Siemens PLM Software

LMS solutions for driving dynamics

Achieving optimal vehicle handling by integrating the entire engineering process

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Taking an integrated approach to driving dynamics engineering

Driving dynamics is one of the primary ways to define the quality of a car. But while developing a vehicle, engineers have to carefully balance often conflicting performance characteristics. A large variety of passenger comfort and vehicle handling factors have to be considered, such as drivability, stability, agility and control. But at the same time, those factors have to be combined with achieving a high level of ride comfort and low road noise levels. On top of that, the increasing integration of active control systems adds even more complexity to this challenging task.

With model-based systems engineering (MBSE), LMS™ solutions from Siemens PLM Software provide an integrated approach to chassis and suspension development. MBSE comprises a set of specific solutions for the development of mechatronic systems that address the multi-disciplinary nature of these challenges as well as integrating control systems. Vehicle handling, durability and noise, vibration and harshness (NVH) are handled in parallel, from concept to vehicle refinement. This allows frontloading design decisions for chassis components and layout, and provides a scalable vehicle handling platform to simulate components, actuators and the vehicle, from functional to detailed multi-body models. These driving dynamics solutions seamlessly integrate with model-in-the-loop (MiL), software-in-the-loop (SiL) and hardware-in-the-loop (HiL) validation processes.

Delivering a scalable solution set

"LMS Imagine.Lab is the reference for vehicle dynamics at PSA Peugeot Citroën for road handling and low-frequency comfort analysis, allowing specification of axles and suspension subsystems, aerodynamics, mass specifications, pilot studies, synthesis and longitudinal dynamics."

Benoit Parmentier
Simulation Engineer
PSA Peugeot Citroën

LMS solutions provide expertise for the concept, design and validation stages of the vehicle development process, and bring efficiency to driving dynamics engineering. This helps our customers to set vehicle dynamics targets and integrate driving dynamics engineering into the vehicle system simulation process, leading to faster time-to-market while keeping engineering brand values.

Unique product portfolio

LMS Imagine.Lab Amesim™ software for multi-domain system simulation helps you design and optimize individual chassis components and integrate them into a system-based model to validate global chassis control strategies. In parallel, LMS Virtual.Lab™ Motion software for multi-body modeling enables effective analysis and real-life performance optimization of mechanical and mechatronic systems. LMS Samtech Samcef™ software can be integrated to account for all nonlinear behavior of various components using LMS Samcef Mecano.

Competence, experience and know-how

LMS™ Engineering services guide customers in all vehicle design process steps, including preprogram competitive benchmarking, target setting, concept development, detailed chassis development and physical prototype refinement of suspensions and steering systems, as well as controls integration. LMS Engineering experts have solid hands-on vehicle co-development experience and best-in-industry process know-how.

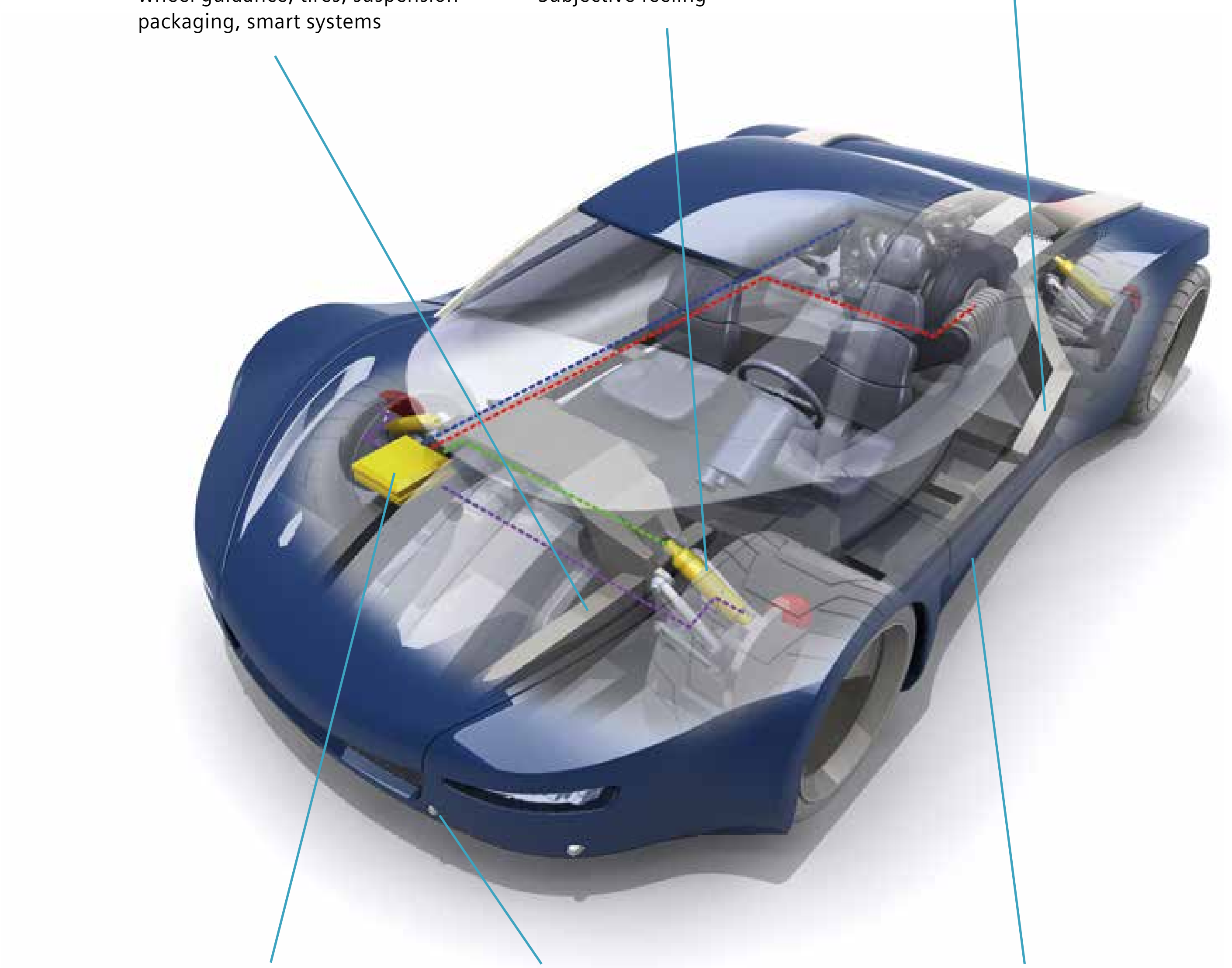
Scalable partnering model

LMS solutions help manufacturers and suppliers worldwide solve development-related issues by offering a tailor-made scalable partnering model; providing everything from quick troubleshooting and answering design refinement questions to technology transfer, method development and full vehicle and subsystem co-development by using a unique hybrid approach combining test and simulation solutions.

