Automotive Simulation Models

- Combustion Engine Simulation
- Vehicle Dynamics Simulation
- Truck and Trailer Simulation
- Traffic Simulation
- Electric Components Simulation
- ModelDesk/MotionDesk
Automotive Simulation Models (ASM)

Tool suite for simulating the engine, vehicle dynamics, electrical system, and traffic environment

Highlights

- Open MATLAB®/Simulink® models
- For ECU testing and function development
- Intuitive graphical parameterization, and road, maneuver, and traffic creation in ModelDesk

Application Areas

The Automotive Simulation Models (ASM) are a tool suite of open Simulink models for the real-time simulation of passenger cars and trucks as well as their components. They are used as plant models for the development and testing of engine controls, vehicle dynamics controls, on-board power electronics and driver assistance systems. The ASMs typically run on a dSPACE Simulator/SCALEXIO for hardware-in-the-loop (HIL) testing of electronic control units (ECUs) or during the design phase of controller algorithms for early validation by offline simulation.

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 properties of modeled components perfectly to individual requirements. The ASMs’ standardized interfaces make it easy to expand a single model such as an engine or body, or even create a whole virtual vehicle. Roads and driving maneuvers can be easily and intuitively created using graphical tools with preview and clear visualization.

Modular Concept

The ASM concept consists of coordinated, combinable models of automotive components. There is a vehicle model with a trailer, plus other ASMs for gasoline, diesel and hybrid engines, exhaust systems, turbochargers, brake hydraulics, electrical systems, electric motors, environment sensors, roads and traffic. The ASMs support a whole range of simulations from individual components to complex virtual traffic scenarios.

Offline and Online Simulation

The ASMs can be used in combination with real controllers in a hardware-in-the-loop environment (HIL or online mode), or for model-in-the-loop simulations (PC or offline mode). The same model configurations and parameters can be used seamlessly throughout all the steps from function development to ECU testing.
Main Features and Benefits

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<thead>
<tr>
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<th>Description</th>
<th>Benefit</th>
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<tr>
<td>Open Simulink models</td>
<td>Almost all models are open down to the Simulink block level</td>
<td>Custom models can easily be added or used to replace model components</td>
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<td>ModelDesk</td>
<td>Graphical user interface with parameter and simulation management</td>
<td>Easy, intuitive parameterization and seamless simulation handling</td>
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<td>Online simulation</td>
<td>Real-time simulation on real-time hardware</td>
<td>Hardware-in-the-loop simulations with ECUs</td>
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<td>Offline simulation</td>
<td>Simulations as early as the design phase</td>
<td>Controller validation in early development stages</td>
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<td>ASMSignalBus</td>
<td>Simulation signals are part of a structured Simulink signal bus</td>
<td>Standardized and fast access to model variables</td>
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<td>Online tunable parameters</td>
<td>Direct parameter access during real-time simulations</td>
<td>Online parameter optimizations and behavior studies</td>
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<tr>
<td>Model interoperability</td>
<td>ASM models are easy to combine to create a virtual vehicle</td>
<td>An entire virtual vehicle can be simulated</td>
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Order Information

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<td>Please inquire</td>
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<td>ASM – Gasoline Engine Simulation Package</td>
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<td>Libraries</td>
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<td>ASM – KnC</td>
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Relevant Software and Hardware

Software

| Required                      | Integrated development environment | MATLAB®/Simulink® from MathWorks |
|                              | dSPACE implementation software     | Simulink® Coder™ (formerly Real-Time Workshop®)³ |
|                              | dSPACE experiment software         | Simulink Accelerator²           |
|                              | Additional software                | Real-Time Interface (RTI)³      |
|                              | Operating system                  | ControlDesk ³                  |

Hardware

| Required                      | Recommended system | Intel® Core™ i7 Processor |
|                              |                    | Memory ≥ 8 GB RAM         |
|                              |                    | Dual-head graphics accelerator card matching the requirements of MotionDesk⁴ |

¹ MATLAB®/Simulink® Student Suite does not support Automotive Simulation Models (ASM).
² Offline simulations only
³ Online simulations only
⁴ 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
Introduction

**Why Use Simulation? Why Use Models?**
In model-based design (MBD), simulation is a widely used and proven method. It is applied to test and validate control algorithms in a virtual world instead of on the real controlled device. For automotive applications this ranges from simulated individual components, such as engines, to complete virtual vehicles, up to virtual environments consisting of a vehicle and its surrounding traffic, traffic signs, and so on.

Virtualized controlled device (vehicle) and controller (ECU) in a control loop.

**ASM Simulation Tool Suite**
The Automotive Simulation Models (ASM) from dSPACE are a simulation tool suite covering four application areas: combustion engines, electric components, vehicle dynamics and the traffic environment. These ready-to-use simulation models exactly represent the behavior of the controlled devices. The ASM tool suite is designed to fully comply with the MBD approach. All models are implemented with MATLAB®/Simulink®.

Tool suite for simulating engines, electric components, vehicle dynamics and traffic.

**Simulation Platforms**
The support of multiple platforms allows for seamless simulation processes from model-in-the-loop (MIL) to software-in-the-loop (SIL) to hardware-in-the-loop (HIL). The ASM tool suite can be executed on different simulation platforms: SCALEXIO, dSPACE Simulator, VEOS, or a PC running MATLAB/Simulink. Depending on the platform, simulations can be performed either with the controller software or the controller hardware (ECU) in the control loop. In either case the simulation model stays the same.

