations.


Trailer simulation for ESP testing.

Virtual test benches for vehicle dynamics analysis.

The Simulation Workbench

Automotive Simulation Models

Automotive Simulation Models (ASM) by dSPACE is industry-proven virtual vehicle software. The ASM Vehicle Dynamics Simulation Package gives you realistic vehicle behavior simulations in real time. The models are the ideal choice for function design and controller testing in model-based development processes.

Jump-start developments with easy-to-use validated tools: a comfortable user interface for all aspects of your tasks and high-performance simulation models that perform under the hood, ensuring precise simulation results.
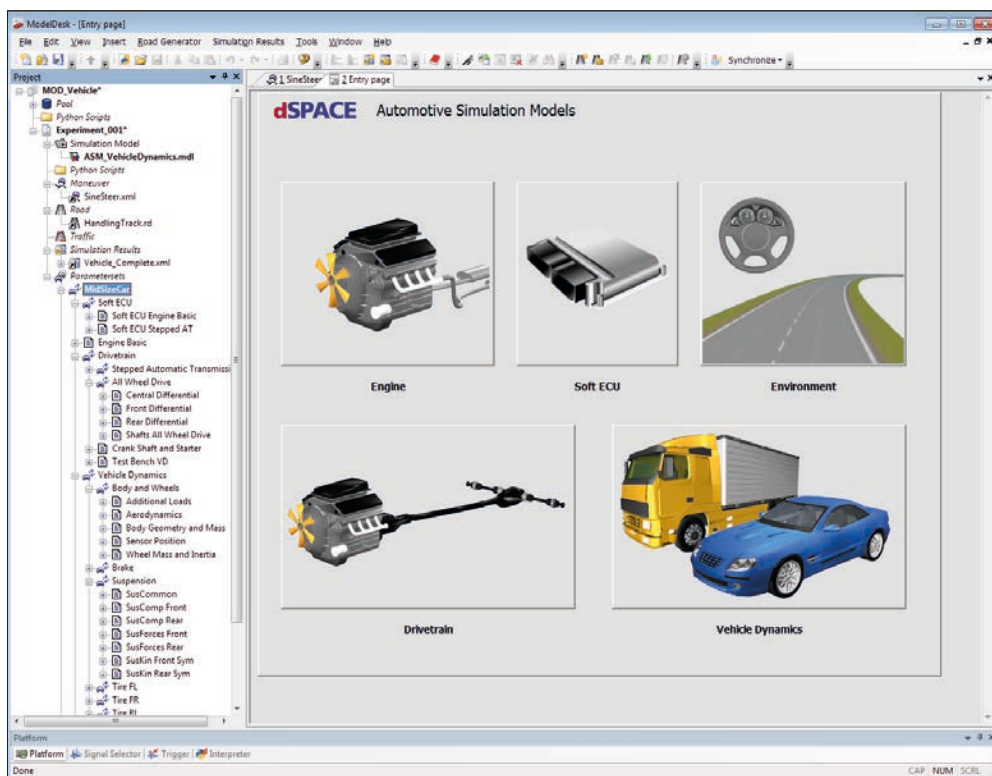
Comfortable User Interface

ModelDesk is the intuitive user interface for defining and initiating virtual test drives. Specify vehicles, roads and maneuvers with easy-to-use graphical methods. Benefit from efficient workflows and seamless data management.
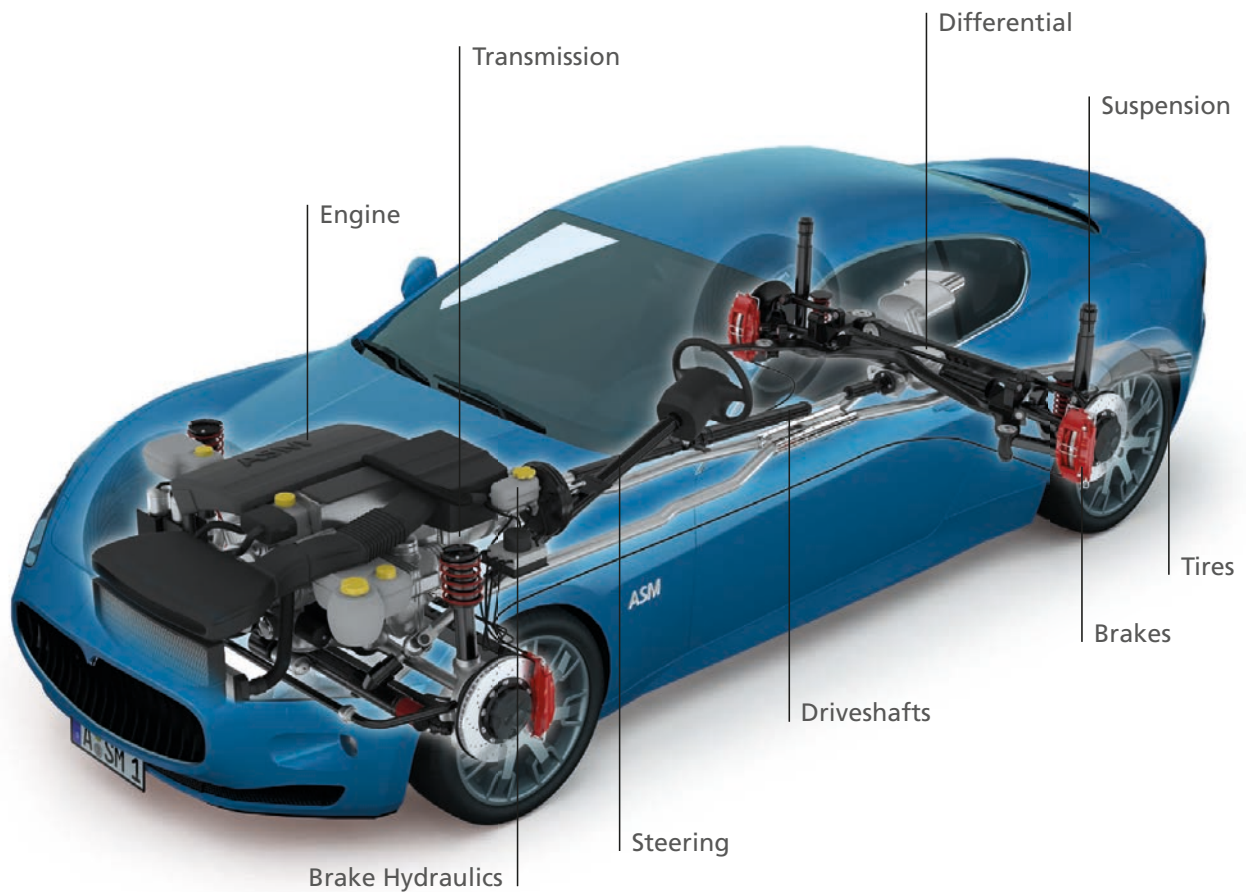
High-Performance Models

ASM are open, validated Simulink models that major OEMs and suppliers rely on to develop controllers for cars, trucks, and off-road vehicles. They support the whole development process from function design to ECU testing.

Virtual Vehicle

ASM comprises models for engine, battery, suspension, traffic and many other components. You can easily combine them to build a whole virtual vehicle. ASM supports application areas such as combustion engines, vehicle dynamics, electric components, and traffic, including the traffic environment.

Overview

Vehicle Dynamics Simulation Software
The ASM Vehicle Dynamics Simulation Package supports a broad variety of application tasks in the area of vehicle dynamics simulation. To provide what is needed for these areas, it consists of specialized simulation models and tools.

Basic Software

ASM Vehicle Dynamics is the base package for virtual test drives with a passenger car on the road.
Page 12
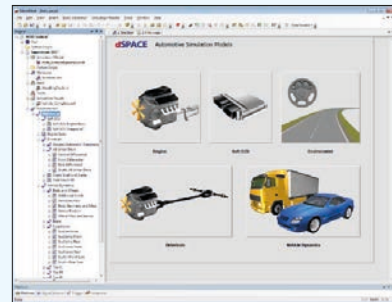
ModelDesk is the graphical user interface to manage simulations, parameterizations and parameter sets.
Page 27
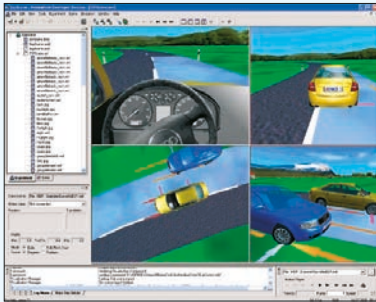
Extension Software

ASM Kinematics and Compliance (KnC) is the model for efficient suspension design and analysis.
Page 18

ASM Truck is used to simulate trucks or, together with ASM Trailer, tractor-trailer combinations.
Page 21

ASM Trailer is used to simulate cars, pickups or truck tractors together with a trailer.
Page 22

With **MotionDesk** all simulations can be observed
in realistic 3-D animation.
Page 40

ASM Brake Hydraulics is the
model of a state-of-the-art ESP
braking system.
Page 24

ASM Pneumatics is the model for air
brake and air suspension simulations for
trucks, trailers and cars.
Page 26

ASM Traffic brings traffic simulation
to ASM to develop advanced driver
assistance systems.
See the ASM Traffic brochure.

The ASM Philosophy

An Open Concept

Open Model Design

For optimum support of customer-specific requirements, dSPACE has chosen an open model concept. This means that models are visible to users right down to the level of standard Simulink blocks. Thus the dSPACE Automotive Simulation Models provide enormous flexibility for projects that require dedicated simulation models. The open model approach allows perfect adaptation to individual projects and requirements. This can be achieved by modifying models or by replacing or adding components.
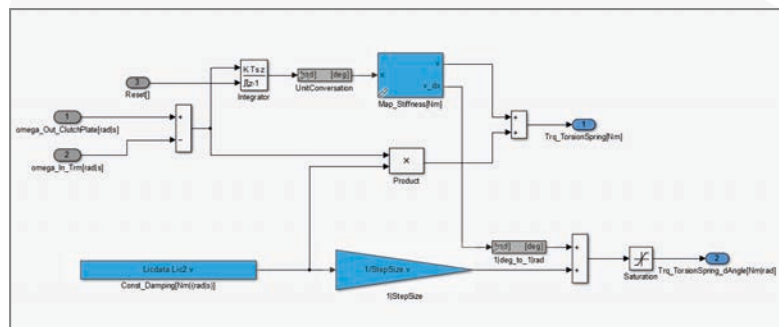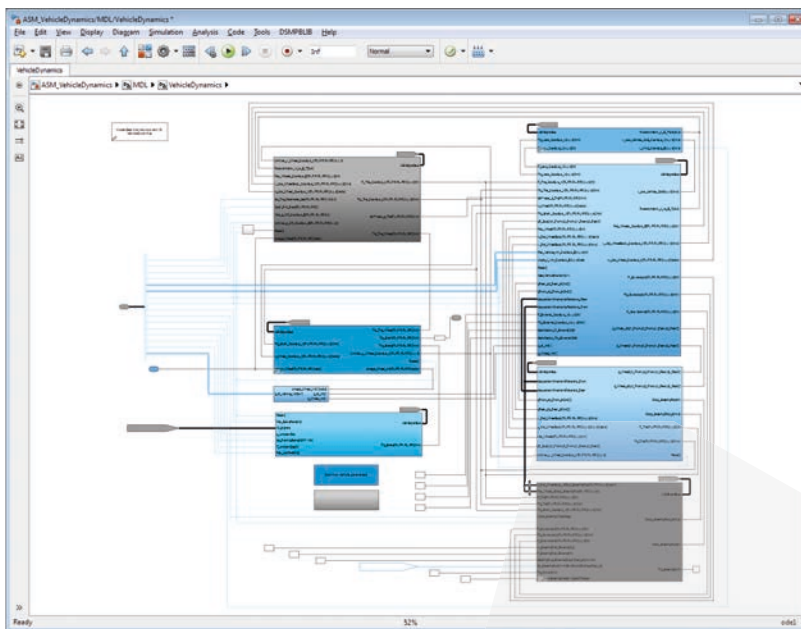
ASM Vehicle Dynamics Simulation Package

Real-Time Vehicle Dynamics Simulation

Highlights

- Open MATLAB®/Simulink® model
- For ECU testing and function development
- Intuitive graphical parameterization and road/maneuver creation in ModelDesk
- Custom component parameterization
- Tool automation for ModelDesk
- 3-D animation

Application Areas

The ASM Vehicle Dynamics Simulation Package provides open Simulink models for the real-time simulation of vehicle dynamics behavior in an environment. The models are typically used on a dSPACE Simulator/SCALEXIO® to perform hardware-in-the-loops tests on electronic control units (ECUs) or during the design phase of controller algorithms for early validation by offline simulation. They are complete and independent models that support all the relevant phases of the model-based development process.

Key Benefits

All the Simulink blocks in the models are visible, so it is easy to add or replace components with custom models to adapt the vehicle's properties perfectly to individual projects. ASM's standardized interfaces make it easy to expand a vehicle dynamics model to meet specific requirements, or even to create a virtual vehicle. Roads and driving maneuvers can be created easily and intuitively using graphical tools with preview and clear visualization. All parameters can be altered during run time.

Vehicle Characteristics

For realistic vehicle simulation, the vehicle model is designed as a multibody system. The model consists of elements such as a drivetrain with elastic shafts, a table-based engine, two semi-empirical tire models, a nonlinear table-based vehicle suspension model with kinematics and compliance, a steering model, and aerodynamics.
An environment with a road, maneuvers, and an open- and closed-loop driver is included as well. All parameters can be altered during run time. To simulate brake systems, models of a dual-circuit hydraulics system and a pneumatics system are available as add-ons.