Chassis components
- Steering systems
- Braking systems
- Suspension and anti-roll, axle, wheel guidance, tires, suspension packaging, smart systems

Vehicle dynamics
- Ride and handling scenarios (roads, traffic, grip conditions)
- Body and powertrain interaction
- Subjective feeling

Chassis loads, durability and customer correlation



Vehicle dynamics control
- Active safety (ABS, ESP, ESC, etc.)
- MiL, SiL and HiL

Advanced driver assistance systems (ADAS)
- Guidance and maneuvering, environment modeling, virtual validation, active safety

Multi-attribute balancing
- Road noise, drive comfort, ride and handling, durability, crash

Improving the vehicle driving dynamics development process

Efficient engineering processes should accommodate verification and validation while limiting prototyping rounds. For many manufacturers, this requires a radically new approach. By aligning test-based engineering, multi-domain system simulation and detailed 3D analysis into a systems-driven, closed-loop product development process, LMS solutions can help customers overcome this major challenge.

Systems-driven, closed-loop product development involves decomposing the design into separable elements, yet considering their intended interaction and controlling global system behavior from the start. Individual elements can be further developed as details become available. This process minimizes risk and avoids late-stage changes by enabling clear target or boundary setting for subsystems, and provides a full understanding of the global system's dynamic behavior throughout the entire development process.

Benchmarking and target setting

Driven by the design experience of the development team as well as customer requirements, full-vehicle targets are cascaded to targets for individual body, chassis and suspension subsystems and components. Optimal ride comfort, drivability, handling and steering performance are determined by both objective testing and subjective assessment.

Concept development

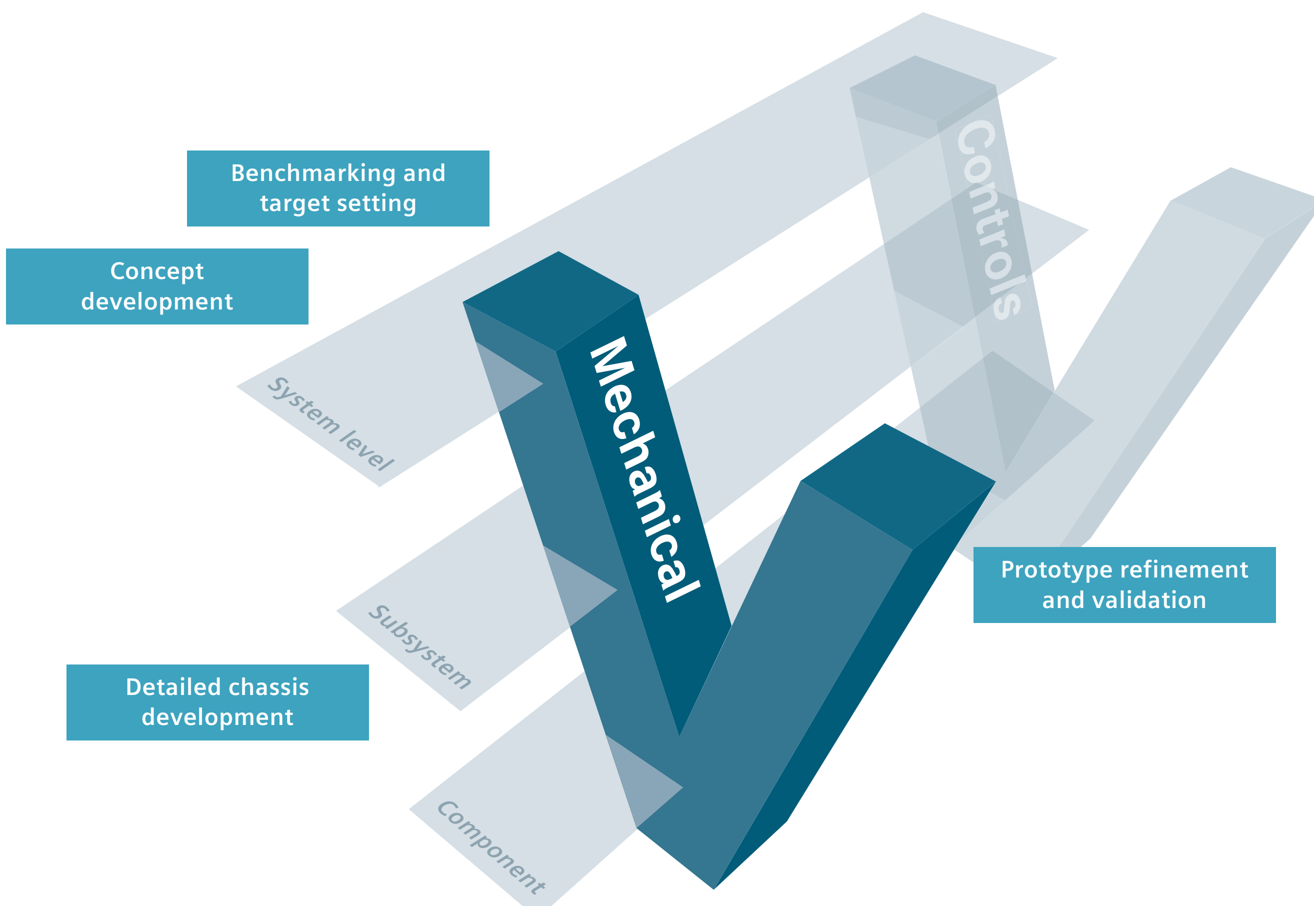
After target setting, the global concept guidelines are defined. This includes suspension architecture, optimized hard point locations and bushing stiffness. Engineers also perform early evaluation of harshness and other secondary ride comfort factors by using simulation to consider the subjective feeling of the driver.