The ASM simulation tool suite supports multiple simulation platforms.
Philosophy

Supports Model-Based Design
- Real-time-capable Simulink models
- Provides access to internal modeling details, down to block level
- Supports all stages of controller software development (MIL, SIL, HIL)
- Soft-ECU network
- Signal interfaces for automotive applications

Ready-to-use Off-the-Shelf (OTS) Models
- One integrated tool chain for parameterization, validation and test automation
- Open documentation, including mathematical equations
- Supports migration, including between MATLAB releases
- Worldwide customer base and mature models

Complete ASM Product Portfolio
- Supports all automotive-relevant modeling areas
- Easily combinable models for building virtual vehicles
- Different levels of model complexity (e.g. mean value, physical) for all controller design and test use cases

Comprehensive Engineering and HIL Knowledge
- The one-stop supplier for all HIL-relevant tasks
- Customer training and worldwide support
- Combination of OTS models and custom specific model engineering
Combustion Engine Simulation

Real-time models for diesel and gasoline engine simulation

Simulation Packages and Models
- Diesel and gasoline engines
- Mean-value and InCylinder plant models
- Physical turbocharger
- Diesel aftertreatment system

Example Use Case: Evaporative System Monitoring

The Task
Validate the correct functionality of the fuel tank evaporation system for onboard diagnostics (OBD) tests.

The Challenge
Because of the hazardous characteristics of gasoline fuel, a reliable tank evaporation system is necessary to prevent a contamination of the environment. While driving, the ECU has to actuate the valves of the evaporation system to draw vaporized fuel from the tank. The vaporized fuel is burned in the engine. Furthermore, venting operation modes are available during refueling and diagnostic routines check for leakages in the tank system. For these complex interactions of the valves, it is crucial to precisely model temperatures, pressure, and gas composition.

The Solution
The evaporation system of ASM supports the calibration of these routines, because important components are physically modeled. The tank and the canister are modeled as dynamic reservoirs and calculated with the laws of mass conservation and energy equilibrium to archive realistic pressure and temperature behavior. The model differentiates between liquid and gaseous fuel, considering the vaporization of fuel. The ASM Evaporation system provides continuous modeling of the vaporized fuel that moves from the tank via the intake manifold to the engine cylinders. Consequently, the effect of the vaporized fuel on the combustion process can be measured by the ECU and is an indicator of a correctly working evaporation system.
ASM Gasoline Engine Basic

Basic mean-value engine model with combustion torque modulation

Main Model Components
- Air system
- Fuel system
- Piston engine
- Turbocharger
- Drivetrain (basic)
- Vehicle dynamics (longitudinal)
- Environment (basic)
- Soft ECU

Features at a Glance
- Up to 20-cylinder gasoline applications
- Up to 4 injections per cylinder per cycle
- Intake manifold with calculation of intake manifold pressure and temperature
- Map-based turbocharger for boost pressure calculation
- Fuel injection system with fuel tank model
- Wall film evaporation taken into account
- Longitudinal driver for standard cycles (FTP75, NEDC, J10-15, …)
- Simulation with real ECU in hardware-in-the-loop (HIL) system and simulated soft ECU in model-in-the-loop simulation
- Start/stop system support

Simulation Model Characteristics
The actual physical engine characteristics are represented by a mean-value engine model with crank-angle-based torque generation, dynamic manifold pressure, temperature calculation, and an injection model. To simulate the engine in an automotive system (car or truck), the engine model incorporates a longitudinal drivetrain model with manual and automatic transmission, a clutch, a torque converter, a starter, and a test bench mode. Models for the environment and driver complement the virtual powertrain.

More detailed information available
- www.dspace.com/asm

Schematic of the air system.
ASM Diesel/Gasoline Engine

Mean-value engine models with combustion torque modulation

Main Model Components
- Air system
- Fuel system
- Piston engine
- Aftertreatment systems
- Turbocharger
- Drivetrain (basic)
- Vehicle dynamics (longitudinal)
- Environment (basic)
- Soft ECU

Features at a Glance
- Up to 20-cylinder diesel/gasoline applications
- Map-based turbocharger for boost pressure calculation
- Gasoline fuel injection system: direct injector and intake manifold injector
- Natural gas fuel supply systems
- Gasoline engine with homogenous and stratified combustion modes
- Gasoline engine with evaporation system support
- Gasoline exhaust system including dynamic three way catalyst simulation with respect to oxygen storage capacity
- Common rail system including rail, fuel tank as well as current or crankbased high pressure pump
- Diesel fuel injection systems: direct injector, unit injector, unit pump
- Up to 8 direct injections and 4 port injections per cylinder per cycle
- Diesel exhaust system including diesel oxidation catalyst (DOC) and diesel particulate filter (DPF)
- High-pressure and low-pressure exhaust-gas recirculation (EGR) of exhaust and unburned air with EGR cooler
- Start/stop system support
- Longitudinal driver for standard cycles (WLTC, FTP75, NEDC, J10-15, ...)

Simulation Model Characteristics
The physical engine characteristics are represented by a mean-value engine model with crank-angle-based torque modulation, dynamic manifold pressure, temperature calculation, and several fuel injection models. A soft ECU is included for scenarios where a real ECU is not available, for example, in offline simulation. To simulate the engine in an automotive system (car or truck), the engine model incorporates a longitudinal drivetrain model with manual and automatic transmission, a clutch, a torque converter, a starter, and a test bench mode. Models for the environment and driver complement the virtual powertrain.