Offline and Online Simulation

The ASM Vehicle Dynamics Simulation Package can be used in combination with real controllers in a hardware-in-the-loop environment (HIL or online mode), or for simulating a vehicle in combination with software controller algorithms together with dSPACE VEOS® (PC or offline mode). The model comes in three different versions and license types for online and offline simulation: ASM Developer, ASM Operator, and ASM Runtime (p. 44). They support either code generation via MathWorks´ Real-Time Workshop® and dSPACE's RTI, or come as run-time models with pre-compiled code.
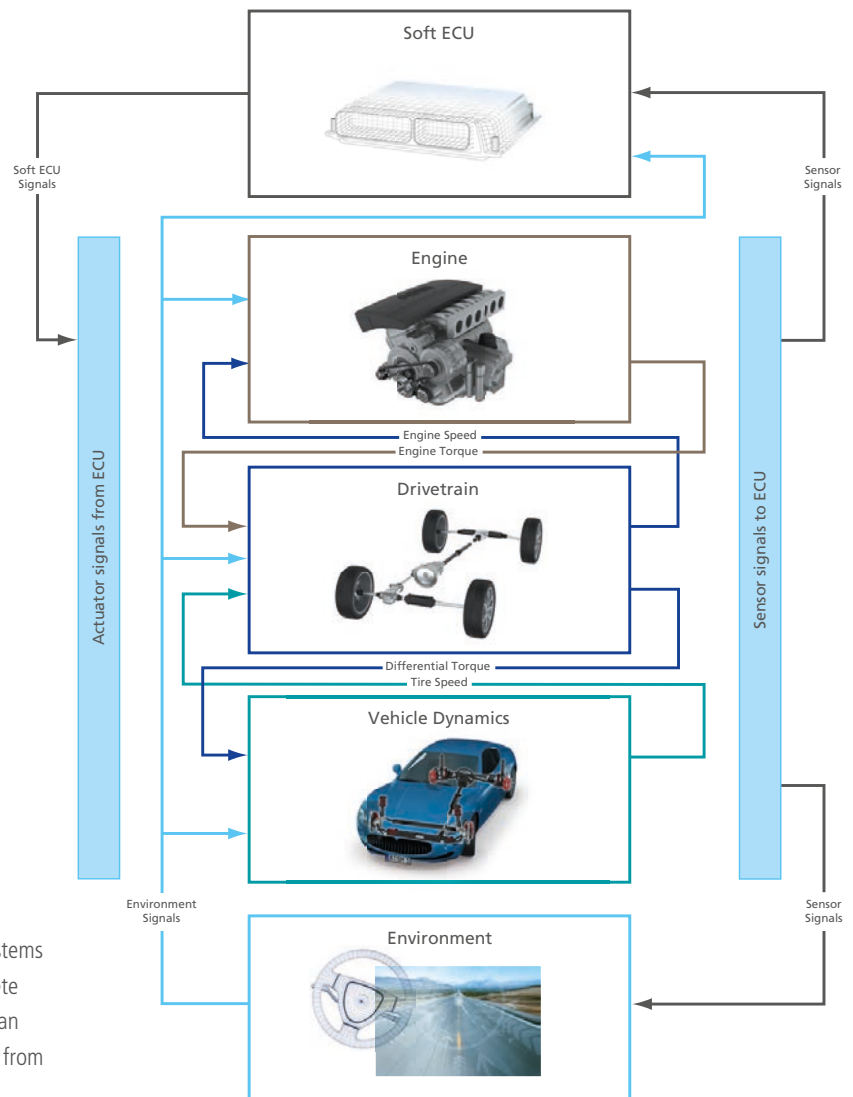
ASM Vehicle Dynamics

Model Overview

Features at a Glance

- Multibody system
- 24 degrees of freedom (DoF)
- Modular, library-based implementation
- Environment model including road, driver and maneuvers
- Brake hydraulics, air suspension and trailer extensions
- Easily expandable up to an entire virtual vehicle with ASM engines and ASM Electric Components

- Custom models integrated and parameterized via the graphical user interface ModelDesk
- Vehicle parameters tunable online during run time (e.g., via ControlDesk or ModelDesk)
- Graphical user interface for parameterization (p. 27)
- Fully integrated into the dSPACE tool chain
- Comprehensive documentation including formulas
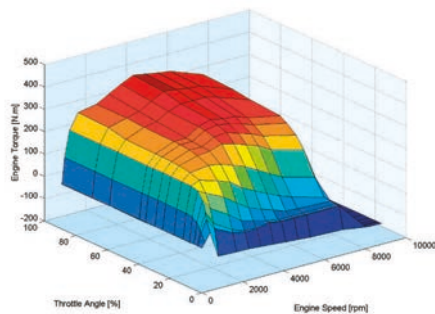
Model Components

The vehicle dynamics model consists of subsystems for a vehicle body with its drivetrain, a complete environment, and a basic engine. The model can be extended by adding other model packages from dSPACE or custom models.

Engine and Drivetrain Models

The Engine Model

The engine model includes a table-based engine. A soft controller model allows ECU interventions to reduce engine torque, for example, if requested by ASR or ESP systems. The engine can be switched on and off and hold a specific idle speed if necessary, like when it is when declutched or thrown out of gear.

Components and Characteristics

- Table-based engine model
- Several strategies (injection, throttle), etc. for reducing and increasing torque as requested by the vehicle dynamics ECU
- Starter to accelerate the engine to idle speed

The table-based engine model can be replaced by a full-featured diesel or gasoline engine model.

- Order information (p. 47)

Engine torque is derived from the engine map.

The Drivetrain Model

The drivetrain model has manual and automatic transmission, and front-, rear- and all-wheel-drive. The shaft drives are modeled as elastic components.

Components and Characteristics

- Manual transmission with clutch
- Automatic transmission with torque converter
- Front-, rear- and all-wheel drive, including differentials
- Automobile layouts like FF, FR, RR, F4, FMR, etc.
- Drivetrain with 13 degrees of freedom (DoF)
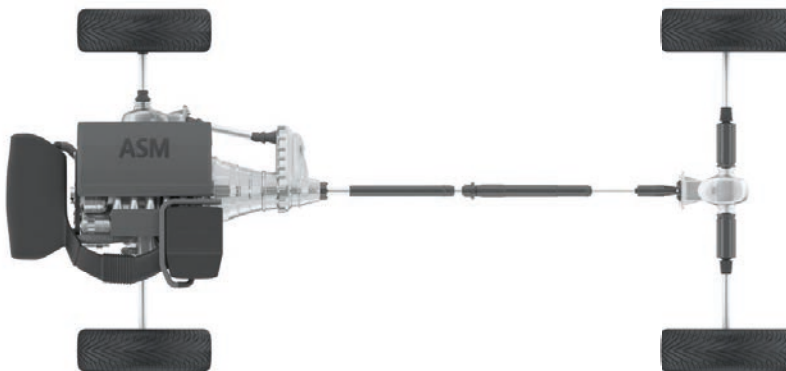
Overview of engine and the drivetrain model configured with all-wheel drive. Modes for rear- and front-wheel drive are also available.

Vehicle Dynamics Model

The Multibody Vehicle System Model

The system is modeled as a nonlinear multibody vehicle system with geometric or table-based suspension kinematics and table-based compliances. It supports the simulation of vertical, longitudinal, and lateral dynamics.

The vehicle dynamics model can be configured for different car types: sports car, limousine, SUV, VAN, etc.

Components and Characteristics

- Multibody system (MBS) consisting of a car body and four wheels
- 11 degrees of freedom (DoF)
- Table-based compliances for suspensions
- Suspension with nonlinear spring and damper characteristics
- Aerodynamic forces and torques included
- Brake model

- Additional masses (fixed on vehicle body)
- Rack-and-pinion steering system with included power steering
- Ancillary spring
- Steerable rear axles
- Two tire models: Magic Formula and TMEasy
- 1st-order lateral, longitudinal, and vertical tire dynamics
- Tires with combined lateral and longitudinal slip
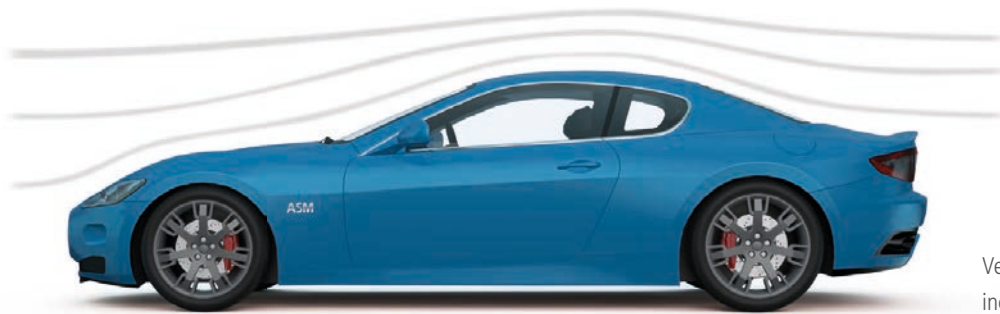
Vehicle dynamics model including aerodynamic forces.

The Steering Model

The steering model simulates a rack-and-pinion steering system applied to the front wheels.

Components and Characteristics

- Power steering included
- Tire forces, tire torques, and driving torques included

Rack-and-pinion steering system.

The Tire Model

The vehicle model includes two tire models based on the published model descriptions Magic Formula and TMEasy which are both fully implemented.

Components and Characteristics

- Magic Formula and TMEasy
- Semiphysical approach
- 1st-order lateral, longitudinal, and vertical dynamics
- Standstill condition included
- Dynamic tire radius
- Camber angle influence
- Combined lateral and longitudinal slip
- Self-aligning and bore torques
- Up to four tire characteristics for different road surface conditions, switchable online

Individual tire characteristics are included in the vehicle dynamics simulation.

Application Example: Mechanical Steering Test Bench

Optimizing Steering Systems

ASM Vehicle Dynamics is ideal for investigating electrical power steering systems (EPS) on a mechanical test bench. The signals of the simulated vehicle are used as reference signals for the steering wheel and the counter forces acting at the steering rod of the steering test bench. The results derived from the test bench are used, for example, to optimize the control algorithms of the EPS.

ASM Vehicle Dynamics

Steering Wheel Angle

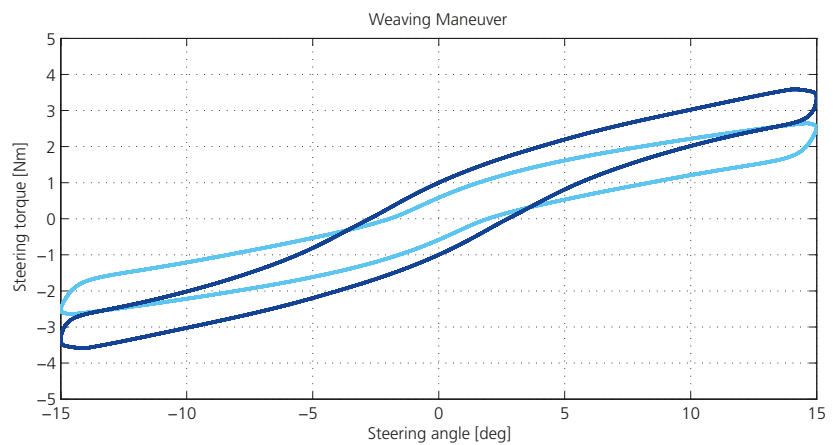Counter Forces at
Steering Rod

Displacement of
Steering Rod

Mechanical Steering Test Bench

Components and Characteristics

- Virtual test bench simulation
- Axle kinematics and compliance
- Steering system
- Realistic vehicle simulation

Steering torque at different vehicle speeds
during weave tests.

Weaving Maneuver

Model Validation

Results of Vehicle Dynamics Simulation

The validation results for different vehicles show that the
simulation matches the measured vehicle dynamics data.
For validation, maneuvers driven on a test track were also
driven in ModelDesk, using the actual vehicle velocity and
steering angles as inputs.
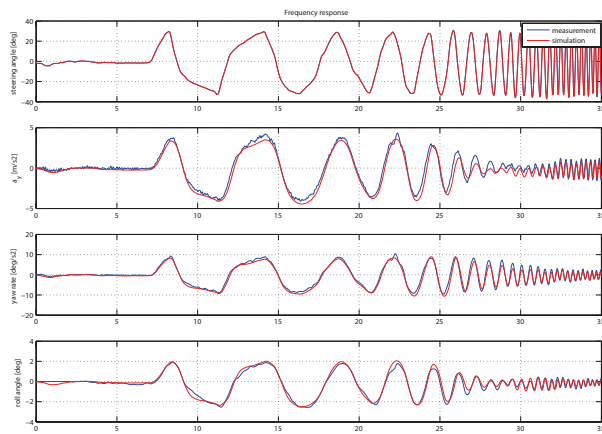
Comparison of a sine steering maneuver for a fully loaded van
(weight 3.5 t).
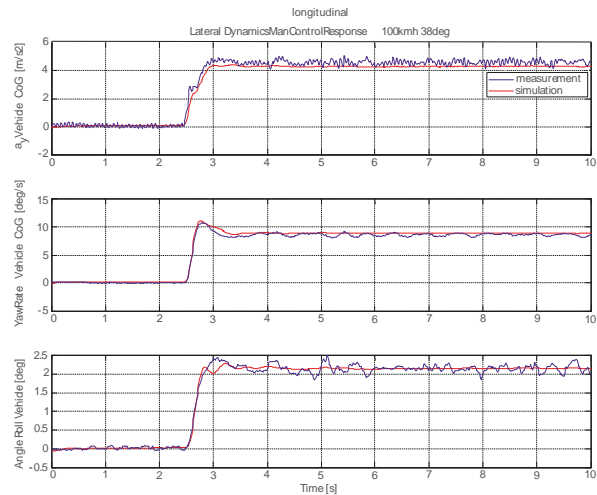
Comparison of a step steering maneuver for a passenger car at
100 km/h and a steering angle of 38°.