Detailed chassis development

Further detailed chassis development comprises suspension design optimization, addressing ride-comfort maneuvers, obstacle crossing and the response to rough road profiles and handling maneuvers. It also includes steering shimmy, brake judder and drivability performances such as tip-in/tip-out, engine start/stop, gear shift and torsional vibrations in the driveline. At this stage it also handles the effect of body flexibility, and the integration of active control systems. Accurate simulation helps you understand the influence of design parameters on performance before you build physical prototypes.

Prototype refinement and validation

After building the physical prototype, a final chassis component assessment is performed. Component specifications are refined, design parameters balanced and control systems tuned in order to meet the vehicle requirements and obtain an optimally balanced chassis performance.



Developing controls earlier in the design process

Car makers are applying mechatronic solutions to develop breakthrough products with brand-differentiating functionalities. Mechatronic solutions leverage electronics and software in advanced control systems to optimize the performance and efficiency of the mechanical system.

Developing a successful mechatronic solution requires optimizing the mechanics, electronics and software simultaneously as an integrated system from the very beginning of the entire design cycle. By using the MBSE approach that enables you to quickly evaluate the performance of a wide range of design concepts without physical hardware, LMS solutions can accomplish this goal of concurrent engineering of controls with the physical system. This approach allows testing controls systems against functional requirements very early, and significantly boosts maturity before the controls system is implemented in the physical prototype. It avoids lots of critical problems in late development, reduces tuning effort and saves time and costs.

Concept design

The first controls development phases occur while defining the system architecture by combining multi-domain model-based system simulation with potential control algorithms in MiL validation processes.

Engineers define subsystem and component-level requirements based on multi-attribute optimization and design tradeoff techniques, targeting design intent and related system functional performance. In iterative simulation processes, they test control unit software models against physical system models.

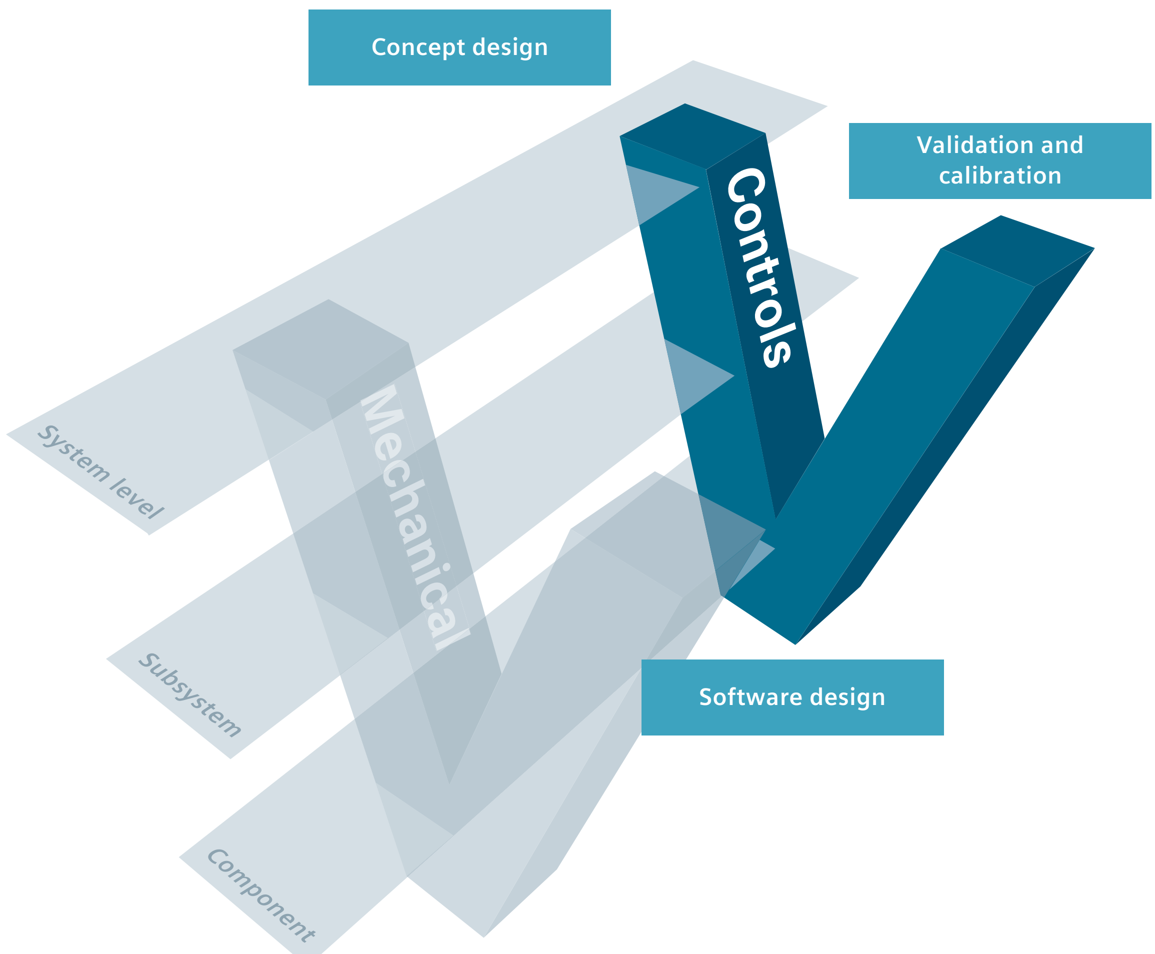
Software design

The embedded C-code is auto-generated from the controller software models and linked with legacy C-code. This is run on virtual electric control unit (ECU) platforms and tested with vehicle system models in SiL validation processes. This helps you understand the impact of a floating point to fixed point conversion as well as scheduling, and allows step-by-step debugging of the C-code in a closed-loop simulation process.

