



Siemens PLM Software

LMS solutions for model-based systems engineering

siemens.com/plm/lms

Your leading partner in test and mechatronic simulation

Mastering the complexity of nextgeneration products and development processes has become a major challenge for most manufacturers.

The industry is facing major challenges inventing, developing and manufacturing the right products efficiently. Design right, first time. Successful products must be attractive, ecologic, smart and distinctive with appealing brand values.

With the current drive for smarter and more ecologic products, engineering innovation takes on a new mission. Simulation and testing are being redefined to support a novel approach to systemlevel engineering. A paradigm shift whereby the mechanics, electronics and software in a new design will simultaneously be optimized as an integrated mechatronics system. This approach is called model-based systems engineering or MBSE. And LMS[™] solutions have taken the lead to empower this next (r)evolution in engineering innovation. With the integration of Imagine and Emmeskay, knowledge and capabilities were brought together for multi-physics system simulation, plant modeling and controls. The implementation of the LMS simulation software solution platform that builds on LMS Imagine.Lab Amesim™ software, LMS Imagine.Lab™ System Synthesis software, LMS Imagine.Lab Sysdm software and LMS Virtual.Lab™ software is an enabler for a successful, company-wide implementation of the model-based systems engineering paradigm as they significantly contribute to acceleration of the development throughout the product design from concept phase to detailed design and validation.



Balancing sustainability and brand value using innovative mechatronic systems design

For automotive manufacturers and suppliers, business success depends more than ever on the industry's capability to bring to market affordable vehicles with a new generation of fuel efficient powertrains - offering lower emissions without compromising brand values, such as driving experience, NVH, comfort and safety. Product innovation is increasingly dependent on the introduction of controlled or mechatronic systems. This implies a fast expansion of electronic control units (ECU) and their flawless integration within the underlying mechanical subsystems and systems delivering the right vehicle experience.

Traditional mechanical engineering processes do not support the optimization of such a mechatronic system with acceptable quality and time-to-market. Instead, it mandates the adoption of a development approach where mechanical and controls engineering are interlocked throughout the design process, enabling upfront impact analysis and validation of different vehicle architectures and detailed designs. More specifically, it requires an evolution from prototyping, using physical hardware, to a "model-based" engineering approach, using simulation models representing the controlled systems. This assumes availability of high-fidelity models for control model development (MIL), control software development (SIL) as well as for validation of the actual controller (HIL).

The automotive manufacturing industry needs to adopt an upfront virtual design and testing approach, combining accurate simulation models of control software and the underlying physical systems, while securing a comprehensive and well-managed testing process against functional, performance and safety requirements. Testing is done virtually to the maximum extent possible, breaking the traditional build-test-(re)design pattern. This approach is called modelbased systems engineering or MBSE.



Model-based systems engineering

In close cooperation with industry-leading OEMs, an innovative, comprehensive solution to support a MBSE development approach has been developed. This offering is based on LMS market-leading multi-physics simulation applications and its engineering collaboration environment, applicable for every phase of the development process, from upfront concept analysis to detailed design and validation.

The scope of the LMS MBSE portfolio is unmatched in the industry as it provides:

- A wide range of validated, automotivespecific, multi-physics simulation libraries enabling scalable multidisciplinary design optimization with the appropriate accuracy and ease-ofuse. These multi-physics subsystem and system models can be made available as real-time-enabled plant models to frontload controls engineering.
- A MBSE collaboration platform facilitating a company-wide, consistent implementation of system simulation technology, capitalizing on previous investments.
- System synthesis for meta-modeling and co-simulation, providing an architectural synthesis environment for multi-physics system models and related controls models for vehicle-level system engineering.
- A scalable, 3D geometry-based modeling capability, supporting a wide range of automotive multi-attribute body, chassis and powwertrain simulation applications.

In addition, a proven track record shows successful execution of engineering services, helping customers with:

- Consulting services giving automotive manufacturers and suppliers insight into industry best practices with respect to MBSE processes and methodologies. It allows customers to define a roadmap for a company-wide introduction of the new development approach, considering current practices and tools.
- Physical plant modeling as well as control system development and validation with a specific focus on technology transfer, development process improvement, deployment support and on-the-job training.