More detailed information available
www.dspace.com/asm

Schematic of the air system.
ASM Diesel/Gasoline Engine In-Cylinder

Real-time engine models with in-cylinder pressure and temperature simulation

Main Model Components
- Air system
- Fuel system
- Valve system
- Piston engine
- Diesel aftertreatment system
- Turbocharger
- Drivetrain (basic)
- Vehicle dynamics (longitudinal)
- Environment (basic)
- Soft ECU

Features at a Glance
- Simulation of in-cylinder pressure and temperature in real time: for example, in response to injection or variable valve timing
- Diesel applications with up to 20 cylinders with common rail and turbocharger for real-time simulation.
- Up to 8 direct injections and 4 port injections per cylinder per cycle
- Gasoline applications with up to 20 cylinders with direct or port injection and turbocharger for real-time simulation.
- Diesel: multiple injection patterns such as pre-, main and post-injection
- Gas exchange simulation related to the lift of the intake and exhaust valves
- Fuel injection systems: common rail injector (Diesel), direct or port injection (Gasoline)
- Exhaust-gas recirculation (EGR) of exhaust and fresh air with EGR cooler
- Start/stop system support
- Simulation of parallel intake and exhaust air paths for V-type engine

Simulation Model Characteristics

The ASM Diesel Engine In-Cylinder Simulation Package and the Gasoline Engine In-Cylinder Simulation Package are open Simulink models for developing and testing electronic control units (ECUs) with engine management based on the in-cylinder pressure. The models simulate in-cylinder pressure in real time by means of a zero-dimensional thermodynamic approach. The diesel combustion process simulation can handle multiple injection patterns such as pre-, main and post-injection. In the combustion process, gas exchange simulation is related to the lift of the intake and exhaust valves. The gas-dynamical behavior of the air path and exhaust path is implemented as a mean value system with manifold pressure, temperature, and mass calculation. The inlet and exhaust valves are modeled as isentropic orifices. They can handle variable valve timing (VVT), variable valve lift (VVL), and the simulation of engines without a camshaft.

To simulate the engine within an automotive system (car or truck), the engine model incorporates a basic longitudinal drivetrain model. Models for the environment and driver complement the virtual powertrain.

More detailed information available
- www.dspace.com/asm
ASM Turbocharger

Physical turbocharger model

Main Model Components
- Compressor
- Turbine
- Wastegate valve
- Shaft

Features at a Glance
- Calculates air path with the precision of a physical model
- Wastegate valve and variable turbine geometry (VTG)
- Turbocharger state calculation based on common manufacturer maps including heat loss calculation
- Alternative to map-based model with easy switching between map-based and physical approach
- Support of diesel and gasoline engine models
- Support of SAE J922 turbine model data format
- Single and double stage turbocharger
- Centrifugal compressor or positive displacement compressor (supercharger) simulation

Simulation Model Characteristics

The Turbocharger Model is an extension for the diesel and gasoline engine models. It provides a more realistic model of turbocharger components and the engine air path than the map-based turbochargers models. It simulates an exhaust gas turbocharger that consists of a compressor, a turbine, and a turbocharger shaft. Turbochargers with variable turbine geometry (VTG) and wastegate can be simulated.

The turbine model calculates the mass flow, the output temperature, and the resulting power output according to wastegate or VTG position. The compressor and turbine are connected by a shaft, and the model provides the shaft speed. The compressor model calculates the boost pressure and the temperature in the compressor, using the equations for compressor power and compressor output temperature.

More detailed information available
- www.dspace.com/asm

Schematic of the turbocharger system.
ASM Diesel Exhaust System

Real-time diesel aftertreatment system

Main Model Components
- Diesel oxidation catalyst (DOC)
- Diesel particulate filter (DPF)
- Selective catalytic reduction (SCR)
- Support of all ASM engine diesel models

Diesel Particulate Filter Model
The diesel particulate filter model is designed to remove diesel particulate matter (DPM) from the exhaust gas.

Diesel Oxygen Catalyst Model
The diesel oxygen catalyst model simulates the physical effects of an oxidation process on the exhaust gas. The underlying but unmodeled chemical process can be described by using excess O₂ (oxygen) in the exhaust gas stream to oxidize CO (carbon monoxide) to CO₂ (carbon dioxide) and HC (hydrocarbons) to H₂O (water) and CO₂.

Selective Catalytic Reduction (SCR) Model
For NOx reduction, a model with selective catalytic reduction (SCR) is included. The model calculates the physical and chemical processes of AdBlue injection into the exhaust gas.

Diesel Aftertreatment System
The diesel aftertreatment system is a combination of models of an oxidation catalyst, a particulate filter, and a selective reduction catalyst. The system assumes an ideal gas with a steady gas constant. The different catalyst and filter models can be combined in any order. During simulation the pressure drop over the aftertreatment system is calculated as well as the temperatures and lambda of the exhaust gas before and after the system.

Components and Characteristics
- Pressure drop over DOC/DPF
- Temperature before and after DOC/DPF
- Lambda before and after DOC/DPF
- Particulate mass in DPF
- DPF regeneration by post-injection or additional injection

Components and Characteristics
- Zero-dimensional approach
- Series connection of identical cells
- Number of cells represents the sectional discretization
- Outputs of one cell are inputs of the following cell
- AdBlue dosing system with and without air supply
- Urea decomposition upstream of the SCR catalyst

More detailed information available
- www.dspace.com/asm

Schematic of the diesel exhaust system with DOC, DPF and SCR models.
NEW: ASM Drivetrain Basic

Longitudinal driving characteristics including dedicated transmission models

**Application Areas**
- Test of dual clutch transmission control units
- Longitudinal vehicle simulation (e.g. for testing power-train control units)

**Components and Characteristics**
- Ready-to-use physical demo model for dual clutch transmission systems
- Soft ECU for automatic transmission including conventional systems, automated manual transmission systems as well as dual clutch transmission systems
- Map-based combustion engine simulation with fuel consumption estimation
- Empirical simulation of conventional transmission systems
- Physical simulation of mechanics and hydraulics of a dual clutch transmission system (also applicable for automated manual transmission systems)
- Longitudinal vehicle dynamics
- Simulation of longitudinal driver behavior for pedal and gear actuation

**Dual Clutch Transmission Tests**
Testing dual clutch transmission (DCT) control systems requires a sophisticated simulation of the coupled mechanical and hydraulic parts. Depending on the shaft speeds of the DCT gearbox, the control unit requests a preselection of the most probable gear by actuating hydraulic valves that create a movement of mechanically synchronized elements. As soon as the shaft speeds reach an adequate range, the next gear is engaged and the control unit smoothly moves from one output shaft to the other by actuating both clutches.