Validation and calibration

In later development stages, experts build accurate precalibration models as well as reduced model versions that can run in real time for extensive, automated HiL validation and verification. This approach allows complete system and software troubleshooting while limiting the total test size and cost.

With the high-fidelity vehicle system simulation model emulating the actual vehicle, further extensive HiL testing is done to calibrate the ECU before final calibration is performed on the actual vehicle.



LMS solution highlights for vehicle ride and handling

“LMS Engineering has three main differentiators. Firstly, they combine high-end testing with CAE. Secondly, they have vast experience with automotive OEMs. And finally, LMS Engineering has a very talented global team of experts.”

Hitoshi Kyogoku
Manager
Vehicle Dynamics CAE Group
Nissan Motor Company

Ride and handling behavior for all vehicle types from passenger cars and motorsport vehicles to multi-axle vehicles, such as trucks and buses, can easily be modeled in a scalable system setup. LMS solutions start from simplified system-based models early in the product design cycle and add detailed 3D modeling in later development stages.

LMS Amesim enables creation of simplified models. Users can rely on a huge set of dedicated standard libraries and parameters, which can be refined as data when it becomes available. Detail can be gradually added using 3D modeling in LMS Virtual.Lab Motion, from the integration of conceptual rigid bodies and the inclusion of flexible components and subframes to the addition of all body details. Using LMS Virtual.Lab Motion in conjunction with LMS Samcef Mecano provides an integrated solution that can account for all nonlinear behavior of various components, such as twist beams, leaf springs, tires, coil springs and rubber bushing elements.

Additionally, LMS Engineering has developed a body flexibility method that provides more insight into the relation between body stiffness and driving dynamics performance. This enables engineers to find the right balance earlier in the development process when confronted with the issues that arise when dealing with NVH performance for next-generation lightweight designs.

Body flexibility methodology for body target setting

The flexibility of a car body influences its driving dynamics, including the subjective driving experience. As established test and simulation methodologies cannot always expose the differences between body variants, automotive original equipment manufacturers (OEMs) look for technologies that provide a better understanding of the relation between body flexibility and driving dynamics performance.

LMS Engineering has developed a unique test-based technology to identify the individual forces in the connection points between suspension and body based on strain gauge measurements. By combining identified time domain loads with a modal model of the body, LMS Engineering experts can visualize the body deformation during handling maneuvers, and decompose it in contributions of global body deformations, such as body torsion and bending, and local body deformations. The results identify weak body areas and allow setting body stiffness targets while considering the call for lightweight vehicles.

Scalable simulation solutions for vehicle ride and handling

"When it comes to ride and handling, LMS Virtual.Lab Motion is a powerful development tool. It has a very stable solver and delivers great quality and reliability."

Professor Dr. Ludger Dragon
Senior Manager
Vehicle Dynamics
Integration Division
Daimler

Model-based system simulation for driving dynamics

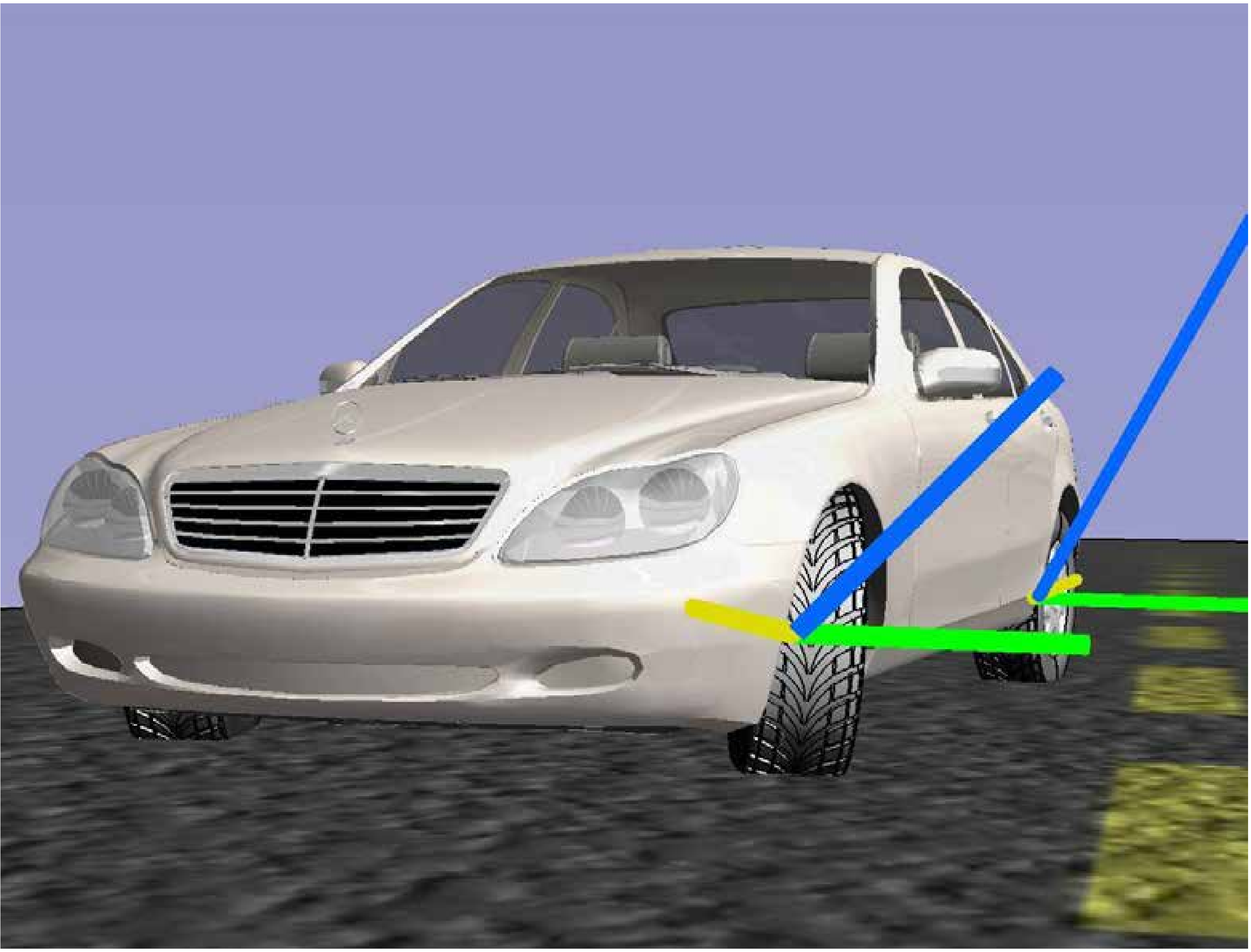
LMS Imagine.Lab™ software for vehicle dynamics is a dedicated LMS Amesim solution that helps shorten the full vehicle development process by offering an easy-to-use environment for chassis and subsystem specification, design and validation. The graphical user interface (GUI) can be modular, specifically for early design stages, or it can be an application-oriented interface that is dedicated to specifying, designing, testing and optimizing the tradeoffs between comfort and handling. The software can consider the interaction between the vehicle, its subsystems and controls, providing insight into major functional aspects and vehicle integration concerns, such as driving pleasure, comfort, safety, fuel efficiency and the impact of electric/hybrid transmission on vehicle stability.