A unique system modeling platform

LMS Imagine.Lab Amesim for multiphysics systems modeling

The LMS platform for multi-physics modeling, LMS Amesim, is based on a single, integrated platform, providing a rich set of thermal, electrical, fluids and mechanical libraries that are packaged and authored into particular models to simulate vehicle systems, such as:

- HVAC systems
- Engine and battery cooling systems
- Lubrication systems
- Energy recovery systems
- Transmission systems (manual, DCT, CVT, automatic)
- Combustion engine systems, including valve actuation and injection systems, air path, crank train
- Chassis, braking and ESP systems
- Electrical/auxiliary systems and batteries

These simulation models are scalable in complexity from simple map-based models to full detailed physics models. They are tuned to fast and efficient calculation, capable of addressing the transient nature of actual driver usage scenarios, including warm-up cycles, start/stop, etc. LMS Imagine.Lab models are tuned to deliver real-time capabilities with regard to offline simulation. LMS Amesim delivers:

- An unmatched library of validated component models that span a very large range of applications available at multiple levels of detail
- A highly acclaimed intuitive user interface with natural support for modeling workflows, enabling quick and efficient model assembly
- Fast, stable and accurate numerical solvers that enable users to productively utilize the models developed for a variety of analysis and simulations, including real-time support for XIL testing
- Co-simulation with 3D modeling environments such as LMS Virtual.Lab and connecting into CFD applications
- Integration with state-of-the-art HiL environments
- Interfaces to Matlab/Simulink[®] controls modeling environments



LMS Imagine.Lab Sysdm for collaborative engineering

Component and system level models, including all the associated data for calibration or usage profiles, are managed in a central database system called LMS Sysdm. This database enables engineeringprocess-oriented organization of the required models and data, providing structured search, query and access capability to the necessary modeling information.

LMS Sysdm features version control for life cycle management, and variant system model management in function of the design stage and required precision. It includes role-based access control, allowing structured collaboration between departmental teams of system model developers, system engineers and project managers.

The data and model management forms the basis for secure updating and sharing as well as for structuring the collaboration workflows between mechanical and central departements. It improves simulation data quality and traceability, increases productivity, accelerates distributed decision-making and secures company IP. The LMS Sysdm solutions complement and can integrate with product life management enterprise applications.

LMS Imagine.Lab System Synthesis

for architectural design decisions LMS System Synthesis provides metamodeling of architectural system configurations that:

- Integrate multi-physics system models and related control models
- Allow system-level performance assessments versus functional requirements for representative usage scenarios
- Clarify interdependencies between a vehicle's interrelated subsystems

These System Synthesis capabilities contribute to overall vehicle performance simulation and optimization by enabling users to balance the performance requirements of individual vehicle systems.





The system allows integrators to author the logical system's view, configure and integrate system models according to various architecture configurations. Configurable data processing and visualization of simulation results enables effective analysis and exploitation to support design decisions.

The LMS System Synthesis application integrates, next to LMS Amesim, Matlab/ Simulink models. The Modelica standard for multi-physics system modeling is also supported, making it possible to assemble heterogeneous system models requiring co-simulation. It provides customization functions for interfacing with legacy applications.

LMS Virtual.Lab for functional performance simulation

LMS Virtual.Lab offers an integrated 3D simulation software suite to simulate and optimize the performance of mechanical systems. It covers all the process steps and

required technologies to perform an endto-end design assessment.

LMS Virtual.Lab connects into the CAD environment, providing capabilities for multi-attribute structural analysis and assembly with support for industry standard FE solvers, like Nastran, LS-Dyna, Radioss, and Abaqus.

The platform facilitates end-to-end NVH, acoustic, durability and safety analysis and result interpretation. LMS 3D simulation capability includes multi-body and flexible body simulations for a range of automotive and ground vehicle subsystem and system kinematics and dynamics, supporting chassis, engine, transmission and mechanism applications, which can be coupled with LMS Imagine.Lab capability and Matlab/Simulink controls models.





LMS Engineering for MBSE

Based on their multi-disciplinary and multi-attribute vehicle expertise, the worldwide LMS Engineering team is uniquely positioned to allow our customers to take advantage of our MBSE competence, covering physical plant modeling – with the LMS Imagine.Lab platform – and controls engineering.

We take full responsibility for the detailed systems modeling, analysis and optimization, relying on experience and leading technologies across multiple physics domains including mechanical, thermal, electrical and controls applications.