Results of Brake Hydraulics Simulation

The hydraulics model, executed in conjunction with a real
ECU, generates a modulated pressure in each brake cylinder
as the brake pressure rises. The vehicle model supplies the
required wheel and vehicle speeds.

Graph of modulated brake hydraulics cylinder pressure and
the resulting wheel and vehicle speeds.
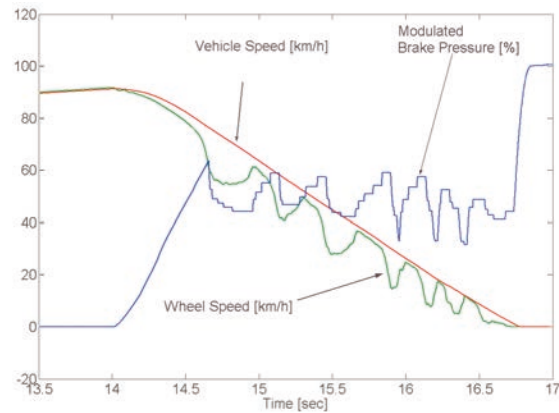
ASM Kinematics and Compliance (KnC)

Simulation for efficient suspension design and analysis

Key Features
- Virtualized vehicle test bench for analyzing wheel suspensions
- Convenient graphical design
- Comprehensive automation and analysis functions

Virtual Test Bench
ASM Kinematics and Compliance (ASM KnC) is an add-on to the ASM Vehicle Dynamics model that provides functions for designing and simulating wheel suspensions on a virtual test bench. Users can run virtual tests for numerous vehicle variants and driving maneuvers to optimize vehicle suspensions and make them available for hardware-in-the-loop (HIL) applications.

### Graphical User Interface for Convenient Design
The graphical user interface imports the suspension geometries from CAD sketches, and can process further features like spring damper characteristics from assembly data sheets. The imported parameters define the suspension kinematics and compliance.

The tool provides preset configurations for common suspension types: McPherson, double wishbone, 3-link, 4-link or multiple-link suspensions. These can also be combined with subframes.

The wheel suspensions are exported as look-up tables for ModelDesk and the vehicle simulation model.

More Efficiency Through Automation
ASM KnC is fully automatable, so simulation results can be optimized to match real measurement data (e.g., the changes in camber and toe-in during jounce and rebound). The automation interface can also be used to forecast the individual properties of materials to meet higher target criteria for vehicle dynamics. Because the simulation parameters correlate directly with the real vehicle design, test engineers can optimize the vehicle dynamics behavior much more efficiently. This reduces the number of real test runs and keeps prototypes to a minimum.
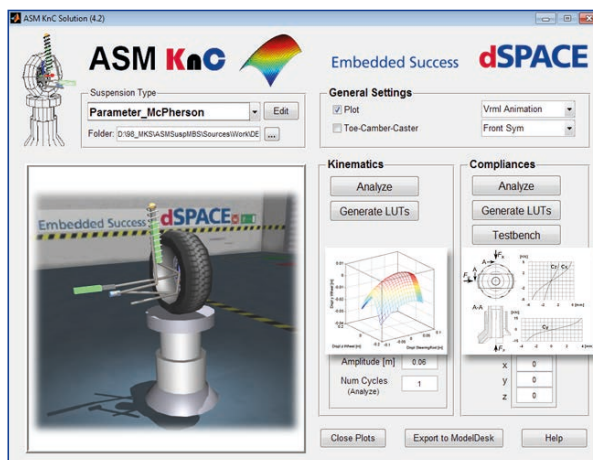
The GUI is used to import and process suspension raw data and turn it into look up tables for vehicle simulation models.

ASM Environment

## Road, driver and maneuver models

The Road Model

Roads are built in ModelDesk's graphical Road Generator. The road model supports everything from straight roads to complex road networks.

Roads consist of a reference line with attributes along the line to define road features like surfaces, lanes, slopes and inclinations. Friction areas can be placed on various locations.

Components and Characteristics

- Graphical road builder (p. 31)
- Complex road networks
- Longitudinal profile with slope and lateral inclination
- Up to 5 lanes
- Local friction areas (split-μ)
- Bumps, holes, water, snow, ice
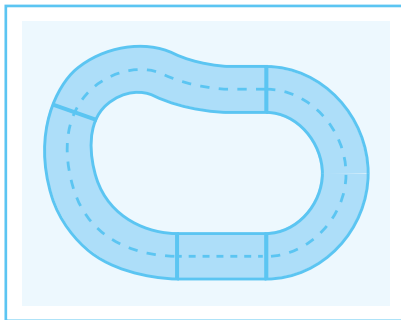
Quick road construction with geometric forms like straight line, curve, spline and clothoid.
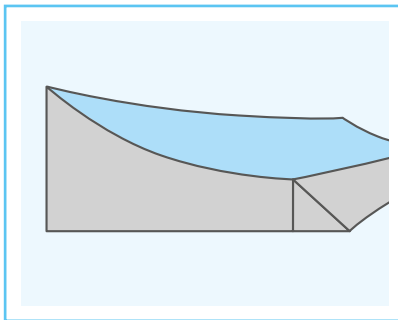
Road with support for inclinations, slopes and banked curves.
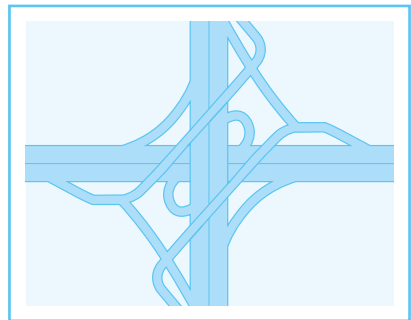
Road networks – here a highway interchange.

The Driver Model

The driver model controls the vehicle. Its main tasks are to drive the vehicle at a desired velocity and follow a given road. The vehicle is controlled via an accelerator pedal, brake pedal, clutch pedal, gear lever, and steering wheel. It features foresight steering behavior to follow the road ahead.

Components and Characteristics

- Longitudinal controller for accelerator pedal and brake pedal, comprising feedforward and feedback control
- Lateral controller for steering wheel, using preview information for road-following
- Gear shifter for manual transmission, including startup
- Reference velocity calculation for driving on arbitrary roads
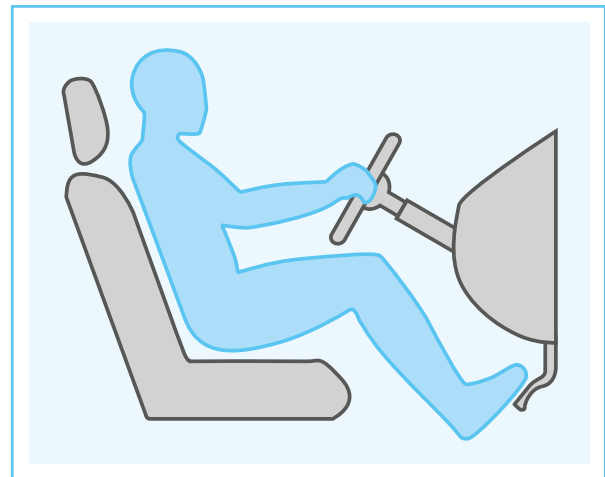
The driver model controls the vehicle based on maneuver, road and vehicle signals.

Environment Model
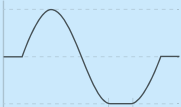
The Maneuver Model

Maneuvers define how a vehicle moves. Depending on the maneuver mode, they either provide stimulus signals directly to certain vehicle components like the accelerator pedal, clutch pedal, brake pedal, steering wheel and gear lever, or give instructions to a driver model which controls the vehicle.

Components and Characteristics

- Graphical maneuver editor (p. 34)
- Maneuver creation via time and distance
- Stimulus maneuvers according to measured data
- Initialization control for road and vehicle model
- Additional interfaces for traffic simulation (see ASM Traffic)

Maneuver – simplified example illustrated as a roadbook

Distance/Meter	Lateral		Longitudinal	
0	Straight ahead	↑	Disengage clutch Release brake	
110	Straight ahead	↑	Accelerate to	80
120	Straight ahead	↑	Keep velocity	80
162	Sine with dwell		Engage clutch	
260	Straight ahead	↑	Brake until standstill	STOP

ASM Truck

Truck Model for Tractor and Trailer Simulation

The Truck Tractor Model

ASM Truck is used together with ASM Trailer to simulate a truck (tractor with dolly) or a tractor-semitrailer combination. The models contain up to 34 degrees of freedom (DoF) in the multibody dynamics and up to 25 DoF in the powertrain. The truck model features a torsional frame. The entire vehicle model has up to 8 steerable axles, which can have twin tires as an option. It is easy to modify the configuration even during run time without manipulating the model. For example, during the simulation, axles can be activated and deactivated, and trailers can be hitched and unhitched.

Components and Characteristics

- Multibody dynamics with up to 34 DoF (depends on truck configuration)
- Powertrain with 25 DoF (depends on truck configuration)
- Truck body based on a torsional frame
- Tractor with up to 4 steerable axles plus trailer with up to 4 steerable axles
- Hydraulic or pneumatic brake system (ASM Brake Hydraulics, ASM Pneumatics)

- Each wheel can be equipped with a brake
- Table-based axles with 3 DoF
- Twin tires as an option on all axles
- Axles can be activated and deactivated during simulation
- Trailers can be hitched and unhitched during simulation
- Dolly extension for road train simulation
- Vehicle configurations with arbitrary numbers of axles available on request
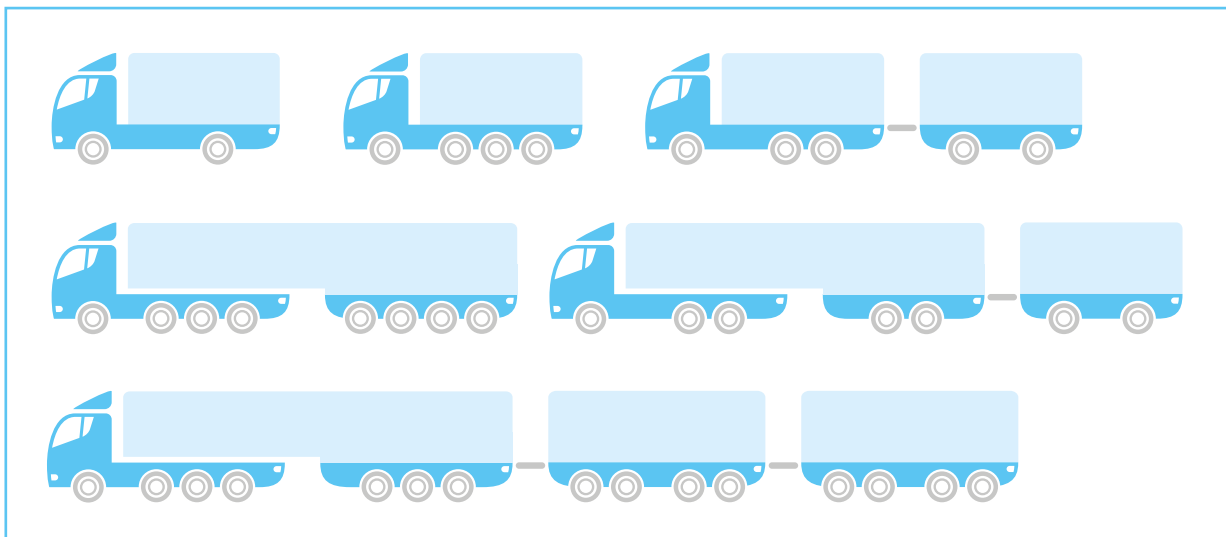
Examples of trailer and axle variants supported by ASM Truck and ASM Trailer.

ASM Trailer

Trailer Model with Hitch and four Axles

The Trailer Model for Cars and Trucks

ASM Trailer is an extension to the ASM Vehicle Dynamics Simulation Package. It is based on a multibody system consisting of a trailer body, up to 4 axles, and an optional dolly. The model also includes suspensions, tires, brakes and aerodynamics. The connection to the towing vehicle is provided via a hitch that includes mechanical stops. The trailer and all axles can be activated or deactivated during simulation without new code generation.

Components and Characteristics

- Modular multibody system (MBS)
- Trailer body
- Up to 4 axles (all axles steerable)
- Dolly extension for full trailer simulation
- Tire models TMEasy and Magic Formula
- Table-based suspension

- Ball-joint hitch (including mechanical stops)
- Brakes
- Aerodynamics
- Additional loads
- Graphical parameterization in ModelDesk

The trailer can be configured as a semitrailer or it can have an optional dolly extension. It supports the simulation of road trains consisting of a truck tractor and multiple trailers.

The trailer model can be configured for different trailer types, and it can be used with various towing vehicles.

Trailer coupling/uncoupling   Axle activation/deactivation

The trailer, axles, and wheels can be modified during simulation, e.g., trailer coupled/uncoupled, axles activated/deactivated, and the wheels can have single tires or twin tires. No code generation is required.