LMS Amesim includes dedicated tools for unmatched vehicle integration design, such as data management functionalities, International Organization for Standardization (ISO) and National Highway Transportation Safety Administration (NHTSA) predefined maneuvers, OpenStreetMap road import, trajectory designer, a specific chassis criteria analyzer, optimization tools and state-of-the-art driver models.

Process and data integration for 3D simulation

Since learning new computer-aided engineering (CAE) software for 3D modeling can be a time-consuming and challenging task, dedicated vertical applications with an easy-to-learn and intuitive user interfaces are growing in popularity. Using LMS Virtual.Lab Composer, expert users can create custom GUI layouts to generate an attribute-oriented vertical application with simple drag-and-drop functionality without requiring extensive programming skills. With this customization capability, expert users can easily build attribute-specific vertical applications and provide them to their colleagues, who will require minimal training.

LMS Virtual.Lab Composer allows easy creation of customized GUIs, only granting access to CAE modeling data relevant to the user's attribute of interest. LMS Virtual.Lab Motion empowers these vertical applications with a rich collection of modeling components in the background.



Introducing nonlinearity for modeling accuracy

Structural components in mechanisms that undergo large deformation – such as suspension components like twist beams, leaf springs and stabilizer bars – need to be modeled, including material and geometrical nonlinearity. For this purpose, LMS Virtual.Lab Motion can include LMS Samcef Mecano nonlinear flexible bodies for coupled calculations. The LMS Samcef Mecano solver also handles contact and friction forces as well as thermal effects (for leaf springs, rubber bushings, brakes, etc.), and contains dedicated capabilities for composite materials.

Combining ride comfort, vibration harshness, handling and steering

LMS solutions include simulation and testing methodologies as well as engineering know-how to optimize low frequency ride comfort and vibration harshness. During design validation, flexible simulation models can address transient and steady state ride comfort issues. Later on the physical prototype, modal analysis, transfer path analysis (TPA) and operational data analysis can be used to help refine the ride comfort behavior.

LMS solution highlights for chassis systems and components

"We have reduced the number of physical prototypes by a factor of 10 using LMS Amesim, which has resulted in huge cost savings and significantly shortened development time."

Urban Forssell
Vice President
Mechatronic Systems
Öhlins Racing AB

Achieving accurate models for chassis components (such as brake boosters, valves and active dampers) and subsystems (such as different suspension, steering, driveline and powertrain architectures) early in the development cycle is crucial for robust product design. Using LMS Amesim in conjunction with LMS Virtual.Lab Motion Driving Dynamics provides engineers with a scalable solution to generate those component models. Users can decide on the level of detail according to their needs, or the availability of data.