Systems engineering benefits from the proven accuracy of the modeling, including the specific ability to deal with transients. This allows a significant shift from late stage prototype optimization to a frontloaded, simulation-based approach. Subsystems engineering is permanently executed in the context of full vehicle performance. Conflicting system requirements are highlighted and resolved in earlier phases to secure convergence.

In addition to the proven development process, the LMS solutions approach offers significant benefits over any other engineering solution as it secures the deployment of the software tools and models for use in future projects. We maintain the delivered software, providing continuous support and release updates for the duration of the project. We organize regular on-site technology exchanges and have a culture of open technology sharing including models, data and milestone reports. This process of cooperation not only guarantees reaching the project targets, but it also deploys a simulation-based, vehicle-level methodology with a complete technology transfer.

Most importantly, we firmly believe in on-the-job involvement, securing a trusted customer relationship, which is key for the success of the program. To date, we have a long list of references in deploying attribute methodology as part of vehicle development programs as well as working with leading car manufacturers on fuel economy in traditional and HEV vehicles. LMS Engineering has successfully performed many projects in vehicle energy management, integrating new eco-friendly technologies while continuing to improve the car's drivability and performance. The vehicle energy management methodology is designed to be integrated into the existing vehicle development process and combines mechanical, thermal, electrical, and control engineering in one software environment.



LMS MBSE service offering for controls engineering

We have built extensive competence helping customers with the definition and process to build reusable, reconfigurable architectures for control development. The LMS MBSE approach enables parallel development of control software and underlying mechanical components, allowing plug-and-play replacements of real-time-enabled physical plant models with the final hardware as it becomes available. Leveraging strong verification and validation processes, we can secure the functionality and safety of the control algorithms using automated ECU testing in MiL, SiL, and HiL development phases.

Taking advantage of vast experience in controls engineering, we support customers by establishing a process for optimal control development, balancing different vehicle attributes with the numerous ECU software alternatives and options.

We have developed an optimized, customizable process with associated tools, migrating legacy ECU C-code to control models and conforming to the MBSE paradigm shift. The resulting Matlab/Simulink[®] models are guaranteed equivalent to the original C-code and satisfy requirements for increased readability and auto-code generation. Leveraging these processes and tools, we offer a scalable service to perform the migration, resulting in production code for ECU control units.

Examples of engagements include vehicle as well as subsystem control development. We pioneered the introduction of an MBSE development approach for production HEVs. We take responsibility for the physical plant models running real-time in a HiL context and as an example support automated verification and validation of the hybrid vehicle supervisory controller. On the supplier side, we cooperated a.o. in the development of a solid oxide fuel cell (SOFC) strategy. Leveraging strong verification and validation processes, LMS took release responsibility for the control strategy of the SOFC system, securing an aggressive development program.





Solutions for MBSE



Vehicle energy management

LMS solutions address the challenge of integrating innovative eco-friendly powertrain concepts, while continuing to improve the car's drivability, comfort and performance. This methodology supports conceptual architectural design iterations for HEV, EV and ICE or mild hybrid vehicles. It can be used to evaluate and optimize subsystem performance in a vehicle context during multiple development phases. Designed for integration into the existing vehicle development process, it combines mechanical, thermal, electrical, and controls engineering in one synthesis platform.



Thermal management

LMS solutions provide dedicated tools to model, size and analyze energy-generating and consuming subsystems. This solution gives design engineers the possibility to work on detailed models of subsystems, like cooling, lubrication, HVAC, auxiliary heating, brake energy recovery and Rankine systems. With this solution, steady-state as well as transient multi-domain conditions can be tested, and heat management control strategies can be optimized to balance thermal comfort and fuel economy.



Internal combustion engine

LMS tools help engineers design comprehensive engine systems as fuel injection, air management and combustion and engine control strategies. We provide accurate physical engine models and components and the process knowledge in controls requirements, implementation and validation phases. Impact analyses of innovative technology choices, such as advanced valve-train systems, multiple injection and multi-stage turbochargers can be processed and analyzed.



Driveline and transmission

LMS solutions facilitate simulation of new transmission design as well as control strategy concepts. This solution provides a comprehensive, flexible development framework ranging from component design to system integration and control validation for any kind of transmission architecture including hybrid, dual-clutch, robotized, automatic and CVT. This technology provides a scalable solution to address not only drivability, but also judder and higher frequency driveline integration and comfort issues.



Battery and fuel cell management

LMS solutions offer battery and fuel cell plant modeling technology together with practical experience in battery management system development. LMS has proven expertise in battery management system testing on MIL, SIL, and HIL platforms to support the requirement, implementation and validation phases.