ASM Brake Hydraulics

Brake Hydraulics Model for ESP Simulation

Features at a Glance

- Contains all the components of a state-of-the-art ESP braking system
- Linear and physical master brake cylinder model
- Valves with continuously controllable cross-sections
- Nonlinear, look-up-table-based wheel brake cylinder
- Offline and online simulation
- Real-time capable
- Graphical user interface for parameterization
- Easy to insert into ASMVehicleDynamics
- Numerical integration stabilized via local oversampling
- Modular, library-based implementation
- Easy variable access

Hydraulics Model Concept

The brake hydraulics model consists of the master brake cylinder and the two independent braking circuits. The braking circuit system calculates the pressure in each wheel brake cylinder.
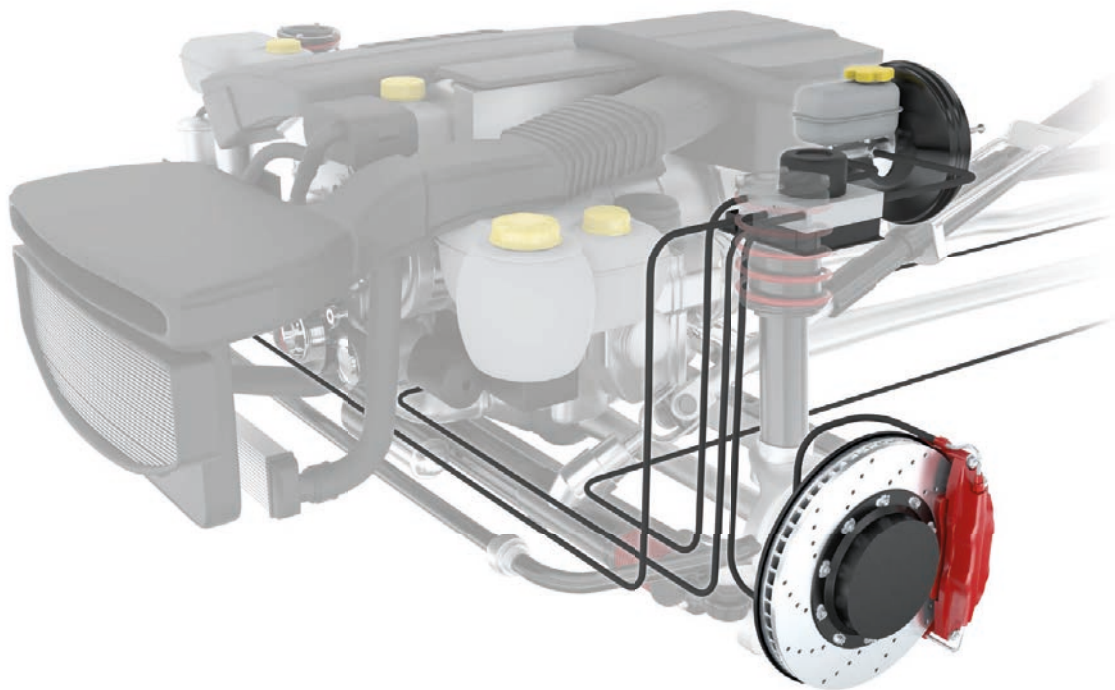
Hydraulic Valves

Valves are used to control the flow of the hydraulic fluid. The flow control valves are modeled as orifices with continuously controllable cross-sections.
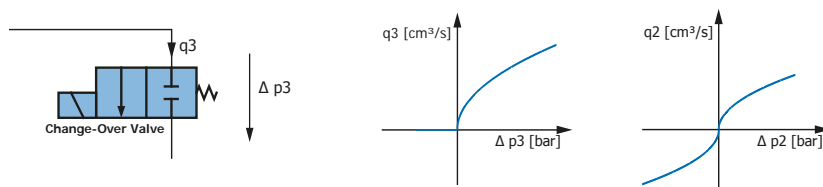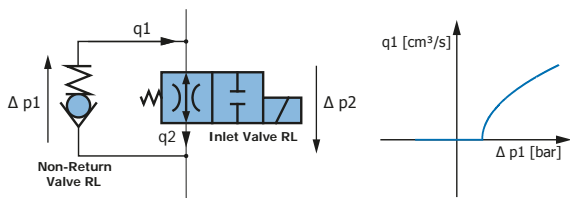
Components and Characteristics

- All valves except the non-return valve with continuously controllable cross-sections
- Model based on the Bernoulli equation
- Different types of valves included
- Precharge valve with two different cross-sections in the opening state. The cross-section depends on the pressure difference.
- Change-over valve with pressure relief function in the closed state
- Inlet valve
- Outlet valve
- Non-return valve

A selection of the valve systems: non-return, inlet and change-over valves with their characteristics diagrams.
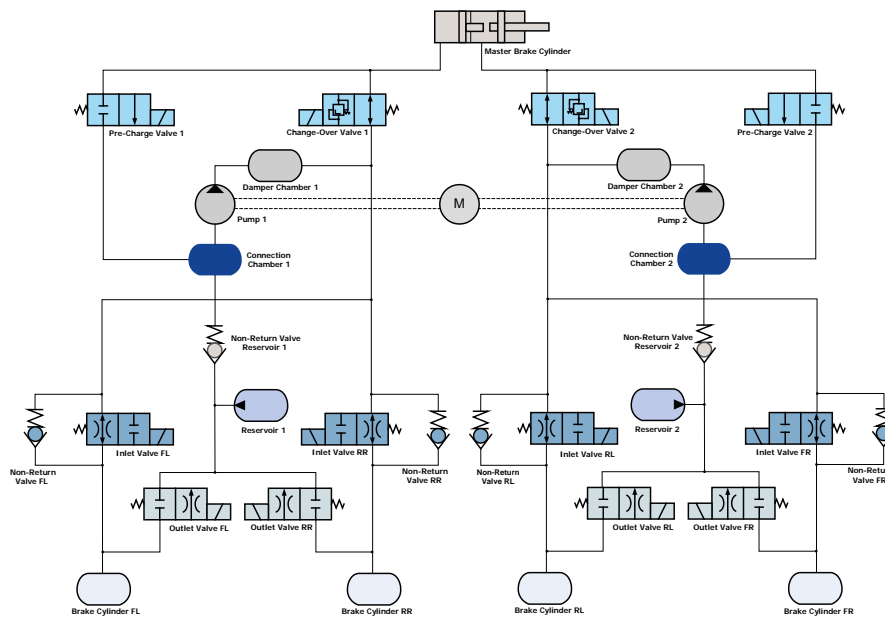
Schematic of the brake hydraulics.

ASM Pneumatics

Air Brake and Air Suspension Models

Application Areas
- Air brakes
- Air suspensions
- Supports ABS/EBS and suspensions (car, bus, truck, truck dolly, tractor trailer, road train)

Features at a Glance
- Complete model including compressor, tanks, valves, and brake chambers
- Ready to use ABS/EBS and suspension configurations
- Support for mechanical/pneumatic backup functions
- Support for trailer brake systems
- Graphical user interface for parameterization

- Offline and online simulation
- Real-time capable
- Modular, library-based implementation
- Easy variable access
- Add-on library for ASM Vehicle Dynamics, ASM Truck and ASM Trailer

Pneumatics Model Concept

The pneumatics model provides ready-to-use configurations for air brake and air suspension simulations. Handling and parameterization are done via a comfortable graphical user interface.
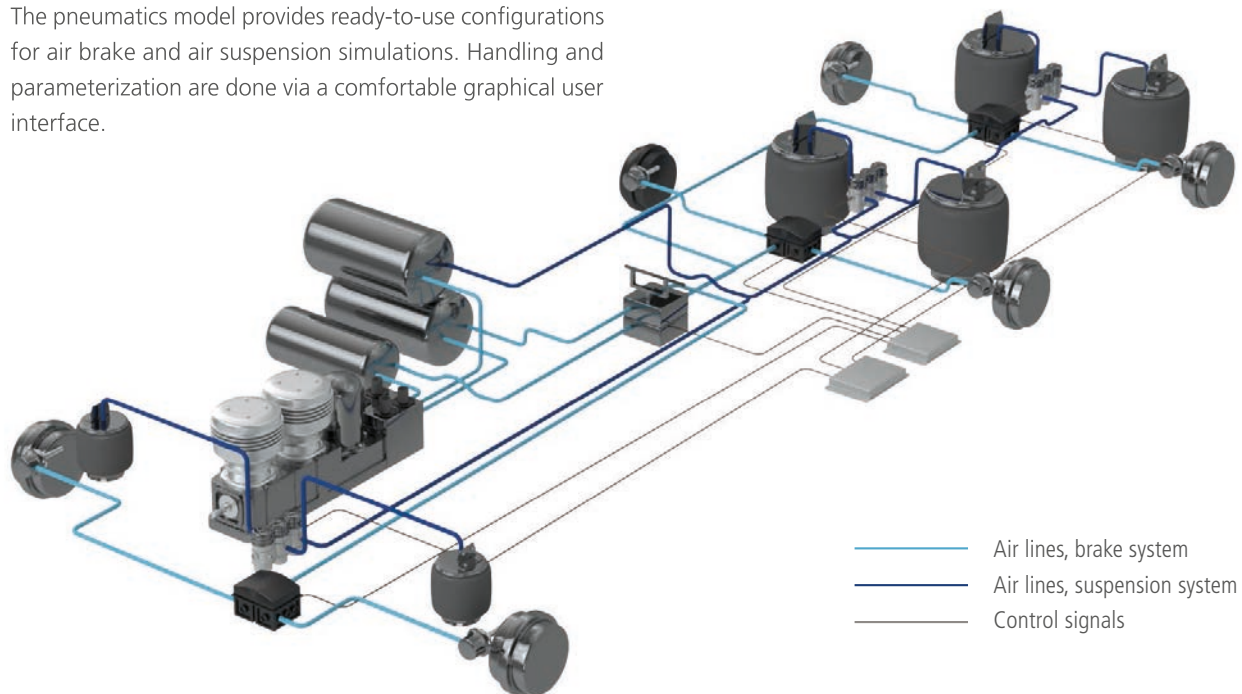
— Air lines, brake system
— Air lines, suspension system
— Control signals

Air suspension and air brake system of a truck together with the controllers for brake and leveling functions.

ModelDesk

The Graphical User Interface

The ModelDesk Concept

ModelDesk is a graphical user interface for simulation, intuitive model parameterization and parameter set management. It also provides project handling and allows parameter sets to be downloaded to offline and online simulations. It

supports tool automation via COM interface. ModelDesk can be used seamlessly from parameterization to offline and online simulation, and finally to parameter and result management.

Main Features

- Graphical user interface
- Parameter set management
- Offline and online simulations
- Road Generator
- Maneuver Editor
- Tool automation
- Custom model parameterization

Benefits

- Seamless simulation process from MIL to HIL
- Intuitive, graphically supported parameterization
- Parameterization during online (dSPACE Simulator) and offline (Simulink) simulations
- Managing parameter sets and entire projects

Graphical Handling

Graphically Supported Parameterization

The model components and their subsystems are represented by graphics that are structured in a hierarchy. The model components to be parameterized can be selected from the

top level. Users have the vehicle model in front of them and can browse through its systems, guided by graphical representations of the modeled components.
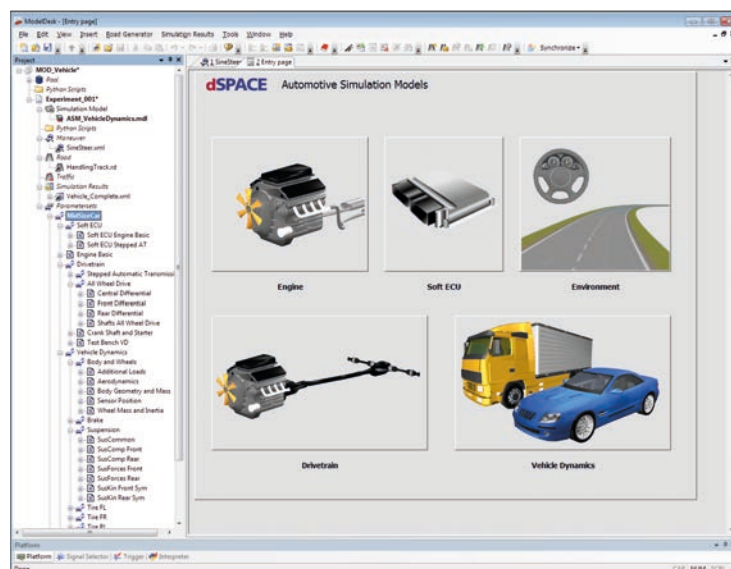
ModelDesk's top-level dialog for selecting model subsystems for configuration and parameterization.

Configuration

Configuration Handling

The vehicle configuration is defined with the configuration wizard. For example, the settings for the drivetrain include front-, rear- and all-wheel drive; and transmission can be automatic or manual. Two different tire models are available as well.
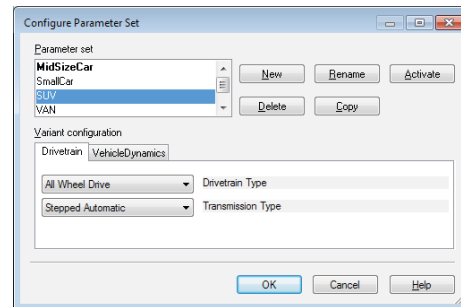
Quick selection of vehicle configurations.