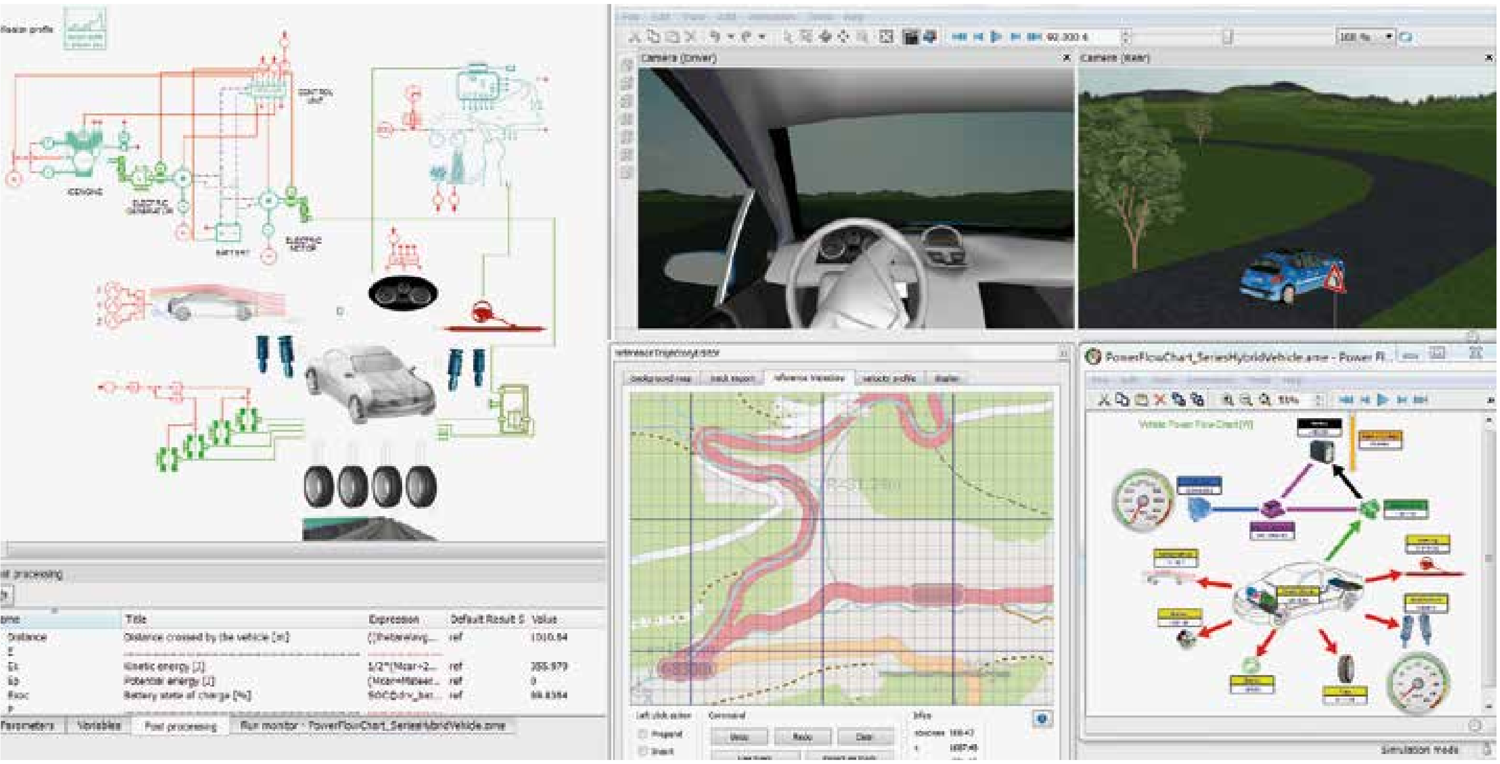
Steering system modeling

LMS Imagine.Lab Power Steering provides the platform and libraries for designing robust power steering systems. This solution allows functional performance investigation for any power steering system, including hydraulic (HPS), electrohydraulic (EHPS) and electric (EPS), to assess technology risks and validate the controls strategy. Off-the-shelf template models help OEMs accelerate their learning curve so they can gradually include all details in supplier models.

All EPS types can be modeled with advanced features such as active front steering (AFS) or electronic steer-assisted steering (ESAS). For HPS and EHPS, the software provides detailed views of the rotary valve, pump and piping circuit (rigid pipe and hose), allowing more in-depth vibration, coupling and stability analyses (shimmy phenomenon) in parking mode or for normal driving conditions.

Braking system modeling

LMS Imagine.Lab Braking System enables the design and optimization of brake components to assess dynamics, compare hydraulic architectures (such as X, H and I) and evaluate braking distance or vehicle stability. Components include booster, master cylinder and electronic stability control (ESC) hydraulic modulator valves, as well as the complete hydraulic braking circuit.



The solution also enables the handling of hydraulic and pneumatic systems for cars, trucks, buses, off-highway vehicles and trains. The multi-domain approach allows you to study evolved brake pedal amplification systems, regenerative braking and electric parking brakes. Complete ESC system template models significantly reduce modeling efforts for real-time simulation while addressing ESC homologation and combining ESC with regenerative brakes.

The relationship between the powertrain and driving dynamics

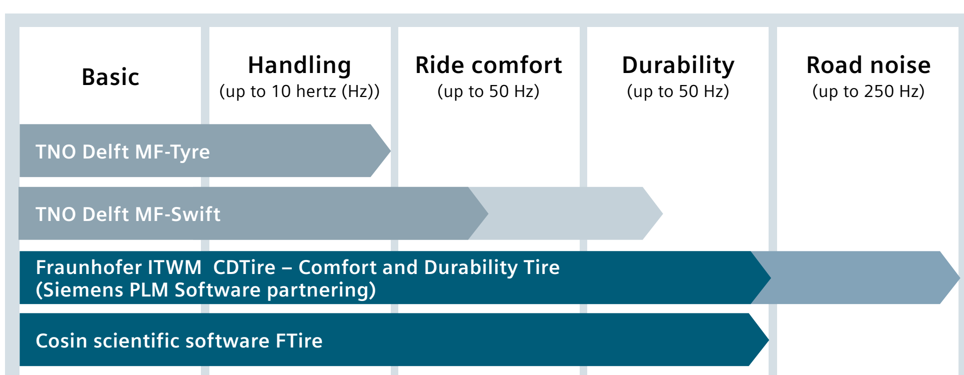
Besides their potential for longitudinal dynamics, torque vectoring systems are also relevant for lateral dynamics. The LMS Imagine.Lab Wheel Torque Management solution allows users to explore the torque impact on vehicle stability and assess the interaction between torque vectoring and ESC controllers. Moreover, LMS Amesim provides a vehicle stability solution for innovative architectures such as electric and hybrid transmissions.

Scalable simulation solutions for chassis systems and components

Suspension simulation methodologies
LMS Virtual.Lab Motion Suspension guides users through the entire process of suspension modeling and analysis using a dedicated interface, starting from importing the hard point locations and defining components and connections, to postprocessing virtual test rig simulation results with dedicated capabilities. The user can use off-the-shelf template models for the most common suspension architectures, or create a new suspension topology in an interactive user interface.

The software also features a dedicated leaf spring tool for fast detailed modeling of all main properties of the spring, including the number of leaves and their geometry, material properties, connections to the suspension elements, as well as contact and friction forces between leaves. The output of this LMS Virtual.Lab leaf spring tool is a 3D parametric model, which can be used as a standalone model or embedded in the suspension and full-vehicle models.

Using LMS Imagine.Lab Pneumatic System simulation solution and pneumatic component design libraries, which account for thermal elements, users can explore the impact of the air-spring system on vehicle comfort and height correction, which are particularly important in luxury cars or sport utility vehicles.