In order to provide a real-time-capable model that can be applied to DCT systems of different topologies, a general approach was implemented, which allows the user to parameterize the system (e.g., gear distribution on the output shaft) or to adapt the system directly in the open Simulink model. A Soft ECU is provided with the dynamic simulation model to control the DCT system without the real controller. As soon as a real ECU is available, the actuator loops can be switched from the virtual to the real controller.

DCT example configuration.

Hydraulic shift actuation system.
Longitudinal Driving Characteristics

Longitudinal driving simulation methods are commonly used in testing scenarios of powertrain control units to follow a given reference velocity. The vehicle resistances, such as slope and aerodynamics as well as the driver capabilities, such as pedal actuation and gear shifting, have to be modeled. Depending on whether the vehicle velocity is defined as a reference signal or the gears and/or pedals are given as stimulus signals, there are several use cases for the driver that have to be taken into account for simulation. Each operation mode has to be simulated as realistically as possible to also account for efficiency analysis. Furthermore, situations, such as engine startup/stall, gear skipping (e.g., truck applications), and adaptable clutch actuating behavior during gear shifting are only some examples of a highly flexible longitudinal driver implementation.
Electric Components Simulation

Real-time models for vehicle electrics and electric drive system simulation

**Simulation Packages and Models**
- Processor-based plant model components, including motors, power electronics and batteries
- FPGA-based plant model components, including motors, power electronics and position sensors

Parameterization of vehicle electric systems, drives, and other electric components.

**Example Use Case: Testing the Regenerative Brake System of an Electric Vehicle**

**The Task**
Developing and testing the torque management for the regenerative brake system of an electric vehicle.

**The Challenge**
Simulating an electric-drive vehicle, energy storage system, and serial regenerative brake system that consists of a hydraulic brake and an electric motor that works as a brake actuator. Both systems must be able to implement the braking torque as required by the driver and illustrate the blending of the electrogenerator and the hydraulic brakes. The driver's desired brake force is captured by a brake pedal that is connected via x-by-wire.

**The Solution**
ASM offers a complete simulation model for an electric vehicle with an energy storage system, an electric drive for the front axle and one for the rear axle, as well as a serial regenerative brake system. The management for requesting the drive and braking torque (electrogenerator and hydraulics) is also simulated or can be substituted by the torque requests of real ECUs at the HIL simulator. Therefore, the distribution of the driver's desired torque to the regenerative and hydraulic brake system can be analyzed. Furthermore, the model supports research into the distribution of the drive torque to the two electric motors of the front and rear axle. Because longitudinal and vertical dynamics of the electric vehicle can be simulated in detail, the model can also be used to analyze the vehicle dynamics properties.
ASM Electric Components

Automotive electrical system

ASM Electric Components consists of automotive electrical system simulation components and closed-loop simulation components. Applications can range from electric drives and inverters for closed-loop simulation with an ECU to a complete automotive electrical system, including battery, starter, alternator, and loads. The automotive electrical system simulation components can be used directly to create the electric circuits of an automotive system since they already have all the necessary automotive features. These models are also optimized for real-time HIL simulation.

Main Model Components
- Battery
- Starter
- Alternator
- Air conditioning
- Loads
- Supercapacitor

Demo Models
- Demo model for simulating a vehicle electrical system with starter, alternator, battery and different electrical loads like an electrically driven air conditioning.
- Demo models for simulating a hybrid vehicle or power-train with ASM Vehicle Dynamics or ASM Engine simulation models.

Features at a Glance
- Ready-to-use components with automotive features
- Simulation of a complete automotive electrical system
- Simulation multicell battery modules connected in series and in parallel
- Prepared for testing battery management controllers
- Temperature simulation of each individual battery pack cell and its thermal interaction with neighbor cells. Cooling plate of battery pack surfaces.

Application Example
To simulate high voltage batteries like Li-ion consisting of a series of multiple battery cells the ASM Electric Components Model features a cell simulation model. The ASM Battery Multicell Model consists of a cell voltage model, a charge state model and a thermal model. With the cell voltage model, individual physical effects such as internal resistance, inductance and double layer capacity as well as diffusion behavior can be simulated. The charge state model deals with the cell’s charge and discharge currents, and also with leakage currents such as those caused by gassing effects in the charging of NiMH cells. The thermal battery model simulates the temperature for each separate cell and the thermal interaction with neighbor cells. A cooling plate can be simulated for the six battery pack surfaces. The dSPACE EV1077 Battery Cell Voltage Emulation Board is used to connect the real BMS controller.
Electric drives closed-loop

The closed-loop components are ideal for HIL simulations of electric devices such as drives or inverters in a closed control loop. The models are especially designed for pulse width modulation (PWM)-synchronous model calculations and optimized solvers for real-time simulation. ASM Electric Components can be combined with other ASM products such as the combustion engine and the vehicle dynamics models.