Navigation

The Project Navigator

ModelDesk's Project Navigator provides the way to organize and manage large-scale model parameterization projects. Parameter files can be created and assigned to each model component (differential, tires, road, etc.), and complete vehicle parameter sets can be created and managed. Existing parameter files can be selected from a parameter pool and applied by drag & drop.
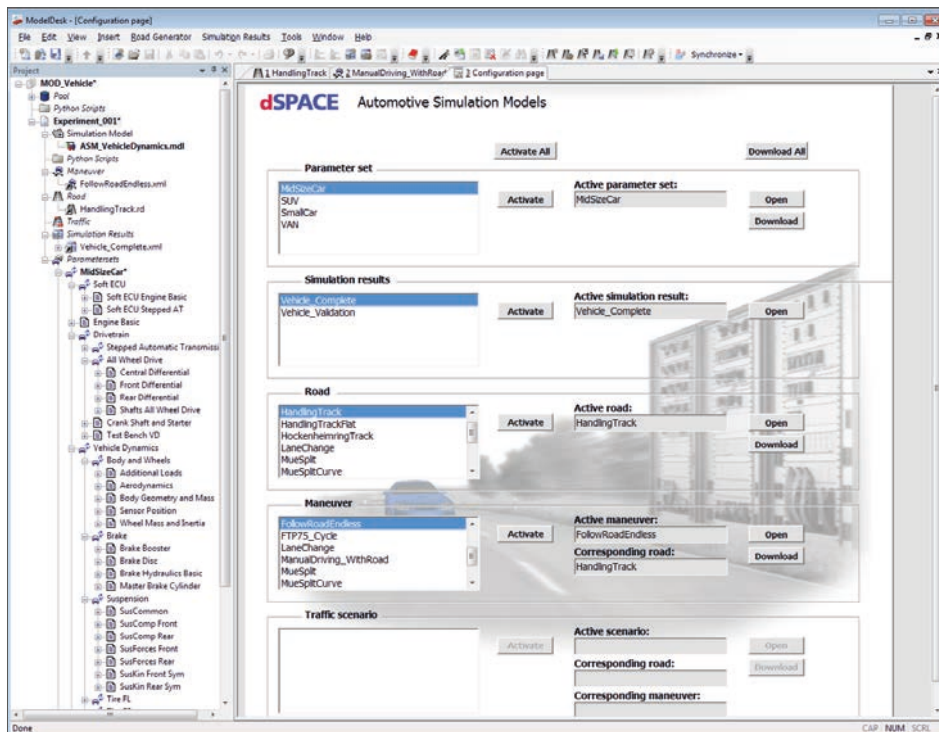
The Project Navigator on the left is used to manage the parameterization projects. A click on the component buttons in the visualized drivetrain model leads to the related parameter pages.

Parameterization

Parameter Handling

For manual parameter entry, ModelDesk has parameter pages with illustrations for each component. Parameters are entered in controls next to the components. Table parameters can be visualized as 3-D graphs and modified using a table editor.

Parameter page to modify characteristics of automotive components..

Table Editor for parameterizing characteristic maps.

Managing and Analyzing Simulations

Simulation Management

ModelDesk includes powerful functions for directly execut-
ing and displaying simulations, and managing their results:
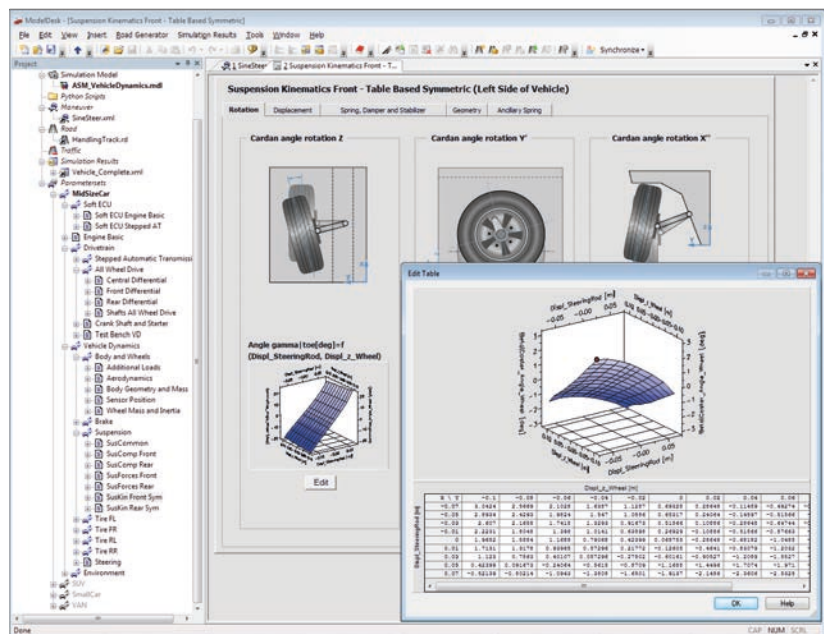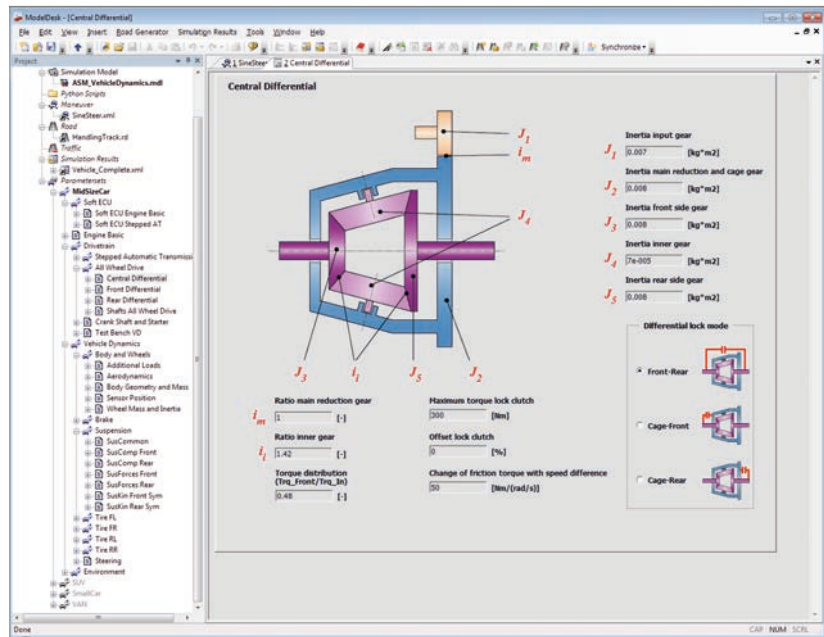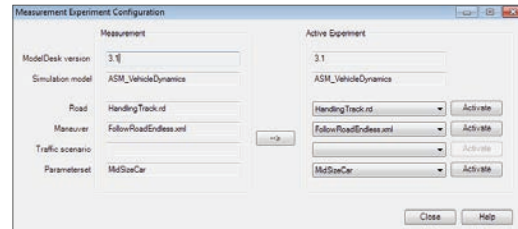
- Starting and stopping a simulation
- Plotters for visualization
- Saving, comparing and managing simulation and
  measurement data
- Saving simulation experiments
  (driving maneuvers, roads, traffic, etc.)

Configuration of a simulation experiment consisting of a vehicle
model, road, maneuver and vehicle parameters.

Plotter

ModelDesk features an integrated plotter which displays
signals from the ASMSignalBus. The signals have the same
structure as in the Simulink model. The bus can include
user-defined signals. Plotter configurations can be defined
and stored, and the same single configuration can be used
seamlessly online (HIL simulations) and offline (Simulink

simulations). A configuration includes the following data:
simulation results, measurements, and parameter sets con-
sisting of vehicle parameters, roads, maneuvers, and/or traf-
fic. A configuration collects together all the sources and
conditions that the plotted results are based on.

Features

- Plots of ASM signal buses
- Plots of user-defined signals
- Plotter configurations can be saved
- The same configuration to be used online and offline
- Plot printouts
- Configuration comprises measurements, simulation
  and parameters
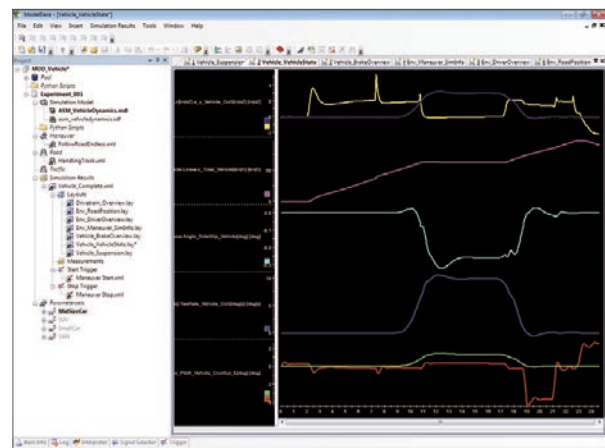
ModelDesk's plotter displaying various vehicle dynamics signals.

Road Definition

The Road Generator

The Road Generator is a graphical tool for planning and defining roads conveniently and efficiently. It helps users create an entire virtual proving ground by defining a reference line for the road and adding attributes for road features such as heights, lanes, and surfaces. There are specialized editors to define these in detail. Comprehensive graphics visualize the whole road and its individual features.

Key Features

- Road creation featuring layouts, height profiles, inclinations, lanes, surface conditions and low-μ areas
- Graphical road definition and preview
- Road definition based on a reference line and individual attributes along the line
- Specialized editors for road features

Defining the Reference Line

The reference line is the basis for a virtual road. The x/y layout of the road is defined by assembling straight, circular, clothoid or spline segments. Parameters like lengths and angles are defined individually for each segment. Road layouts can also be imported. Buildings along the road can be created automatically. The result is displayed in a 2-D preview.
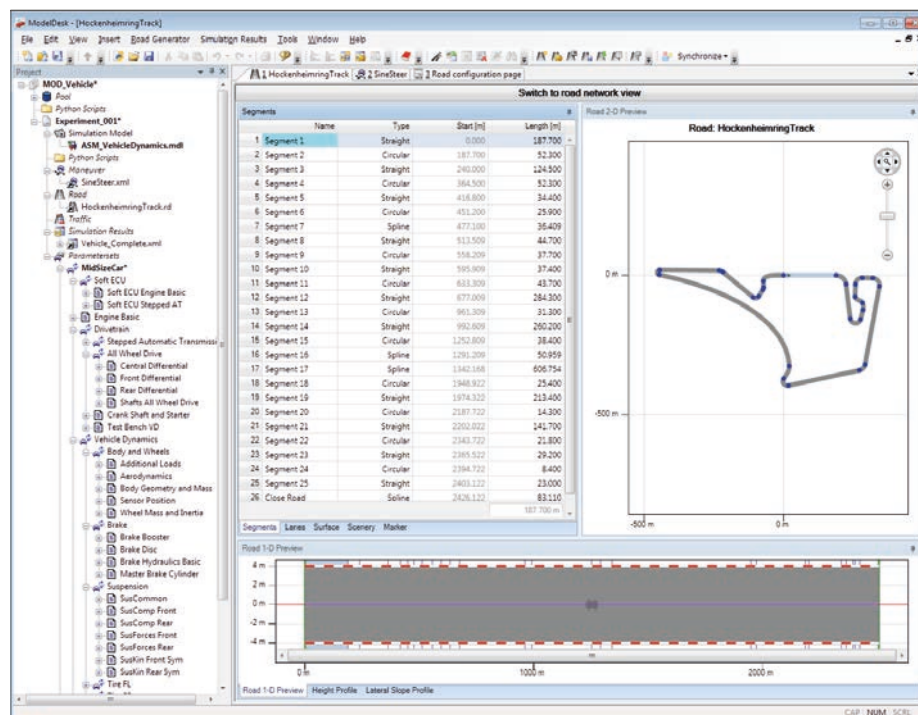
Properties of a longitudinal road profile.

Defining the Height Profile

Height points along the reference line are defined in a graphical editor. Parameters like the position, height, slope or gradient can be set individually for each height point.

Longitudinal road profiles can also be imported. The result is displayed in a 1-D preview.
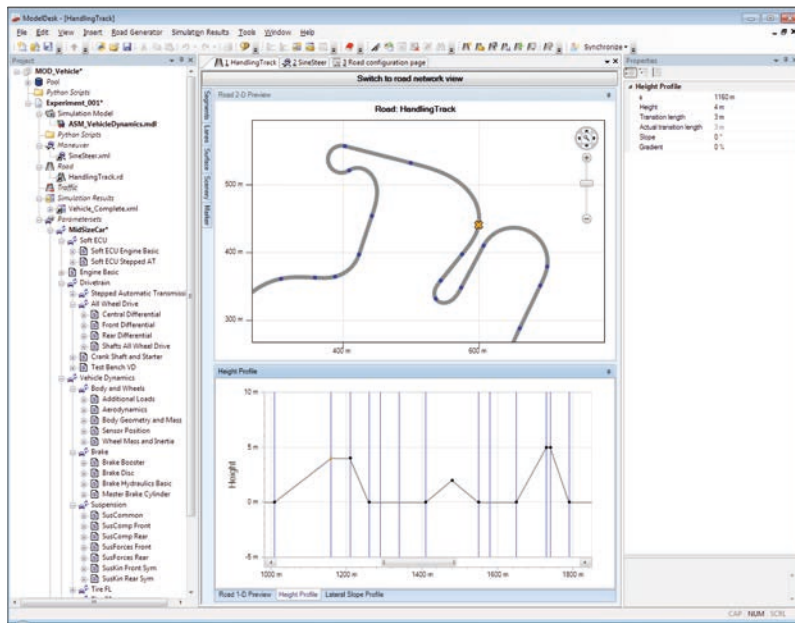
Definition and preview of the height profile.

Defining the Lanes

Each road can be split into a number of lane sections with up to 5 lanes of individual widths. The line types and colors

for the lanes are configurable. The result is displayed in a 1-D preview.
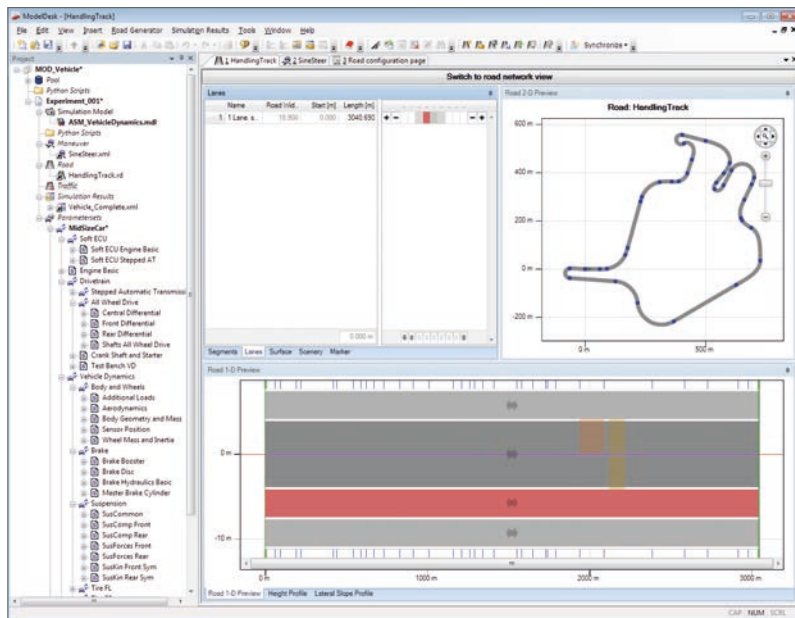
Preview of the lanes.