LMS multiple tire solutions.

Suspension packaging

OEMs typically perform suspension packaging and clearance studies with a kinematic solver in a computer-aided design (CAD) environment. This usually happens with simplified suspension models (rigid joints instead of bushings, for example), in which additional clearances can act as safety factors, accounting for introduced inaccuracies. With LMS Virtual.Lab Motion, users can leverage their fully detailed elasto-kinematic half or even full vehicle models in a CAD environment with the actual geometry, enabling them to consider the inertia effects during dynamics, and analyze potential collisions between components. Adding structural flexibility to the vehicle model (for example, until there is a full trimmed body vehicle) further increases accuracy.

Tire models

LMS Virtual.Lab Motion supports multiple dedicated tire models for specific applications, such as handling, ride comfort, durability and NVH.

The LMS Virtual.Lab Motion tire switching capability reduces computational overhead by featuring automatic use of higher fidelity tire models on durability track sections. In case of large tire deformation, LMS Virtual.Lab Motion can be complemented by LMS Samcef Mecano for more details and accuracy.

Also, LMS Imagine.Lab Amesim contains tire models that enable users to optimize driving dynamics and fuel economy.

LMS solution highlights for controls engineering

While developing controls or intelligent systems, the complex interactions between different subsystems, as well as between subsystems and the control unit, call for an accurate, efficient and synchronized simulation process in the early design stages. This can ensure that the complete integrated product performs as expected before late-stage physical prototype testing, and allows active controls optimization upfront in the design process.

This concurrent simulation approach requires software capabilities for MiL, SiL and HiL controls validation. As it is necessary to run HiL in real time, it also needs to be possible to build reduced degrees of freedom (DOF) models without sacrificing accuracy.

Combining the use of LMS Virtual.Lab Motion chassis subsystem modeling with LMS Amesim real-time simulation offers all the necessary modeling capabilities as well as the solver speed and accuracy to fulfill these requirements.

On top of that, the LMS Engineering services team can help you implement effective verification and validation methods and processes using MiL, SiL and HiL to test control strategies for the driver simulator, driver actuator feedback and integrated vehicle controls.

Model-based systems engineering in support of controls development

LMS Amesim software brings more physics to the simulation of active steering, braking and suspension for designing the controller. For example, it features sizing and analysis of active anti-roll and suspension system components and related controls. The software helps to better balance vehicle handling and comfort by combining improved damper design, air-spring-system modeling and active roll stabilizer components with a vehicle-level performance analysis.

The LMS Amesim hydraulic and pneumatic libraries enable functional design of passive, adaptive, semi-active and active shock absorbers, and detailed analysis for component performance assessment and control strategy testing.

Co-simulation in support of controls development and validation

LMS Virtual.Lab Motion provides a state-of-the-art co-simulation interface with LMS Amesim for accurate simulation of complex 1D and 3D mechatronic systems. The LMS Virtual.Lab Motion Real-Time solver uses a parallel approach for multi-core solving that offers speed and accuracy when it truly matters.

Controls co-development

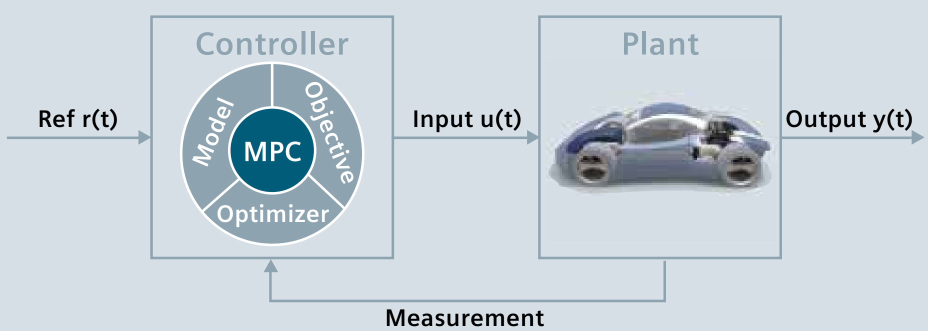
LMS Engineering experts can combine LMS simulation tools with controls know-how to implement an MBSE process for controls development. Specialists can help you frontload various stages of the process and concurrently develop a physical system and an associated controller. Multiple process steps include requirements engineering, executable specifications development, implementation, system integration and testing, calibration and vehicle integration.

