SIEMENS

Siemens PLM Software

LMS solutions for aviation engineering

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A transformation towards new design process and better use of technology

The aviation industry has an extensive innovation agenda. Market demands, such as increased safety and comfort, better fuel economy, reduced emissions and noise levels, and overall lower operating costs, are forcing the aircraft industry to rethink traditional engineering methods.

Managing a growing complexity
Aircraft development becomes much more complex and interdependent. Managing this growing complexity throughout the supply chain is a major challenge that calls for profound innovation and a system-level approach. New technologies introduce the need to re-evaluate traditional systems, subsystems and structural design. The most prominent examples of new technology are the use of composite material in airframes and the increase of electrically powered systems. Electrical systems significantly reduce the weight, making the aircraft much more economical to operate.

Early aircraft maturity
To lead the aviation race, time to market is critical and therefore, achieving earlier aircraft maturity is a top priority for every aircraft manufacturer. Current aircraft programs accumulate immense amounts of rework. Making the right architectural and technology choices early in the aircraft program will significantly reduce rework and related costs. This requires an engineering platform that enables quick trade-off studies early on. Ideally, this early decision-making process will include dynamic, performance-based, system-level modeling capabilities during the concept phase. Such a tool will allow engineers to manage the complexity of highly integrated aircraft systems by obtaining the right requirements in time.

Solving the integration issue
Modern-day aircraft are a system of systems that dynamically interface with each other to perform a specific function. Recent aircraft programs have had quite a few structural and systems integration issues, which cause long program delays and tremendous budget overruns. The root cause of these integration issues is the aircraft requirement process itself. In most cases, requirements do not consider dynamic interaction on a system level. We currently provide dedicated test, mechatronic simulation and engineering solutions to help both integrators and suppliers achieve earlier aircraft maturity as efficiently as possible.

The paradigm shift in aircraft engineering

The aviation industry sets the agenda for the next-generation aircraft.

Future aircraft will answer new economic and ecological expectations and will be built on new design concepts and technologies. In preparation for this the industry must introduce new and more efficient development processes, such as model-based systems engineering.

Why is a transformation towards model-based systems engineering needed now?

From both the mechatronic system simulation and testing perspective, it is important to make solid and accurate decisions regarding technical choices and system integration during the earliest phases of the aircraft program. Engineers must be able to analyze conflicting requirements and various interaction scenarios to anticipate any system-level integration challenges from the outset. They also need to increase simulation realism and productivity. They require the ability to combine simulation and test to frontload subsystem validation. And the propagation of mechatronic systems makes it necessary to frontload controls engineering tasks into the development program of the encompassing system or subsystem. The industry needs a process to cover all of this and model-based systems engineering is the solution.

Do we have specific solutions to optimize the early stages of aircraft development?

With increased system integration and interaction, system-level performance analysis has become increasingly critical. With this in mind, the LMS Imagine.Lab™ platform has been developed to include multi-domain modeling, validated simulation and multi-level system synthesis to assure the optimal architecture.

We also deliver solutions for virtual integrated aircraft analysis to optimize and validate integrated hydraulic, pneumatic and electrical subsystems performance upfront. Co-simulation between LMS Imagine.Lab, LMS Virtual.Lab™ and LMS Samtech™ technologies form a scalable and open platform to model aircraft systems integration and check the 'system of systems' performance upfront. All these solutions are aimed at making the right technological choices upfront and preventing costly reworks downstream.


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How do LMS simulation solutions increase realism and productivity for component and subsystem development?

LMS™ solutions provide scalable capabilities to model systems at the required fidelity covering multiple physics, including stress and failure analysis. LMS Imagine.Lab is a rich system modeling environment covering fluid, electrical and mechanical systems. LMS Virtual.Lab increases the model reliability for the systems where a 3D representation is required. LMS Samtech technologies cover structural analysis including rotor dynamics, composite and thermal analyses. LMS Test.Lab™software complements this with experimental based acquisition and analysis technologies.

Will better and smarter testing also play a role in the paradigm shift in aircraft engineering?

Entering the world of the unexplored, as one does when adopting new materials, design concepts and technologies, naturally leads to more testing to understand the physical phenomena. Validation testing is very expensive. The secret is to be smart about how to combine testing and simulation.