Defining the Surface Conditions and Low-µ Areas

The road friction, plus road surface conditions like damp, wet, icy, and dry can be freely applied to the road. Users can define the length and width of each area and place it anywhere on the road. Uneven road conditions like bumps and potholes are defined in the same way. Modified road areas are highlighted in the road preview.
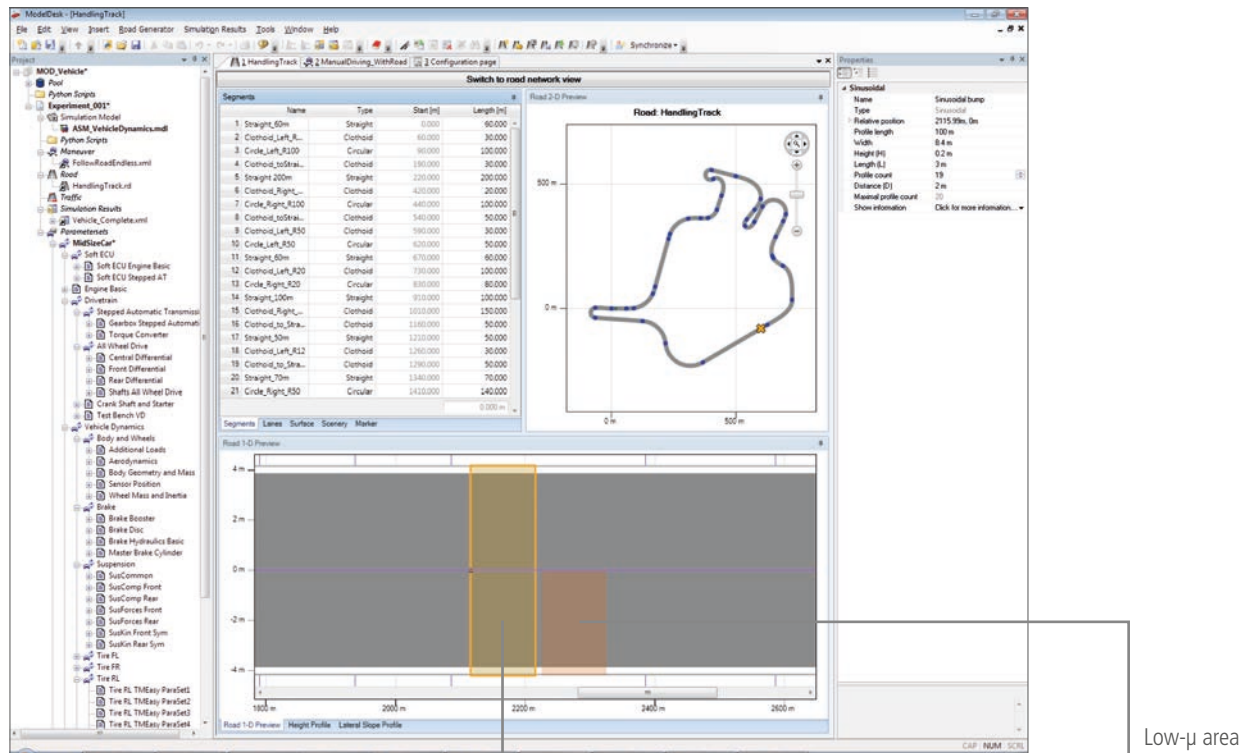
Definition of a sinusoidal bump in ModelDesk ...
          ... and the resulting road in MotionDesk.

Low-µ area

Bump area
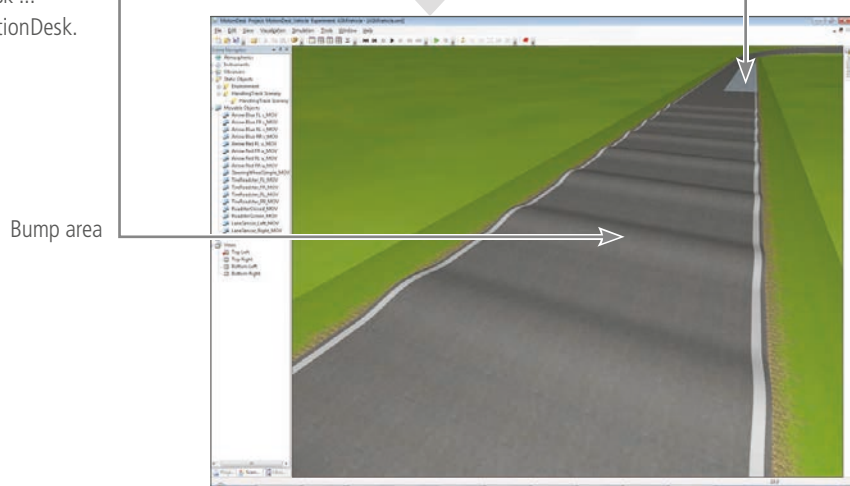
Maneuver Definition

The Maneuver Editor

The Maneuver Editor is used to define how and where a vehicle moves. Maneuvers can consist of several segments with their own individual properties. Segments are assembled in a maneuver list. When a maneuver is created the related road is visualized. Road and maneuver files can be linked.

Key Features

- Maneuver segment definition over distance or time
- Maneuvers assembled from individual maneuver segments
- Open- or closed-loop maneuvers
- Standard maneuvers included (lane change, μ split, steady state cornering, etc.)
- Lateral and longitudinal stimuli imported from measured data (MAT files)
- Lateral and longitudinal stimuli received as Simulink or ControlDesk signals
- User output signals programmable over time or distance
- Optional switching from one segment to the next regulated by segment end conditions such as a specific speed
- External input for ADAS controllers
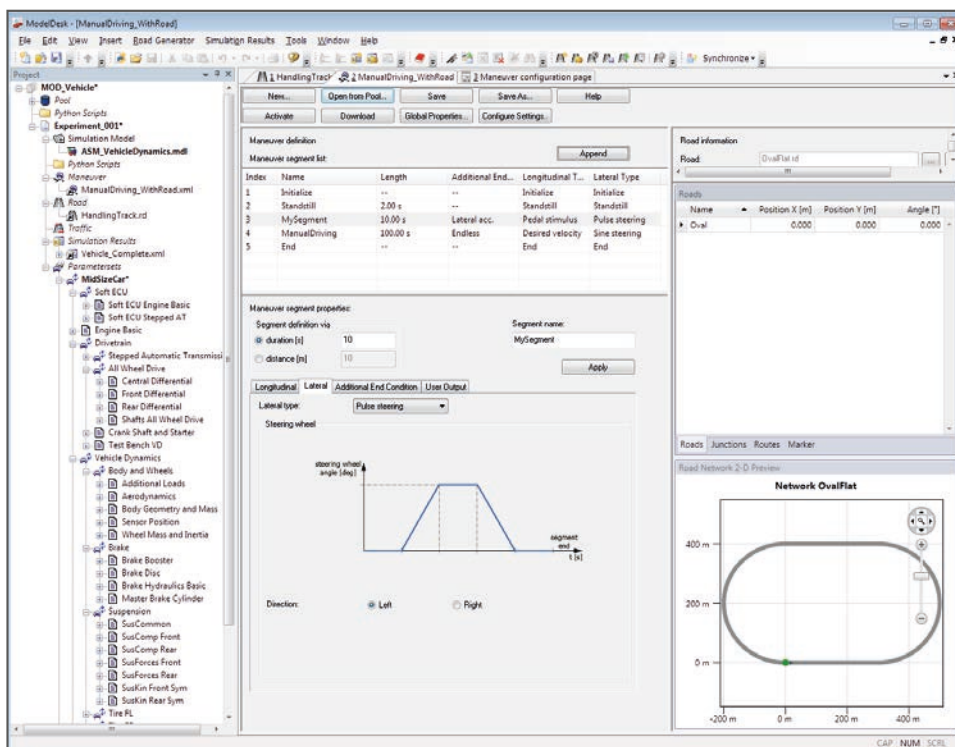
The ASM Maneuver Editor: the Navigator with the project data on the left, the list of maneuver segments and tabs with maneuver settings in the middle, the imported road with segment information and a visual preview on the right.

Longitudinal Maneuver Definition

The Maneuver Editor offers a wealth of stimulus options for accelerating, driving, and braking the vehicle. There are simple profiles such as constant and ramp. Stimuli can also be defined in tables or come from external sources, such as measured data (MAT files), Simulink signals, or defined manually via ControlDesk. The stimuli either define the de-

sired velocity or are applied directly to the accelerator and brake pedal to drive the vehicle. The sources for the accelerator pedal, brake pedal, clutch pedal, and gear stimuli can differ. Frequently used functions like 'brake until stop' and 'open clutch' are included.
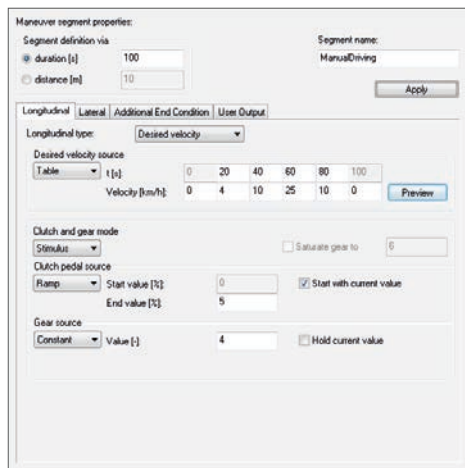
Longitudinal settings for stimulating the accelerator pedal, brake pedal, clutch pedal, and gears.

Lateral Maneuver Definition

Maneuvers for steering the vehicle include lateral stimuli and instructions for the driver. There are steering wheel stimuli profiles like step, pulse and sinusoidal steering. Driver instructions comprise options for driving on straight, circular,

and arbitrary roads. Steering can also be controlled from external sources like measured data (MAT files) and Simulink signals, and manually via ControlDesk.
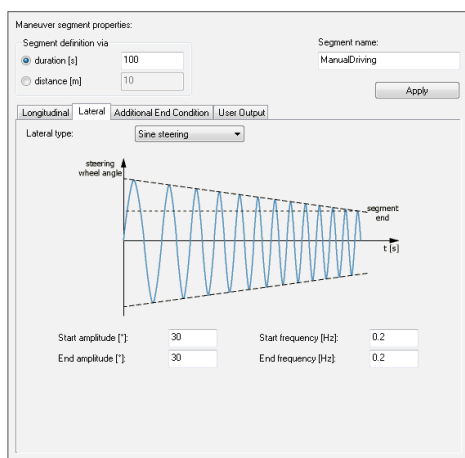
Sine steering can be configured in the lateral maneuver properties.

Maneuver Definition

User Signals

A maneuver itself can trigger output signals at any point or time to be used in other model parts, so specific milestones can be flagged to the outside world. 30 user signals are provided.
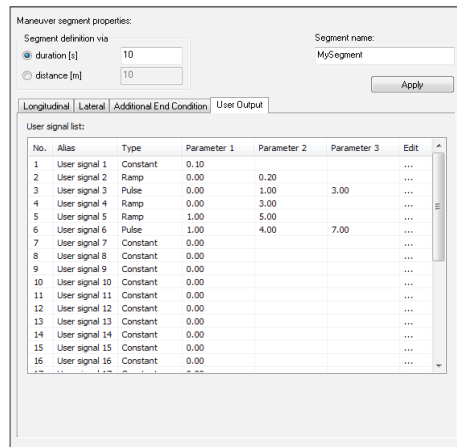
Three different user outputs per segment.

Additional Segment End Condition

To change from one segment to the next before the actual time or distance limit is reached, additional segment end conditions can be used.

If the vehicle reaches a certain speed or lateral acceleration or if an external trigger is active, a segment transition is forced.
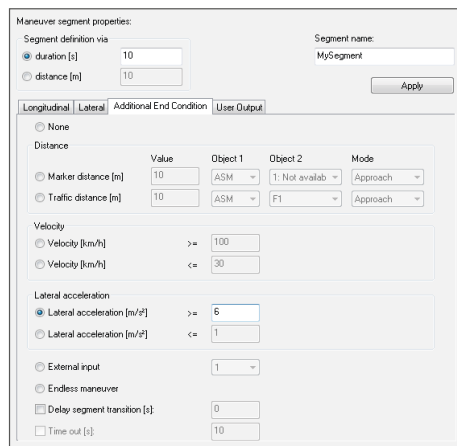
Switching from one segment to the next regulated by segment end conditions such as a specific speed.

Custom Model Parameterization

Graphical Parameterization of Custom Models

Graphical parameterization of model parts that were replaced by custom models or custom extensions to ASM is supported by ModelDesk. This allows you to manage all the parameters of a project from a single source.

Features

- Automatic generation of new parameter pages based on custom models
- Controls provided according to parameter dimension (scalar, vector, table)
- Display of original ASM and customized models as one system

Benefits

- Centralized parameter management
- Graphical parameterization without detailed modeling knowledge

Model Preparation

To use custom model parameterization, the customer models have to be prepared in libraries according to ASM guidelines in order to parameterize them in ModelDesk. These rules mainly define how parameters are declared. Libraries can include multiple model components, and each subsystem will be treated separately during parameterization, equipped with an individual parameter page.