Developing advanced driver assistance systems of the future

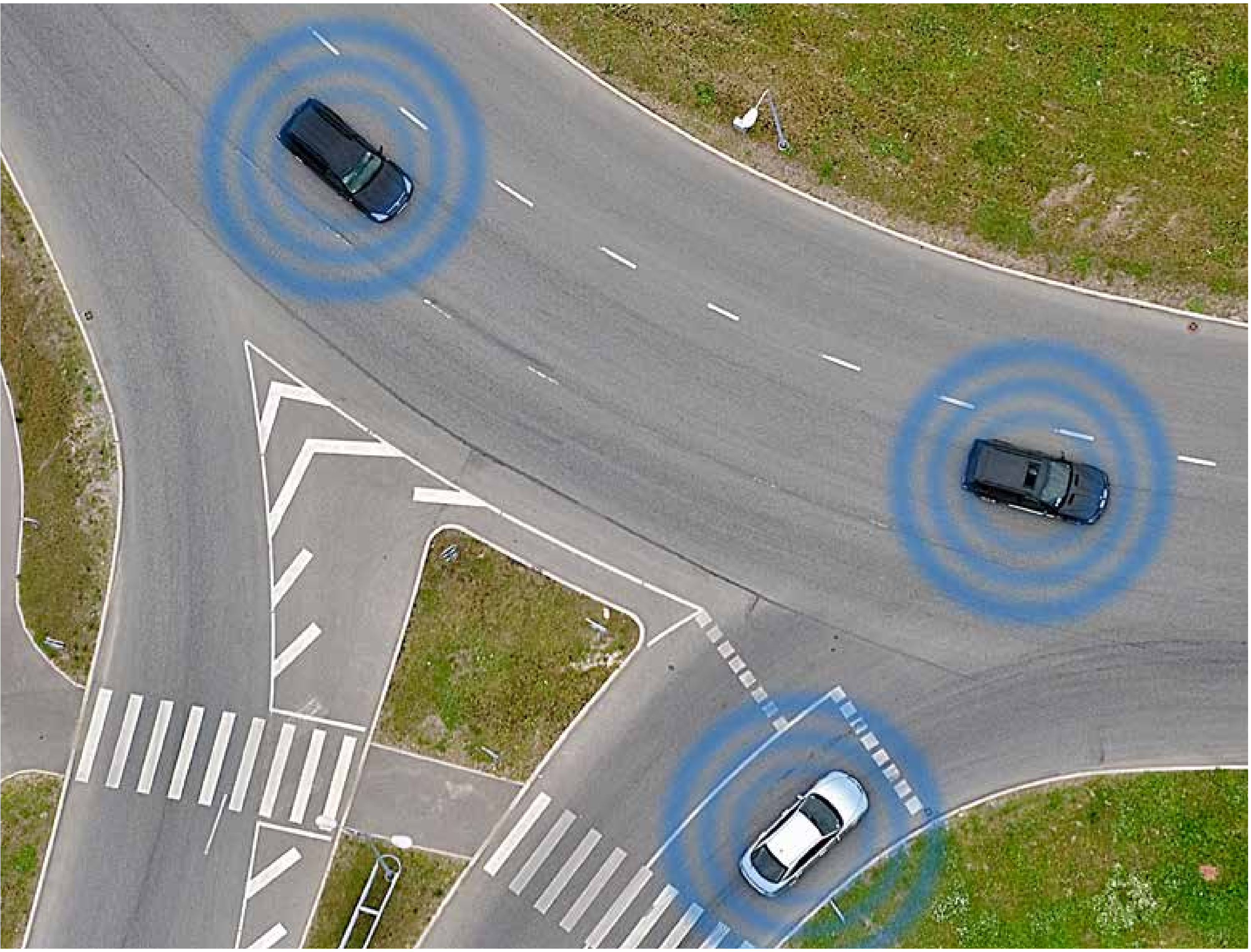
Advanced driver assistance systems (ADAS) are developed to make modern traffic safer, cleaner and more efficient. Equipped with a variety of sensors, an ADAS solution measures the state of the vehicle, the driver and the environment. Based on this information, it is able to inform a driver about a hazardous situation, improve passenger comfort, optimize energy consumption, or actively assist the driver to ensure safe vehicle operation.

Many ADAS technologies are already part of our daily driving experience, and their importance will only increase in tomorrow's vehicle development. The ultimate goal of every automotive manufacturer is to design a vehicle that can drive autonomously, safely and efficiently.

LMS Imagine.Lab Amesim enables users to accelerate the design of ADAS technologies by integrating a detailed vehicle model with realistic sensors into real-life traffic situations. LMS Engineering supports ADAS engineers with expertise in developing and testing control strategies combined with extensive experience in vehicle modeling and integration.



Model predictive control development.



Model predictive control development
Human decisions are mainly based on a prediction of the resulting outcome. Why should electronic controllers behave differently? Model predictive control (MPC) is a promising control strategy that exactly follows this process. MPC is based on a numerical model to predict the system response to a sequence of control actions. Using a fast, real-time optimization algorithm, the MPC controller computes the control actions that optimize your objective.

LMS Engineering offers significant experience in developing MPC-based strategies for a wide variety of automotive control strategies. One particular success story in the domain of ADAS technology is a trajectory optimization module that uses digital map data to extend a driver's limited viewing horizon, enabling a curve speed warning system and driver assistance when overtaking other vehicles.

Balancing functional performance characteristics early in development

"Thanks to LMS, the technology transfer will enable Jaguar to leverage this leading-edge work in future development projects."

Faruk Turgay
Manager
Vehicle NVH
Jaguar Land Rover

Our advanced products and technologies and considerable engineering experience cover myriad applications, helping engineers perform multi-attribute balancing between road noise, ride and handling, drivability, fuel economy, durability and passive safety.

The chassis design significantly affects vehicle dynamics, comfort and NVH performance, yet these performance attributes have conflicting requirements. Traditionally, ride and handling drives the chassis design, starting early in the development process when only limited component details are available. Road noise is typically analyzed later in the development process. By then, however, design freedom for solving issues is often limited to fine-tuning bushing stiffness on physical prototypes based on trial-and-error, which includes risk for a suboptimal balance in the ultimate solution.

Multi-attribute balancing from the concept stage on is essential for reaching the best balanced end result. LMS Engineering experts implement an integrated approach to chassis and suspension engineering, in which vehicle dynamics, comfort, NVH and durability are handled in parallel from concept to vehicle refinement. LMS Engineering has broad experience balancing conflicting attributes, helping customers to frontload design decisions.

The main enabling technologies are:

Conceptual NVH suspension models

In early design stages, when limited geometry details are available, LMS Engineering experts build conceptual NVH models based on the available information in the ride and handling models, such as hard point locations, component mass properties and bushing stiffness. Later on, when more design details become available, those models are enriched for higher accuracy.

Common parameterization

Ride and handling requires time domain simulation in LMS Virtual.Lab Motion, whereas for NVH, engineers work with frequency domain models, such as LMS Virtual.Lab Noise and Vibration. Common parameterization allows you to run both models in parallel in a single integrated optimization loop.

About Siemens PLM Software

Siemens PLM Software, a business unit of the Siemens Digital Factory Division, is a leading global provider of product lifecycle management (PLM) and manufacturing operations management (MOM) software, systems and services with over nine million licensed seats and more than 77,000 customers worldwide. Headquartered in Plano, Texas, Siemens PLM Software works collaboratively with its customers to provide industry software solutions that help companies everywhere achieve a sustainable competitive advantage by making real the innovations that matter. For more information on Siemens PLM Software products and services, visit www.siemens.com/plm.

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