Using virtual models to prepare the test not only reduces test-related costs and risks, it cuts time off the test campaign itself. For example the LMS ground vibration testing (GVT) solution and its corresponding Engineering Services cover the process from pretest structural dynamics simulation, to ground vibration testing to the use of GVT results for calibrating structural dynamics models for flight flutter testing. They are recognized by specialists around the world as a key factor to accelerate the launch of new aircraft programs.

Our unique capabilities to create high-fidelity real-time simulation models enable to frontload hardware-in-the-loop (HIL) tests. This capability could eventually result in the virtualization of the aircraft's iron bird, referred to by the industry as a 'virtual iron bird'. This opens an entire new world of possibilities in terms of frontloading and validating integrated systems.

We strengthened our 3D simulation portfolio through the acquisition of a controlling stake in the Belgian company Samtech. How powerful are the complementarities?

The simulation technology of Samtech is very complementary to the simulation approach we have developed through the years. Samtech offers 25 years of excellence in comprehensive structural analysis and aircraft certification process support based on top class simulation technology. LMS Samtech provides technical added value for us in its 3D, highly nonlinear static or quasi static analysis on a micro and macro level. Its material models for composites and dedicated products for structural, thermal and mechanisms analysis, composites optimization, structural and failure analysis, jet engine rotordynamics, and certification process support are unrivalled.The partnership with LMS Samtech also strengthens our market position in the integration arena. For example, Airbus and its major suppliers use LMS Samtech Caesam™ software as the process integration platform for aircraft structural certification.

Airbus' ISAMI project integrates validated analytical and LMS Samcef parameterized finite element methods on the LMS Caesam process integration platform. LMS Caesam enables the deployment of these methods into the extended enterprise of Airbus and its risk sharing partners. ISAMI creates a single engineering environment for every engineer working for or with Airbus. Internal and external users will share role-specific and context driven information, tools and services.

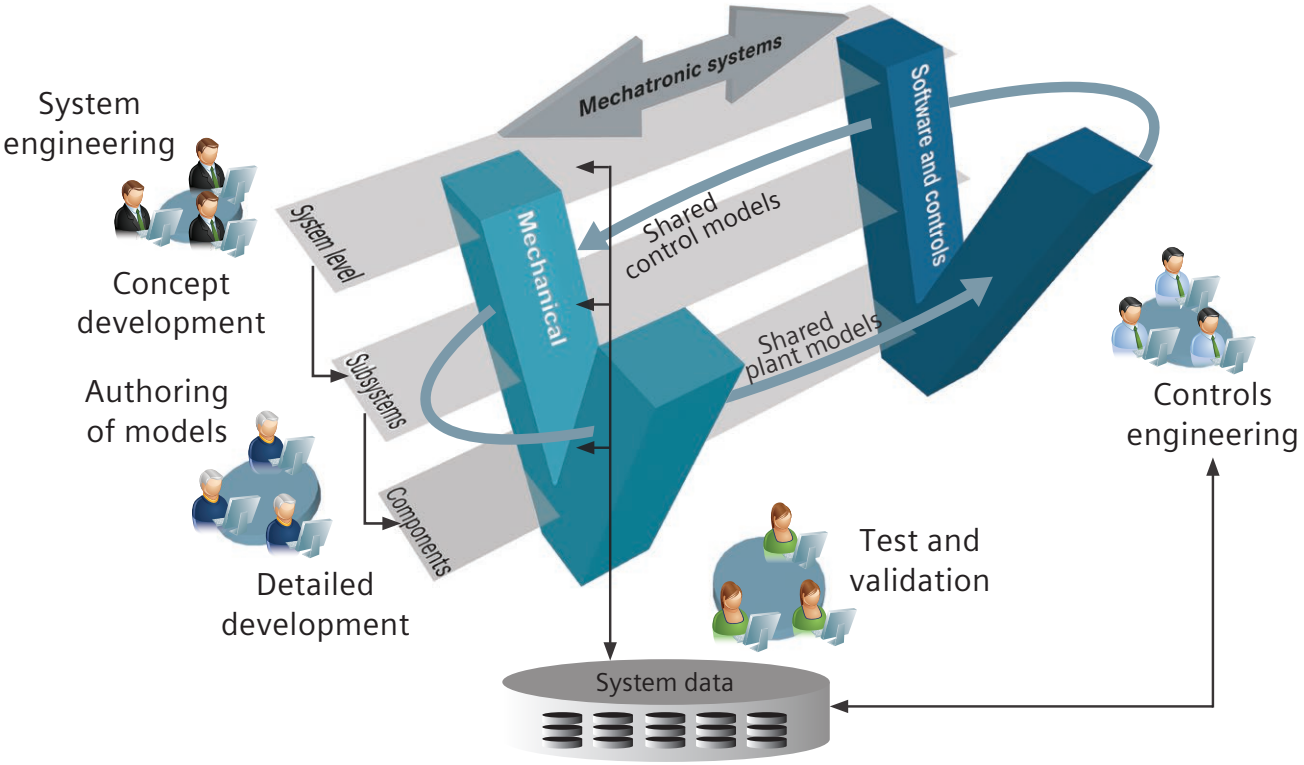
As an aircraft integrator, Airbus is now certain that consistency is increased in the structural and certification process. Add to this the fact that the platform increases calculation efficiency, leaving more time for optimization. Last but not least, risk sharing partners get a day-by-day dashboard of the structural performance related to their structural work package.