Main Model Components
- Permanent magnet synchronous motor (PMSM)
- Brushless DC motor (BLDC)
- Asynchronous squirrel cage induction motor
- Discontinuous conduction mode (DCM) inverter
- Three-level inverter
- Controllers
- Various auxiliary blocks
- Three-phase rectifier

Demo Models
- Demo models for brushless DC motor, induction motor and permanent magnet synchronous motor available.

Features at a Glance
- Simulation of electric drive components and power electronics in a closed loop with an ECU
- PWM-synchronous model calculation
- PMSM machines with current-dependent differential inductances
- Three-phase rectifier with six power diodes connected in a bridge configuration.
- Delta-star connection configurable for three-phase motor models
- Advanced inverter model supporting DCM (discontinuous conduction mode)
- Open models can be modified or partly replaced by users

Application Example
For a closed-loop simulation on signal level, all power electronics devices are removed from the device under test. Power electronics models and motor models from ASM Electric Components are simulated together on the HIL system. To close the loop, the HIL system is connected to internal interfaces of the device under test such as the signals of the gate drivers and to the signals of the current transducers. This approach allows maximum scalability and full model access. For the real-time simulation of electric drive systems, dSPACE provides a FPGA-based I/O solution (SCALEXIO EMH Solution) for capturing the gate driver signals, simulating the motor current, and simulating various position sensors. This is where the power electronics and motor models are calculated on real-time processors (e.g. SCALEXIO). If faster model calculation is required, the HIL hardware can also be used for FPGA-based simulation using XSG Electric Components.

Current output signal of a processor-based mean-value motor model resulting in a stepped current simulation.
XSG Electric Components

Electric motor control applications that demand great precision and correspondingly high sample rates are simulated best on field-programmable gate arrays (FPGA). In addition to the plant models for electric drives and power electronics, the XSG Electric Components Library is supplemented by enhanced I/O functions for position sensor simulation. All components are implemented as Xilinx® System Generator (XSG)¹ models that run on dSPACE FPGA boards (e.g. DS2655).

Main Model Components
- Permanent magnet synchronous motor (PMSM)
- Brushless DC motor (BLDC)
- Asynchronous squirrel cage induction motor
- Discontinuous conduction mode (DCM) inverter
- Position sensor models
  - Resolver
  - Sine encoder
  - TTL encoder
  - Hall encoder

Demo Models
- Demo models for permanent magnet synchronous motor available.

Features at a Glance
- Simulation of electric motors and power electronics in a closed loop with an ECU
- Advanced inverter model supporting DCM (discontinuous conduction mode)
- Delta-star connection configurable for three-phase motor models
- High precision and stability
- No PWM synchronization necessary
- Current ripple (PWM effects) can be simulated
- Increased precision when simulating higher fundamental frequencies
- Open models can be modified or partly replaced by users
- Highly nonlinear electric motor models available on request

Application Example
Using FPGA-based simulation, closed-loop simulations of electric devices and their controls is supported at very high sample rates in real time. XSG Electric Components can be used for electric-motor simulation both at signal and power level. For simulations at power level, the power stage is a real component. To generate real currents and voltages high-performance electronic loads are required (DS5381). To integrate FPGA models on a dSPACE system the RTI FPGA Programming Blockset provides a Simulink library created with the Xilinx® System Generator Blockset.

Current output signal of a FPGA-based motor model resulting a quasi continuous current simulation.

¹ Please note that due to the introduction of the Vivado® software, Xilinx® will no longer support the Xilinx System Generator for DSP in combination with the ISE Design Suite after MathWorks® MATLAB® and Simulink® Release R2013b.
Vehicle Dynamics Simulation

Real-time models for ground vehicle simulation

Simulation Packages and Models
- Passenger cars
- Trucks
- Trailers
- Brake hydraulics and pneumatics

The Task
Simulate real driving emissions (RDE) tests early on in the development process based on measured vehicle data.

The Challenge
Get insights into the emission behavior of a vehicle under RDE test conditions, even in early development phases. Understand the influence of varying environment conditions and driver behavior. Use measurement data for realistic vehicle dynamics simulations.

The Solution
With the dSPACE Automotive Simulation Model (ASM) tool suite, RDE tests can be simulated virtually with different driving scenarios on rural roads, highways, and urban areas as well as complex surrounding traffic. The data captured during real test drives is used to make the simulations as realistic as possible. For this, the ASM tool suite supports importing map data as well as satellite navigation data. Altitudes, slopes, and lanes are also considered for simulating realistic maneuvers. The vehicle dynamics and environment simulation can be executed with an engine test bench to evaluate the actual emissions of the real combustion engine.

Example Use Case: Realistic Virtual RDE Drives

More detailed information available:
- www.dspace.com/go/rde
ASM Vehicle Dynamics

Vehicle multibody system plus drivetrain, roads, maneuvers, and driver

Main Model Components
- Engine (table based)
- Drivetrain
- Vehicle dynamics
- Environment
- Brake hydraulics and pneumatics
- 3DoF steering model

Application Software
- ModelDesk
- MotionDesk

Engine Model
Included table-based engine that supports ECU interventions. It can be easily replaced by a full-featured gasoline or diesel engine model.

Components and Characteristics
- Several strategies (injection, throttle) for reducing and increasing torque as requested by an ESP/TCS ECU
- Starter to accelerate the engine to idle speed

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
- Clutch with elasticity (torsion spring)
- Elastic shafts included
- Front-, rear-, and all-wheel drive including differentials
- Manual and automatic transmission with torque converter
- Model stabilized by semi-implicit Euler integration method
- Drivetrain with 13 degrees of freedom (DoFs)

Overview of the drivetrain model configured with all-wheel drive. Modes for rear- and front-wheel drive are also available.
ASM Vehicle Dynamics

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

ASM Kinematics and Compliance (KnC) Testbench
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.