Custom Library Registration

ModelDesk's registration function lets you select new custom libraries to parse them and make their parameters available graphically. During registration, parameter pages are created. Each page lists the controls of declared parameters. Controls can be single entry fields for scalar types, multiple entry fields for vectors, or complex tables for table-based parameters.

Navigating Custom Parameters

Whenever a model containing blocks from a registered custom library is loaded into a ModelDesk experiment the related parameter pages of these blocks are provided. They can be selected in the Navigator. Each library is represented as a branch in the hierarchy with links to the subsystem pages. The new pages can be used in exactly the same manner as the standard pages.

Custom parameter page created by ModelDesk. Controls for scalar, vector or table parameters are automatically labeled with the unit and caption as defined in the custom library.
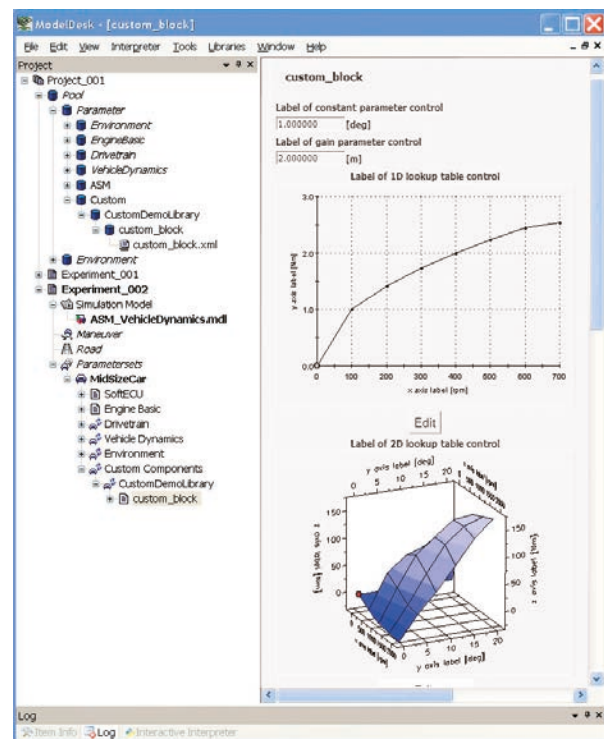
Automation Features

Tool Automation

Remote Control for ModelDesk

To perform long-term tests or parameter studies, ModelDesk provides script-based tool automation. This offers users maximum flexibility for defining custom simulation scenarios. Tool automation can be performed by means of scripting languages like Python and MATLAB M scripts.

Functionality

All ModelDesk's functions for experiment management and model parameterization that are available via its GUI can now also be accessed via its COM (Component Object Model of Microsoft Windows) interface. You can load existing model parameterization projects and activate predefined experiments. All the vehicle parameters such as the vehicle mass, suspension kinematics, engine torque, additional loads, and also environment or maneuver settings like road friction or vehicle velocity, can be controlled from within scripts.

Features

- Script-based tool automation
- Direct access to project and experiment management
- Direct alteration of all vehicle model parameters
- Direct alteration of maneuver segments
- Direct alteration of road features

Benefits

- Simulation-based parameter studies
- Automated marginal condition analyses/detection
- Long-term behavior studies
- Sequential maneuver executions
- Seamless integration into automation systems for HIL test

The script-based tool automation for ModelDesk provides functionality for parameter set management and for direct model parameterization. The parameters of online and offline simulations can be changed during a simulation run.
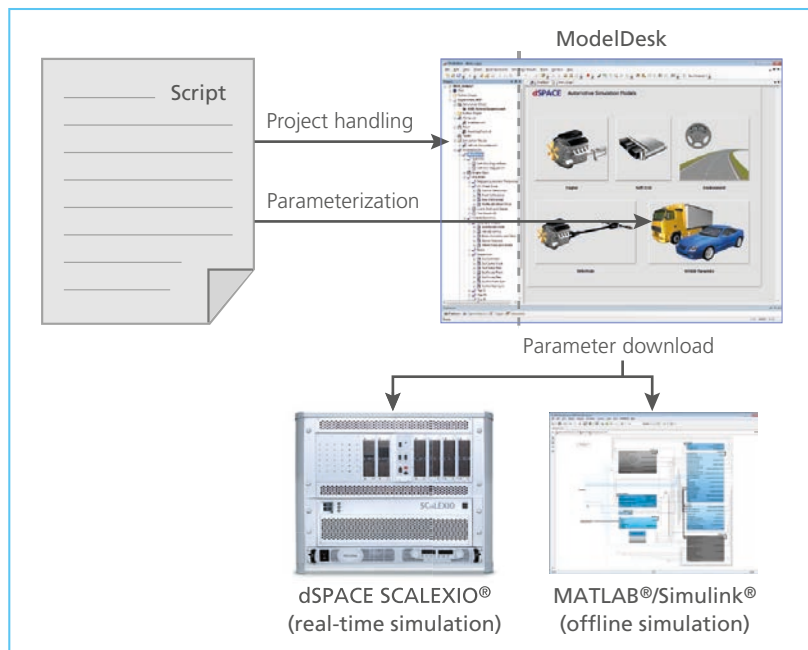
Tool Automation

Example:
ABS Braking With Varying Vehicle Mass

```python
TestDescription =[
   { 'TestName' :   'Low vehicle mass',
    'Maneuver'  :   'ABSBrake',
    'Parameter' : { 'Path': 'VEHICLE_MASS_AND_ADDITIONAL_LOADS.Const_m_Vehicle',
                'Value': 1800.0 }},
   { 'TestName' :   'High vehicle mass',
    'Maneuver'  :   'ABSBrake',
    'Parameter' : { 'Path': 'VEHICLE_MASS_AND_ADDITIONAL_LOADS.Const_m_Vehicle',
                'Value': 2200.0 }}]
try:
  Initialize(TestEnvironment)

  for Test in TestDescription:
    DownloadManeuver(Test['Maneuver'])
    SetParameter(Test['Parameter'])
    RunManeuver(TestEnvironment)

    GetResults(TestEnvironment)
    EvaluateResults()

finally:
   CleanUp(TestEnvironment)
```

Simplified extract from a Python script that shows how to define several tests and perform them in a loop.

Test Automation

AutomationDesk is dSPACE's environment for powerful and convenient test automation.
With the ModelDesk Access Library, tests created in Auto-mationDesk can control ModelDesk directly. Tasks such as changing parameters, switching between configurations and initiating simulation runs can therefore all be automated. A comprehensive report details the results.
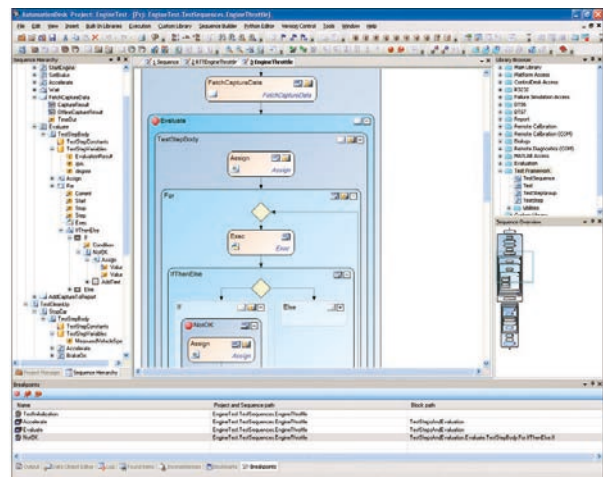
MotionDesk

3-D online animation of simulated mechanical systems in real time

Highlights

- Intuitive graphical scene design
- 3-D object library with objects in COLLADA format
- Completely new rendering engine guarantees much more detailed and realistic visualization
- Integrated 3-D Scene Editor
- Multitrack mode for synchronized replay of multiple simulations
- Tool coupling with ModelDesk

Application Area

When developing vehicle dynamics controllers such as ESP you need to be certain that they perform correctly, for example, by running HIL simulations. The best way to understand the behavior of a simulated system is animated visualization in realistic 3-D scenes. Combining a simulation system with real-time animation is the ideal way to get the whole picture. Since animations can be recorded and replayed, it is easy to compare different controller development strategies by using overlay techniques. MotionDesk supplements the dSPACE tool chain by visualizing vehicles in the 3-D world. MotionDesk is the perfect tool to visualize any kind of vehicle dynamics development and driving maneuvers, such as lane change, µ split, and cornering.

Key Benefits

MotionDesk helps you get more out of your HIL simulator, by visualizing your simulation in virtual worlds that exactly represent the simulation scenarios. MotionDesk reads the data from the dSPACE Simulator or VEOS® and displays the animation of the moving objects (vehicle, wheels, steering wheel, etc.) in real time, using the perspectives and render modes that you choose yourself, to give you a clear understanding of how the simulated objects actually behave. You can store the animations as experiment files and AVI video files to document and illustrate your developments.

Multitrack Mode

For you to compare different simulations, MotionDesk synchronously replays multiple simulations that have been assigned to different tracks. One track acts as the reference. Each of the other tracks contain clones of the simulated vehicle and synchronously replays data from previous simulation runs. The clones can be given different colors and render modes, e.g., textured, transparent, or wire frame, so that the simulations are easy to distinguish. Synchronized replay makes it easy to pick the best strategy for your control application.

Online and Offline Animation

MotionDesk has two animation modes:
- Online – connected with dSPACE real-time system or VEOS
- Offline – connected with Simulink®

The two modes let you start observations as early as the specification phase and later compare them with the results of hardware-in-the-loop simulation with the final electronic control unit. The sooner you are aware of certain effects and understand the problems, the easier it is to solve them.

Functionality at a Glance

3-D Animation of Simulated Mechanical Systems

- Lossless, time-based data acquisition with time stamps
- Synchronized replay of different simulations in multiple tracks
- Tracks consist of cloned 3-D objects and observers with individual colors and representations
- Slow and fast motion
- Up to 500 movable objects

- File-based recording and analysis of motion data
- Video file generation (for example, AVI, MPEG4) to export MotionDesk's animations to high-quality video files
- Intuitive operation
- Support of multichannel visualization with highest graphical requirements

Realistic Visualization

- Connection of objects and model data streams via drag & drop
- Structured access to all objects of the scene via navigator (movable and static objects, observers, environment light and fog settings)
- Freely configurable observers that can follow movable objects with different behaviors

- Various rendering techniques (wire frame, flat shading, Gouraud shading, textured)
- Render modes selectable for whole scene and for individual objects
- Improved driver camera with more realistic viewpoint (smooth follow behavior)
- Scene statistics

Everything You Need in One Tool

The new MotionDesk is easier to handle. You can now perform all the important operations such as 3-D scene creation in one tool, mainly by drag & drop.

- Scene navigator
- 2-D scene view
- New rendering kernel

- 3-D library
- Property grid
- Instruments

New rendering kernel

Scene navigator

2-D scene view

Property grid

3-D library
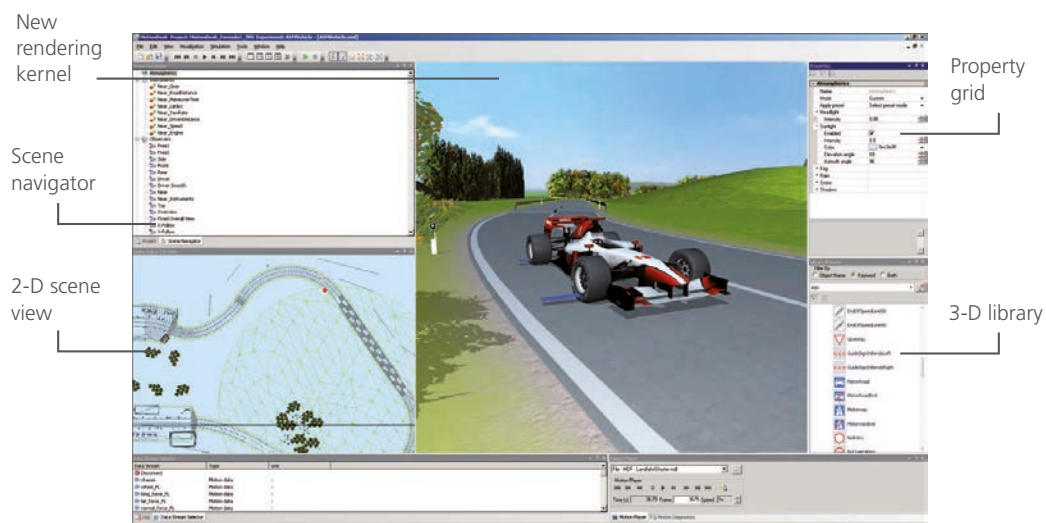
3-D Authoring: Creating a Virtual World

Integrated Tools

MotionDesk gives you a complete 3-D authoring package for easy creation of virtual worlds. You can choose objects from libraries and import 3-D data from 3-D CAD applications. The new, comprehensive library of 3-D objects lets you set up scenes very fast by simply selecting and positioning the objects. A 3-D Library Browser helps you find the objects you need, for example, by keyword search. Library expansion is easy as the 3-D object geometries are described in the COLLADA standard. Road geometries for automotive applications can be generated automatically using vehicle dynamics models such as the dSPACE ASM Vehicle Dynamics Simulation Package.