We are now the first and only provider in the industry to deliver a full and unique portfolio of test and multi-physics 3D and systems simulation solutions to engineer the functional performance of aviation structures and systems. We support all phases of product development, from early concept structure sizing and detailed design stages, through to the final refinement and physical prototype validation and certification.

How does the LMS solution portfolio support the trend towards model-based controls engineering?
When developing mechatronic systems, engineers cannot afford to wait for the physical hardware to be available. Controls engineering tasks need to be frontloaded into the development program. The best option is to use simulation models representing the system that will be controlled, or so-called 'plant' models.

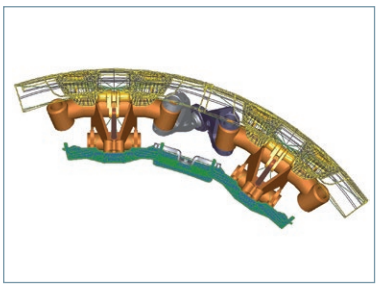
In model-based controls engineering, the plant models are synchronized with the simulation models of the components and subsystems.

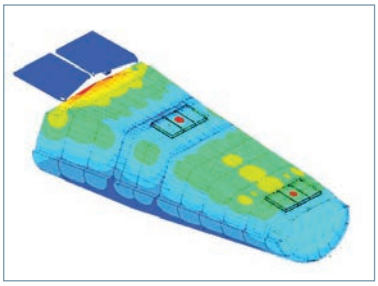
LMS simulation platforms feature unique functions to couple plant models with applications used for actual controls engineering. This can be done offline or in real-time to support the entire model-based Controls engineering process – from model-in-the-loop (MIL), to software-in-the-loop (SIL), and hardware-in-the-loop (HIL). This capability is a critical link between mechanical engineering and controls engineering for all types of controlled systems.



LMS Samtech technologies

High fidelity structural simulation and unique process support from early aircraft sizing until certification





Nonlinear structural and mechanical analysis, including rotor dynamics analysis

Modeling complicated aircraft components is a challenge, as mechanisms as well as structures often behave in a nolinear way. High-lift devices like flaps and slats are designed to operate safely also in case of failure, for example, failure of actuator jamming, linkage breaking. Structural parts plastify quickly in case of failure and the resulting deformation can prevent normal operation and endanger the whole aircraft. LMS Samcef Mecano predicts the failure of the structure thanks to its unique ability to mix nonlinear finite elements with kinematic joints. Accurately predicting the stress distribution in structural parts of landing gear during the take-off and landing operations is another example illustrating the same capabilities.

Composites

Composite components become more and more important in aircraft. LMS Samtech offers a comprehensive solution to simulate the structural behavior of such components: large finite element models to analyse and optimize stress, buckling and post-buckling of panels. Customer specific methods based on the results of the latter can also be included in the optimization processes. Both global and local stress analysis and optimization can be performed and interact to close the design loop.