Components and Characteristics
- Multibody system (MBS) consisting of car body and four wheels
- 13 degrees of freedom (DoF)
- Table-based kinematics and compliances for suspensions
- Suspension with nonlinear spring and damper characteristics
- Aerodynamics forces and torques included
- Brake model incl. physical brake booster model
- Additional masses (fixed on vehicle body)
- Sophisticated steering model with 3DoF, friction elements and rack and pinion based EPS support.
- Tire models: Magic Formula and TMEasy
- Data import from suspension design tools like ADAMS available on request

<table>
<thead>
<tr>
<th>Item</th>
<th>DoF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elastic powertrain</td>
<td>13</td>
</tr>
<tr>
<td>Body</td>
<td>6</td>
</tr>
<tr>
<td>Steering system</td>
<td>3</td>
</tr>
<tr>
<td>Wheels</td>
<td>4(^1)</td>
</tr>
</tbody>
</table>

\(^1\) One independent degree of freedom per wheel for wheel vertical displacement. The wheel kinematics are included via the MBS algorithm.

Environment
The environment features models for road, maneuver and driver. Roads and maneuvers are generated in ModelDesk.

Components and Characteristics
- Driver with lateral and longitudinal control
- Roads consisting of segments with slope, inclination and individual profiles
- Driving maneuvers from ModelDesk or manual driving

For more information about maneuvers, refer to page 32

For more detailed information available
- Product Brochure: ASM Vehicle Dynamics
  www.dspace.com/asm

A road consists of segments that can be configured individually: bumps, a longitudinal and lateral inclination, etc.
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 more than 30 degrees of freedom (DoF) in the multibody dynamics and more than 25 DoF in the powertrain depending on the configuration. The truck model features a torsional frame and truck cabin. The entire vehicle model can have an arbitrary number of axles, each of which can be steered, driven, and equipped with twin tires. Even road train, thus multiple trailers, can be simulated. It is easy to modify the configuration even during runtime 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 more than 20 DoF (depends on truck configuration)
- Powertrain with more than 25 DoF (depends on truck configuration)
- Truck body based on a torsional frame
- Tractor and trailer with an arbitrary number of axles, each of which can be steered
- 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
- Truck cabin with additional DoFs
- Each axle can be driven

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, an arbitrary number of 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
- Arbitrary number of axles (all axles steerable)
- Dolly extension for full trailer simulation
- Multiple trailers (road train) as an option
- 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.

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 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)

**Components and Characteristics**
- 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.

ASM Brake Hydraulics

Dual-circuit brake hydraulics

**Hydraulics Model for Braking Systems**
The modeled ESP braking system consists of a dual-circuit hydraulics system. The model contains all the components like valves, chambers, accumulators, pumps, and braking cylinders that are necessary for simulating a standard state-of-the-art ESP braking system.

**Components and Characteristics**
- Linear and physical master brake cylinder model
- Valves with continuously controllable cross-sections
- Nonlinear, look-up-table based wheel brake cylinder
- Graphical parameterization in ModelDesk
- Active brake booster
- Simulation of X- and II-brake system structures

More detailed information available
- Product Brochure: ASM Vehicle Dynamics
- www.dspace.com/asm
Traffic Simulation

Real-time models for traffic and environment simulation

Simulation Package

- Traffic

Graphical definition of an intersection.

Example Use Case: Variable Traffic Sign Recognition

The Task
Detecting and interpreting variable message signs and traffic lights in virtual traffic scenarios to test the controllers for highly automated and autonomous driving via simulation at an early stage.

The Challenge
Define virtual traffic scenarios with variable message signs and traffic lights that can influence the allowed speed or control the traffic in an adaptive manner, for example. Detect and interpret the variable message signs and traffic lights to test the algorithms for traffic sign recognition and to control the vehicle under test.

The Solution
With ModelDesk you can add variable message signs and traffic lights to virtual traffic scenarios and define their behavior using a convenient graphical user interface. ModelDesk provides variable traffic signs that can display numerical or color information. The ASM Traffic Model includes a traffic sign sensor that detects the signs even if they are attached to a gantry, interprets them, and assigns them to the relevant lanes. The signals of the traffic sign sensor are then available to be processed further by the traffic sign recognition algorithm.
ASM Traffic

Real-time environment simulation with traffic and objects

**Features at a glance**
- Simulation of complex traffic scenarios
- Road network simulation
- Static and moving objects like traffic signs and vulnerable road users
- Multiple traffic sensor types supported
- Graphical definition of roads, maneuvers, and environment

(For information on defining traffic scenarios, please see the Traffic Editor which is part of ModelDesk, p. 33)

**Application Areas**
ASM Traffic adds traffic and environment simulation to dSPACE’s Automotive Simulation Models (ASM). It supports you in developing and testing advanced driver assistance systems (ADAS) that react to other vehicles or objects, like adaptive cruise control (ACC) and intersection assistants. The model simulates a road network, the vehicle under test, a multitude of fellow vehicles and the necessary environment. The test vehicle can be equipped with multiple sensors for object detection and recognition (ego-vehicle). ASM Traffic is typically used for hardware-in-the-loop testing of electronic control units (ECUs) or for early function validation by offline simulation during the design phase of controller algorithms.

**Key Benefits**
ASM Traffic is so flexible that any kind of traffic scenario can be created to ensure thorough testing of ADAS controllers. It supports the creation of complex road networks, and you can define sophisticated traffic maneuvers on the roads. The simulated environment can consist of static and movable objects, like traffic signs and pedestrians. Various sensor models and user-definable sensors are available to detect these objects. To test pre-crash functionalities, you can define traffic scenarios that in real life could result in an accident, and observe system behavior under challenging conditions. Traffic scenarios can be modified and immediately simulated without having to generate code again.