Automotive electrics

The LMS automotive electrics solution supports the design and optimization of automotive power networks and related control strategies. This solution helps size the power network, checks the wiring size, validates the control laws for optimization of the electric power management, and estimates the transient behavior of each component and its related impact on the entire network.



Chassis and controls

Dedicated LMS solutions were developed to frontload design decisions for chassis-system components, like brakes, suspension, steering and anti-roll systems. It is possible to integrate them into a single system model to simulate and validate global chassis control strategies. LMS presents a scalable approach to model and simulate actuators and the vehicle itself from functional to multi-body approaches. The solution offers straightforward integration with MiL, SiL and HiL validation processes.



Kinematics and controls

The LMS solution for frontloading development closures and other kinematic-driven systems guarantees the smoothest operation possible according to geometrical design constraints. This solution takes into account safety and energy factors related to integrated electric or hydraulic drives and actuators and allows for optimization of the system. For powered systems like automatic trunks, power dimensioning of electric and hydraulic devices is evaluated under normal and specific conditions, and safety factors are checked under controlled conditions.



Off-road and ground vehicle

Dedicated LMS model-based solutions are provided for evaluating and balancing requirements like speed, precision, stability, driver comfort, load hoisting, and power supply dimensioning for hydraulic or electric drives. With complex interaction between mechanical and hydraulic subsystems and control elements, only a total system simulation provides representative results. 3D geometry-based capabilities to model vehicles, such as wheeled or crawler loaders and backhoes, cranes, skid steers or forklifts are complemented with 1D functional simulation for transmission and power systems, driven by the control unit. The simulation also covers the engine's power supply and the hydraulic circuits.



Verification and validation for controls strategy

Scalable and suitable for various development phases, we let customers translate control requirements into prototype controller elements traceable to specific systems requirements. Controller algorithms are implemented in executable models like Matlab/Simulink, which are then rigorously validated against customer requirements, and suitable for automatic code generation. We support executable specifications development, which allows scenario testing of the control strategy to guarantee the quality of the control strategy and embedded software.



System and code migration services

To support migration from legacy C-code to Matlab/Simulink control models, we have developed an optimized, customizable migration process and tools that quantifiably guarantee the results to be equivalent and satisfy readability and auto-code generation requirements.



"Just consider the challenge of model identification. With more and more engine variants under development, multiple engine models need to be validated. This explosion of models and variants poses the problem of identification or even re-identification of existing models. A joint project with LMS Engineering has enabled us to reduce by five the time required for complete model identification from 50 days to only 10. Our next objective is to reduce this process to two days."

Vincent Talon Modelization Engineer Renault

About Siemens PLM Software

Siemens PLM Software, a business unit of the Siemens Industry Automation Division, is a world-leading provider of product lifecycle management (PLM) software, systems and services with nine million licensed seats and 77,000 customers worldwide. Headquartered in Plano, Texas, Siemens PLM Software helps thousands of companies make great products by optimizing their lifecycle processes, from planning and development through manufacturing and support. Our HD-PLM vision is to give everyone involved in making a product the information they need, when they need it, to make the smartest decision. For more information on Siemens PLM Software products and services, visit www.siemens.com/plm.

Headquarters

Europe

Granite Park One 5800 Granite Parkway Suite 600 Plano, TX 75024 USA +1 972 987 3000

Americas 5755 New King Court Troy, MI 48098 USA +1 248 952 5664 Researchpark Haasrode 1237 Interleuvenlaan 68 3001 Leuven Belgium +32 16 384 200

Asia-Pacific

Suites 4301-4302, 43/F AlA Kowloon Tower, Landmark East 100 How Ming Street Kwun Tong, Kowloon Hong Kong +852 2230 3308

© 2014 Siemens Product Lifecycle Management Software Inc. Siemens and the Siemens logo are registered trademarks of Siemens AG. LMS, LMS Imagine.Lab, LMS Imagine.Lab Amesim, LMS Virtual.Lab, LMS Samtech, LMS Samtech Caesam, LMS Samtech Samcef, LMS Test.Lab, LMS Soundbrush, LMS Smart, and LMS SCADAS are trademarks or registered trademarks of LMS International N.V. or any of its affiliates. All other trademarks, registered trademarks or service marks belong to their respective holders.

39461-X12 3/14 C