Rotor dynamics

Modeling the dynamic behavior of an aircraft engine is sometimes a challenge. Engine rotors rotate at high speed, inducing gyroscopic and centrifugal effects. LMS Samcef Rotors is taking up that challenge, thanks to its multi-harmonic technology (2D models to represent 3D phenomena) and multi-stage cyclic symmetry that keeps model sizes reasonable while producing results that the classical 1D technology cannot obtain. Other components, like Variable Stator Vanes (VSV), variable geometry convergent/divergent nozzles and others require the ability to include mechanisms inside finite elements models. LMS Samcef Mecano includes this unique feature and can accurately predict fatigue onblades of the VSV or thermal expansion of the petals in the CD nozzle.

Integration framework

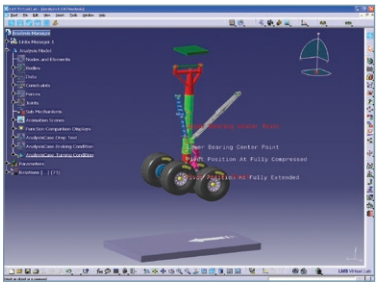
LMS Caesam is an engineering integration framework for the management and sharing of methods and tools, enabling to manage processes and to deploy them within the extended enterprise. The framework makes it possible to automate the processes on different levels and over different design cycles. On top of that, LMS Caesam has embedded capabilities for parametric design and optimization. The goal is to gain efficiency, consistency and to avoid rework, save costs and reduce time-to-market.

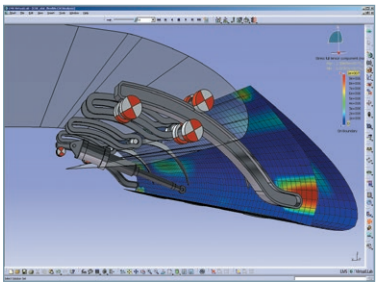
LMS Caesam can help you to provide role-specific, context-driven access for internal and external users to relevant information, tools and services. It supports strategic outsourcing, improves decision-making and product quality. It increases strategic and operative control by monitoring product and production changes affecting timelines, costs and resources.

LMS Samcef Mecano	LMS Samcef Composites	LMS Samcef Rotors	LMS Caesam Aircraft
Combine finite element analysis and multi-body simulation in the same model	A dedicated LMS Samcef solution for simulating the normal, degraded behavior of composite and mixed structures	A dedicated LMS Samcef solution for the dynamic modeling of rotors	Engineering integration framework enabling to share engineering models, methods processes and tools with external partners
• Nonlinear structural analysis • Flexible nonlinear multi-body simulation • Structural stability (buckling) • Thermal	• Simulation of the progressive damage inside the ply (fiber breaking, matrix cracking), and at the interface of the plies (delamination – crack propagation) • Ply-by-ply result recovery • Classical failure criteria (maximum stress, maximum strain, Tsai-Hill, Tsai-Wu, Hashin, Puck) • User material and criteria	• Rotor-dynamics • Critical speed analysis, harmonic response, transient (time dependent) analysis • Scalable from concept until detailed analysis • 1D, 2.5D, 3D including multi-harmonics, classical and multi-stage cyclic symmetry	• Merge, manage and share processes, methods and tools • Increase efficiency by deploying and automating processes throughout the extended enterprise over different design cycles • Run iterative processes using advanced optimization tools to find the optimal design • Safeguard data consistency

LMS Virtual.Lab

3D system simulation for functional performance analysis





"Sensitivity analyses help to determine which counter-measures are effective and which are not. Performing two-step sensitivity analyses with LMS Virtual.Lab is easy and fast. I can't imagine how we could optimize the acoustic countermeasures without it. LMS Virtual.Lab results provide a clear insight into which panels contribute the most to the unwanted noise."

Pierre Huguenet
Group Leader/Project Manager
Sener

LMS Virtual.Lab offers an integrated software suite to simulate and optimize the performance of mechanical systems for structural integrity, noise and vibration, acoustics, system dynamics and durability – from initial concepts, complete modeling and simulation of wing flaps and slats, landing gear and door systems to advanced full-aircraft landing simulations.

Making virtual simulation realistic

LMS Virtual.Lab covers all the process steps and required technologies to perform an end-to-end design assessment in a single simulation environment. With LMS Virtual.Lab engineers are able to build models faster and simulate real-life performance accurately. They can quickly assess multiple design alternatives and optimize their designs way before prototype construction.