**Components and Characteristics**
ASM Traffic consists of a graphical user interface (GUI) and a set of simulation models that perform in real time. The GUI provides several interfaces to define the necessary components like road networks, traffic signs, traffic vehicles, and sensors. Trajectories for all vehicles, objects and pedestrians are calculated in real time according to the defined traffic maneuvers. ASM Traffic supports specific scenarios such as oncoming traffic, stop and go, and pedestrians. The Traffic Editor is the user interface for very flexible and easy traffic scenario definition.
Road Networks

Features
- Road networks with roads and intersections for vehicle dynamics and ADAS use cases
- Segment- and coordinate-based road definition
- Lanes with smooth transitions and specific line definitions
- Up to 5 lanes per lane segment
- Support for lane detection sensors
- GPS coordinate exchange with turn-by-turn navigation development tools
- Simulation of tire characteristics and road surface conditions like split-μ surfaces, bumps, potholes
- Simulation of lines according to EU regulation 351/2012 and support of free lines and barriers for construction area simulation.
- Import and Export of OpenDRIVE-format

Define roads and junctions graphically.

Maneuvers

Features
- Movement control of vehicle under test (ego-vehicle)
- Maneuver segments defined by distance or time
- Event-based segment changes
- Lane driving and lane transition/change definitions
- Trigger events for specific maneuver activities
- Open- and closed-loop maneuvers
- Velocity, steering, and pedal actuation can be set by using measurement data.
- User output signals programmable via time and distance
- External velocity and pedal access for man-in-the-loop use cases

Define where and how the ego-vehicle drives on the road network.
Traffic

Features
- Simulation of objects around ego-vehicle
- Definition of various traffic situations and complex scenarios
- Lane driving and lane change definition
- Support for intersections with oncoming and crossing traffic
- Maneuvers based on distance, velocity and acceleration
- Independent and interdependent movements
- Time- and road-based trigger events
- Direct link between model and animation update
- Unlimited number of moving objects possible

Objects and Sensors

Features
- Definition of any number of traffic objects
- Road- and intersection-based positioning
- Graphical representation in MotionDesk
- Moving objects like pedestrians
- Static objects like variable traffic signs, traffic lights, parked vehicles, houses
- 2-D object sensor
- 3-D object sensor
- 3D-sensor with realistic cone scope and timing behaviour
- Line sensor
- Custom sensor
- NEW: Variable traffic sign and traffic light sensor

Overview of Objects and Sensors

<table>
<thead>
<tr>
<th>Sensor Type</th>
<th>Object</th>
<th>Sensor Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Signs</td>
<td><img src="image" alt="80mph sign" /></td>
<td>Speed limit, 80</td>
</tr>
<tr>
<td>2-D</td>
<td><img src="image" alt="2-D object" /></td>
<td></td>
</tr>
<tr>
<td>Custom</td>
<td><img src="image" alt="Adult/Child" /></td>
<td>Adult / Child</td>
</tr>
<tr>
<td>3-D</td>
<td><img src="image" alt="3-D object" /></td>
<td></td>
</tr>
</tbody>
</table>

More detailed information available:
- Product Brochure: ASM Traffic
- www.dspace.com/asm
ModelDesk

The graphical user interface

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 Python scripts. ModelDesk can be used seamlessly from parameterization to offline and online simulation, and finally to parameter and result management.

Main Features
- Offline and online simulations
- Graphical user interface
- Parameter set management
- Road Generator
- Maneuver Editor
- Traffic Editor
- Tool automation
- Preprocessing for engine models
- Custom model parameterization
- NEW: ASM demo model access

Benefits
- Seamless simulation process from MIL to HIL
- Intuitive, graphically supported parameterization
- Parameters changed online and offline
- Managing parameter sets and entire projects

Graphical Parameterization
The model components and their subsystems are represented by a hierarchical graphical structure. The model components to be parameterized can be selected from the top level. Users have the vehicle model before them and can browse through its systems, guided by graphical representations of the modeled components.

Parameter Management
ModelDesk’s Project Navigator provides a means of organizing and managing 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.
Simulation Management
ModelDesk includes powerful functions for directly executing and displaying simulations, and managing their results:
- Starting and stopping a simulation
- Maneuver control: starting and stopping vehicle dynamics maneuver and traffic scenarios.
- Plotters for visualization
- Saving, comparing and managing simulation and measurement data
- Saving simulation experiments (driving maneuvers, roads, traffic, etc.)
- Direct demo model access

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

Visualization with MotionDesk
ModelDesk and MotionDesk work seamlessly together. In ModelDesk, users can define scene types such as country roads, tree-lined roads, and urban areas. The scenes are then automatically generated in MotionDesk with appropriate objects like buildings, trees, borders, reflector posts, and street lamps. These can also be modified as required in MotionDesk’s integrated Scene Editor.
Road Networks

Road Generator

The Road Generator is the graphical user interface for defining road networks and sophisticated road features. Roads can be assembled from geometric segments or imported. Features such as lanes, intersections, height, inclination, surface condition, etc., can easily be added to a road by editing attributes that are displayed in 1-D diagrams. The whole road network is visualized in a 2-D view. The road design also interacts closely with the 3-D animation software MotionDesk to define the environment. The Road Generator gives ideal support to complex traffic scenario creation in the development and testing of advanced driver assistance systems (ADAS).