Animation with MotionDesk

Once created, the 3-D scene comes to life in MotionDesk. dSPACE Simulator provides the motion data, and Motion-Desk moves the 3-D objects in the scene accordingly. For example, when a car is simulated, the movement of the chassis is displayed with four individually rotating wheels, including force vectors visualizing the forces between road and wheel. You can adjust the transformations, scalings, colors and render modes of objects within MotionDesk.
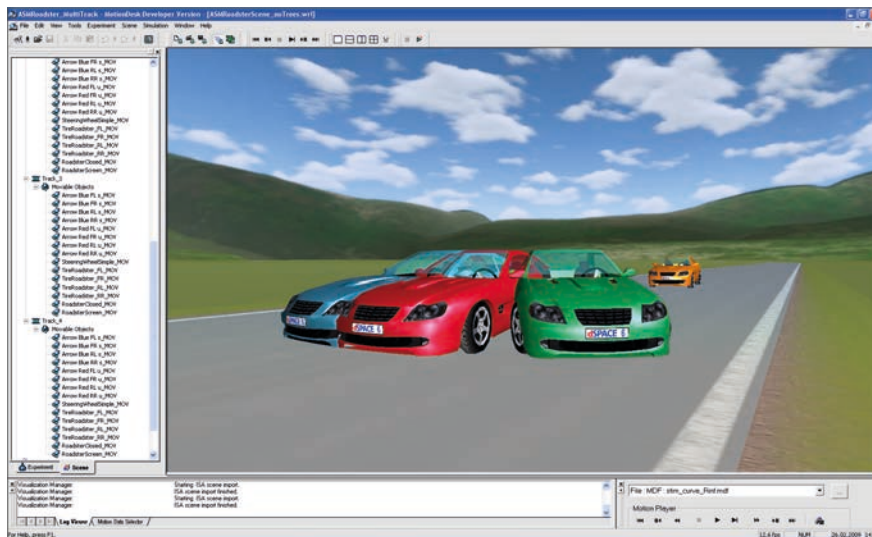
Four different strategies for a driving maneuver lead to four different simulations. You can visualize the four simulations together in one animation by using a different color for each simulation.

Offline Simulation
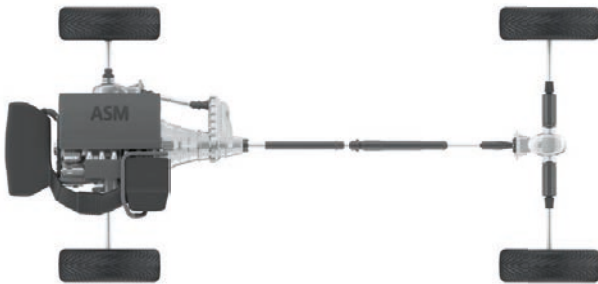
Operator Version for PC-based Offline Simulation

ASM Vehicle Dynamics Simulation Package – Operator Version

The Operator Version of the ASM Vehicle Dynamics Simulation Package is a model variant specifically designed for offline simulation with Simulink. It is therefore the ideal choice for PC-based vehicle dynamics investigations during function development. The model offers the same functionality, simulation quality and parameterization options as the standard simulation package, whose range of applications runs from function design to hardware-in-the-loop testing.

The fundamental difference with this model is the way the library components are implemented: They are encapsulated in separate systems to ensure good performance during Simulink simulation. The systems are accessible in the model so that their input/output behavior can be studied.

Key Features

- Component-based Simulink libraries
- Encapsulated on lower levels (S-functions)
- For offline simulation only
- Full MATLAB/Simulink support
- Full ModelDesk support
- Same functionality, level of detail and parameterization options as a standard ASM package

Use Cases

Typical applications are closed-loop tests on controller functions with model-in-the-loop (MIL) and/or software-in-the-loop (SIL), and also vehicle dynamics investigations such as:
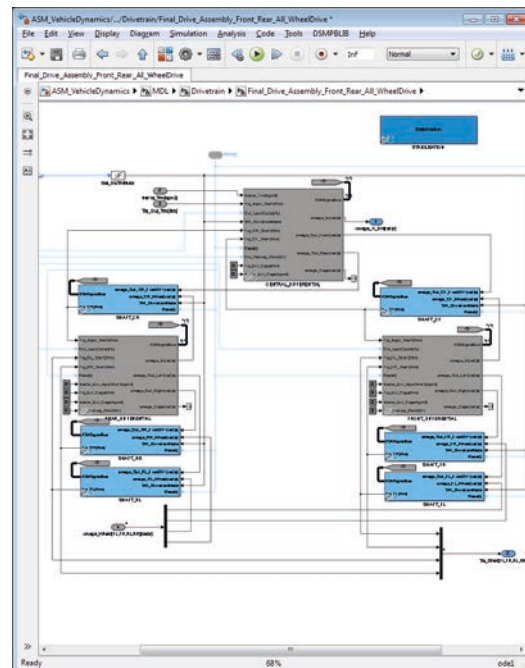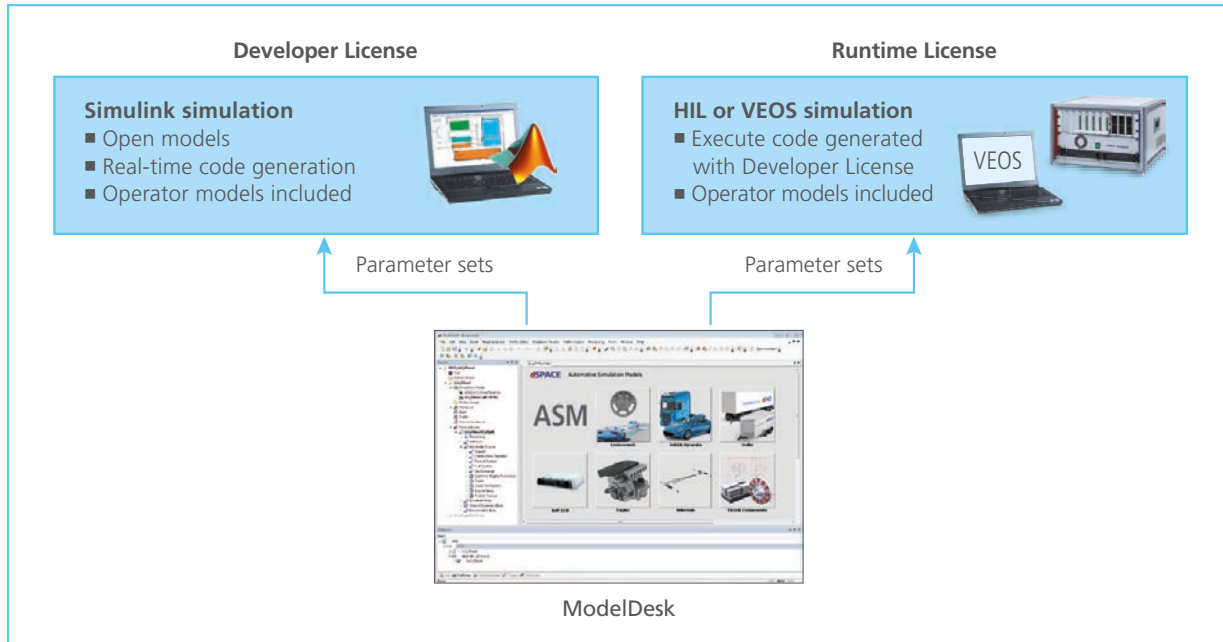
- Parameter studies
- Maneuver handling studies
- Parameter set variant handling

Model structure of the ASM Operator drivetrain. Each component has a corresponding block in the library.

ASM Versions and Licenses

Developer License

Simulink simulation
- Open models
- Real-time code generation
- Operator models included

Runtime License

HIL or VEOS simulation
- Execute code generated with Developer License
- Operator models included

Parameter sets   Parameter sets

ModelDesk

The ASM License Concept

The ASM models come with two different license types: the Developer License and Runtime License. This lets users integrate the models in various kinds of applications, without losing any of the characteristic ASM flexibility.

- **Exchangeability** – You can use both licenses on one PC or split them to have one PC for model maintenance and one PC for simulation platform operation.

- **Mutual Parameterization** – Both license types let you parameterize all models with ModelDesk's parameterization options for simulation on a PC (offline) or on dSPACE real-time hardware (online).

- **Seamless 3-D Animation** – The vehicle dynamics and traffic models provide access to MotionDesk with both license types. The models must include the MotionDesk blockset.

The Benefits

- A simulation environment that seamlessly covers the offline and real-time worlds
- ModelDesk is the parameterization tool throughout the entire process, which means that you can reuse parameter sets.

- Cost-efficient license types for offline and online (real-time) simulation
- Simulation models are parameterized and reconfigured in ModelDesk with the Runtime License also. This enables real-time simulation on a dSPACE platform without an additional MATLAB license.

ASM Developer License

The Developer License is designed specifically for modifying, parameterizing and preparing the open Simulink models for simulation on a real-time platform. The license lets you generate real-time code. Moreover, the license can be used for Simulink simulation on a PC (offline).

Properties

- Modular *developer models* viewable down to the Simulink block level
- Modular, encapsulated *operator models*, designed specifically for Simulink simulation (offline)
- Easy substitution or extension of ASM models by customer-specific model parts
- Support for real-time and VEOS code generation
- Simulink simulation on a PC (offline)

ASM Runtime License

The Runtime License is designed specifically for simulation on a real-time platform (online) and Simulink simulation of *operator models* (offline).

Properties

- Code execution on dSPACE real-time hardware (dSPACE Simulator, SCALEXIO)
- Code execution on dSPACE VEOS
- Code already generated from the models via the Developer License
- Simulink simulation of *operator models,* which are modular, encapsulated, and designed specifically for Simulink simulation (offline).

Technical Aspects

Parameters, Signals, and Performance

Parameters Sets and Examples

The model is preconfigured with default data, which means that all parameters and tables have suitable values and are fully functional.

The model comes with standard driving maneuvers like lane change, µ split, fishhook, steady-state cornering, etc. It is therefore ready to use immediately after installation.

Performance

At a sample time of 1 ms, the model's turnaround time is about 10% of the total available processing time when executed on a dSPACE processor board clocked at 2.2 GHz. There is therefore enough headroom for I/O operations and other calculations.

Parameters Tunable Online

The parameters of the model can be tuned while the model is performing a real-time simulation on a dSPACE Simulator. A parameter (vehicle mass, etc.) is implemented as a single constant block in the model. ControlDesk provides access to each parameter when the model is used in online mode.

ASMSignalBus

The ASMSignalBus comprises the relevant signals of all model components in a hierarchical structure. Signals for I/O access with an interface board or for display with a Simulink Scope can be chosen conveniently via a Simulink Bus-Selector.

ASMSignalBus displays all the relevant signals in a clear structure.

The vehicle dynamics Simulink model with the main components and signals.

Main Features and Benefits

Feature	Description	Benefit
Open Simulink models	■ Almost all model blocks are visible	■ Custom models can easily be added or used to replace model components
ModelDesk	■ Graphical user interface with parameter management for vehicle dynamics model	■ Easy parameter handling, maneuver planning, and road construction
Online simulation	■ Real-time simulation on real-time hardware	■ Hardware-in-the-loop simulations with ECUs
Offline simulation	■ Simulations as early as the design phase	■ Controller validation in early development stages
ASMSignalBus	■ Simulation signals are part of a structured Simulink signal bus	■ Standardized and fast access to model variables
Online tunable parameters	■ Direct parameter access during real-time simulations	■ Online parameter optimizations and behavior studies
Model interoperability	■ ASM models are easy to combine to create a virtual vehicle	■ An entire virtual vehicle can be simulated

Order Information

Classification	Type	Order Number
Packages	ASM – Gasoline Engine Basic Simulation Package	■ Please inquire
	ASM – Gasoline Engine Simulation Package	■ Please inquire
	ASM – Diesel Engine Simulation Package	■ Please inquire
	ASM – Gasoline Engine InCylinder Simulation Package	■ Please inquire
	ASM – Diesel Engine InCylinder Simulation Package	■ Please inquire
	ASM – Vehicle Dynamics Simulation Package for VEOS®	■ Please inquire
	ASM – Vehicle Dynamics Simulation Package	■ Please inquire
	ASM – Truck and Trailer Simulation Package	■ Please inquire
Libraries	ASM – Turbocharger Model	■ ASM_L_TC
	ASM – Electric Components	■ ASM_L_EC
	ASM – Brake Hydraulics Model	■ ASM_L_BH
	ASM – Pneumatics	■ ASM_L_PNEU
	ASM – Diesel Exhaust Model	■ ASM_L_DEXH
	ASM – Traffic	■ ASM_L_TRF

Relevant Software and Hardware

Software		
Required	Integrated development environment	■ MATLAB/Simulink from MathWorks ■ Simulink® Coder™ (formerly Real-Time Workshop®)[2] ■ Simulink Performance Tools[1]
	dSPACE implementation software	■ Real-Time Interface (RTI)[2]
	dSPACE experiment software	■ ControlDesk®[2] Next Generation
	Additional software	■ Microsoft® Excel®
	Operating system	■ www.dspace.com/goto?os_compatibility

Hardware		
Required	Minimum system	■ Pentium® 4 processor, 1.4 GHz or higher ■ Memory = 2 GB RAM ■ Graphics accelerator card matching the requirements of MotionDesk[3]
	Recommended system	■ Intel® Core™ i5 Processor, 3 GHz or higher ■ Memory ≥ 4 GB RAM ■ Dual-head graphics accelerator card matching the requirements of MotionDesk[3]
	SCALEXIO; dSPACE Simulator, equipped with	■ DS1005 PPC Board or DS1006 Processor Board[4]

[1] *Offline simulations only.*
[2] *Online simulations only.*
[3] *Graphics accelerator required for MotionDesk which is part of the ASM Vehicle Dynamics Simulation Package. More details on graphics card requirements and compatibility at www.dspace.com/go/mdhwrequ*
[4] *ASM Traffic, ASM Truck, ASM Trailer, and ASM Engine InCylinder Models support the DS1006 only.*

05/2016

Embedded Success

dSPACE