From simulation preprocessing to final reporting

LMS Virtual.Lab is an ideal engineering environment for any engineer concerned with performance analysis. Offering an intuitive environment, LMS Virtual.Lab integrates parameterized CAD models from Catia V5 and other software packages with powerful structural, multi-body, acoustic and fatigue analysis solvers. The platform provides the required process support to automate engineering tasks and maintain associativity with the CAD models.

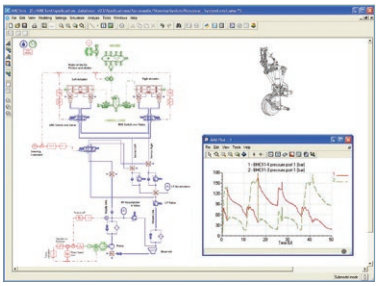
Linking to mission-critical engineering processes

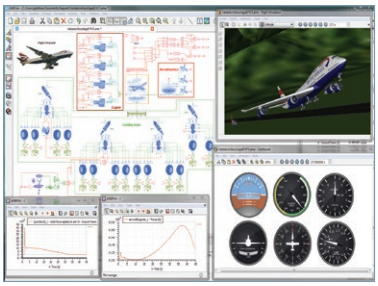
We focus on compatibility throughout all product platforms. With aircraft system integration becoming more and more important, LMS Virtual.Lab can be linked to other system simulation software, like LMS Imagine.Lab, to support plant modeling for real-time validation tests. LMS Virtual.Lab connects to the test world as well, providing better virtual testing, risk mitigation for physical tests, and analysis and modeling improvements.

LMS Virtual.Lab Motion Durability	LMS Virtual.Lab Acoustics Noise and Vibration	LMS Virtual.Lab Correlation and Updating	LMS Virtual.Lab Optimization
Scalable modeling, sizing and analysis of mechanical systems	Simulation and analysis of system vibro-acoustics	De-risk physical structural dynamic testing via virtual testing	Multi-disciplinary sensitivity analysis and optimization
• Controls • Actuation systems • Flexible structures • Kinematic and dynamic functional and performance specifications for safety, reliability and stability	• Accurately predicts aircraft interior and exterior noise and vibration • Address structural and airborne transmission paths • Reduce noise of structures, engines, power equipment, ECS • Optimize passenger comfort	• Increase productivity by combining test-based and virtual component models into system-level models. • Correlate noise and vibration data sets: Test – FEM, Test-Test, FEM-FEM • Update FE models with test data systematically	• Reach optimal design with multiple performance targets. • Easily identify key variables that influence the functional multi-attribute performance of a mechanical system

LMS Imagine.Lab

An open multi-domain simulation approach for model-based systems engineering





"Thanks to LMS Imagine.Lab Amesim, we managed to reduce the test rig development time by 25 percent and since we were able to perform part of the tests via simulation, the availability rate of the physical testing platform increased by approximately 60 percent."

Achour Debiane
R&D Manager
Certia

LMS Imagine.Lab provides a market-leading, multi-physics simulation environment tuned to the needs of aviation engineering. Geared towards mechatronic system simulation, the LMS Imagine.Lab platform offers an open approach starting from functional requirements to detailed physical modeling and simulation. It supports component and detailed level design as well as system level analysis.

User-friendly and collaborative, the LMS Imagine.Lab platform provides engineers with a flexible, cutting-edge toolset to address specific design requirements in terms of performance, safety, comfort, reliability, fuel economy and reduced emissions for various industry applications including virtual integrated aircraft analysis and virtual iron bird testing.

LMS Imagine.Lab Amesim for simulation and analysis of multi-physics controlled systems

LMS Imagine.Lab Amesim™ software lets you create and run multi-domain simulation models to analyze complex dynamic system behavior and support the design of controlled systems from early specification to subsystem testing. Tuned to your evolving needs, LMS Imagine.Lab libraries for aerospace evolve continuously with dedicated aerospace components and demonstrators.

4500+ validated multi-domain models

LMS Amesim comes with a set of standard and optional libraries for the aerospace industry, with dedicated predefined, validated components and demonstrators, covering different physical domains (fluid, thermal, mechanical, electrical), all directly executable within the LMS Imagine.Lab solvers.