Features

- Support for vehicle dynamics and advanced driver assistance traffic scenarios
- Segment and coordinate-based road definition
- Intersections and junctions
- Lane, line and traffic sign definition
- Height, inclination, and surface condition applied via segment-independent road coordinates
- Easy definition of bumps, profiles, split-μ areas, etc.
- Dedicated 1-D and 2-D views of road features
- OpenDRIVE® format export
- Road import: map data (like OpenStreetMap, Google Maps, etc.), ADAS RP (Nokia HERE), and OpenDRIVE® format
- Road networks and predefined sceneries are automatically imported into MotionDesk (city center, country road, highways)
- Definition of driving routes
- Definition of lane-independent lines and shapes for concrete barriers or repeating objects
- NEW: Unlimited number of lanes
Maneuver

**Maneuver Editor**

The Maneuver Editor is used to define how and where a vehicle moves on the road network. Maneuvers consist of several segments with their own individual properties. There can be simple maneuvers that just follow the road or very sophisticated ones based on several stimuli, or user inputs. A maneuver also defines the driving lane and the lane changes of the test vehicle. The road or road network the maneuver relates to is visualized for intuitive maneuver creation.

**Features**

- Definition of driving maneuvers based on road network routes
- Maneuver segment definition by distance or time
- Lane driving and lane change definitions
- Definition of steering and pedal stimuli or driver-based maneuvers
- Standard maneuvers included (lane change, \(\mu\-split, steady-state cornering, fish hook, etc.)
- Lateral and longitudinal stimuli can be imported from measured data (MAT files)
- User output signals programmable by using time or distance

The ASM Maneuver Editor: 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.
Traffic

Traffic Editor
The Traffic Editor is the graphical user interface for defining the movements of the fellow vehicles on a road network. The Traffic Object Manager (TOM) is used to give fellow vehicles additional characteristics. Traffic objects like signs or construction barriers can also be defined and placed in road networks. Traffic scenarios are defined on a single page that can be completely customized from complete overview to maximum detail.

Features
- Definition of traffic fellow movement based on road network routes
- Segment-based definition of fellow vehicle movement
- All vehicles on one page
- Overview and detailed view
- Convenient graphical editing
- Definition of fellow and traffic object parameters in Traffic Object Manager
- Easy-to-use fellow vehicle activity definitions

Example of the traffic definition page.
Processing

Parameter Processing
ModelDesk provides a fully integrated parameterization workflow. Users can include initial data, such as measurements, functions, and settings, flexibly and process it into parameters optimized for simulation models. Users can write the processing routines for parameters in the well-known MATLAB programming environment. In addition to this customizable parameter calculation, sophisticated error handling procedures have been integrated to support the users during parameterization.

Features
- Read and process measurement data
- Function administration
- Settings administration
- Execute functions with appropriate error handling
- Adapt parameter as a result of a processing function

Use Cases
- Engine parameterization based on testbench measurement
- Battery parameterization based on impedance spectroscopy
- Suspension kinematic parameterization based on kinematic and compliance testbench data

Custom Models and Demo Projects
This feature can also be used in combination with custom components to parameterize own libraries with ModelDesk. A demo projects for the ASM engine models provide predefined parameterization routines, to deliver a semi-automated calculation of all model parameters.

The processing feature transfers measurements, settings, and functions into parameters optimized for simulation.
Tool Automation

Remote Control and Batch Processing for ModelDesk
To perform long-term tests or parameter studies, ModelDesk provides script-based tool automation. This gives you maximum flexibility to define custom simulation scenarios. Tool automation can be performed by means of scripting languages like Python and MATLAB M scripts. The scripts can be executed either externally to remote-control ModelDesk or internally when ModelDesk’s batch mode is used. The batch mode functionality is realized by a Python interpreter that supports Python 2.5.1.

Features
- Script-based tool automation
- Integrated Python interpreter
- 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
- Direct alteration of traffic maneuvers
- Simulation-based parameter studies
- Automated marginal condition analyses/detection
- Long-term behavior studies
- Sequential maneuver executions

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 (except road and maneuver creation). You can load existing model parameterization projects and activate predefined experiments. All the vehicle parameters such as vehicle mass, suspension kinematics, engine torque, additional loads, and similarly also environment or maneuver settings like road friction or vehicle velocity, can be controlled from within scripts.

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.
Custom Model Parameterization

Graphical Parameterization of Custom Models
ModelDesk supports the graphical parameterization of model parts that were replaced by custom models or custom extensions to ASMs. 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)
- Original ASM and customized model parts displayed as one system

Benefits
- Centralized parameter management
- Graphical parameterization without detailed modeling knowledge

Model Preparation
For use in ASM, custom model libraries have to be prepared according to ASM guidelines in order to parameterize them in ModelDesk. The guidelines mainly define how parameters are declared with masked variables and a fixed declaration structure. Libraries can have multiple masked subsystems, and each subsystem has its own parameter page for separate parameterization.

Custom Library Registration
ModelDesk’s registration function lets you select new libraries to parse them and make their parameters available graphically. During registration one or more parameter pages are created automatically, depending on the number of masked subsystems. 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.
ASM Versions and License Concept

The ASM License Concept
The ASM models come with different license types: Developer License, Runtime License. This lets users apply 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 models provide access to MotionDesk with all license types. The model must include the MotionDesk blockset.

The Benefits
- A simulation environment that seamlessly covers the offline and online (real-time) worlds.
- ModelDesk is the parameterization tool throughout the entire process, which means that the parameterizations can be reused.
- Cost-efficient license types for offline and online (real-time) simulation
- Simulation models parameterized and reconfigured in ModelDesk with the Runtime License. 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

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). Not included with ASM Engine InCylinder models and ASM Electric Components.