LMS Imagine.Lab Flight Controls	LMS Imagine.Lab Landing Gear
Supports the design and optimization of flight control systems	Helps designing any landing gear system and its multi-disciplinary wnature
• Primary and secondary flight controls • High-lift devices • Spoilers • Air brakes	• Actuation systems • Braking systems • Steering systems • Shock absorber

LMS Imagine.Lab Sysdm for system model and data management

LMS Imagine.Lab™ Sysdm software organizes and manages mechatronic system models including its related data. It covers both physical and controls models. It takes care of the efficient interchangeability of your models and data within your company.

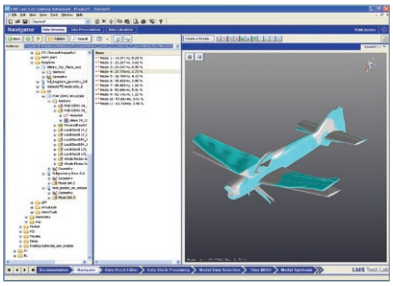
LMS Imagine.Lab System Synthesis for configuration management and physical model execution

LMS Imagine.Lab™ System Synthesis software support system configuration management, systems integration and validation. It synthesizes system models on a variety of platforms, including real-time platforms, in support of MiL, SiL and HiL processes for virtual iron bird testing.

	LMS Imagine.Lab Environmental Control Systems	LMS Imagine.Lab Engine Equipment	LMS Imagine.Lab Aircraft Fuel Systems	LMS Imagine.Lab Aircraft Engine	LMS Imagine.Lab Electrical Aircraft
	Simulate and analyze complex fluid systems	Design fuel systems and controls as well as engine control actuators	Design complete aircraft fuel systems and analyze the thermal integration	Assess the dynamic behavior and performance of jet engines	Design the aircraft electrical network and tackle new challenges of the more electrical aircraft
	• Bleed air • Anti-icing • Ventilation circuit • Oxygen and life system	• Fuel systems • Lubrication • Heat exchangers • Thrust reversers • Accessory gearbox	• Reservoir • Tank and gauges • Pumps, ejector pump, valves	• Jet engine • Boundary conditions on electrical power generation, bleed system, fuel system and flight dynamic	• Electrical components • Electrical networks • Actuators • Thermal integration

LMS Test.Lab and LMS SCADAS

The market-leading dynamic testing and analysis solution



"We've been extremely impressed by the flutter analysis results and the way that the LMS Test. Lab software can handle the challenges of processing the immense amount of Airbus A380 in-flight data during the offline analysis."

Jean Roubertier
Flight test department
aeroelasticity expert
Airbus

LMS Test.Lab™ software is a complete, integrated solution for test-based engineering, combining high-speed multi-channel data acquisition with a full suite of integrated testing, analysis and report-generation tools.

Setting new standards for ease-of-use

LMS Test.Lab is designed to make testing more efficient and more convenient for each and every user. With its unique workflow-based interface, LMS Test.Lab sets new standards for ease-of-use, productivity and data consistency.

The software naturally follows the test campaign process, guiding the user through the different steps and suggesting optimal settings for measurement and analysis parameters. In addition, LMS Test.Lab allows easy process integration and implementation of proprietary legacy test and analysis methods through the Windows-automation interface combined with the direct support of a wide range of industry standard data formats.

Transforming test data into engineering conclusions

LMS Test.Lab is the perfect solution to obtain deep engineering insight and share this insight with others. It transforms test data into engineering conclusions. Sharing those conclusions with the engineering team is easy thanks to the integration with LMS Virtual.Lab and LMS Imagine.Lab as well as other system simulation packages. LMS Test.Lab provides physical testing support to calibrate models to fidelity levels that make model-based systems engineering a reality.

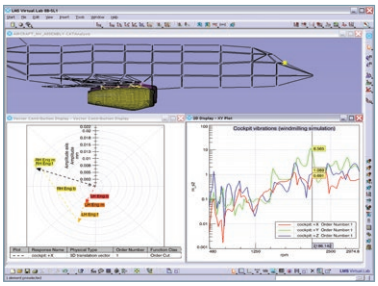
Top-performing data acquisition hardware

LMS Test.Lab is tightly integrated with the LMS SCADAS™ data acquisition hardware family for accelerated measurement setup and correctly formatted results. Using the LMS SCADAS tool enables you to deliver reliable results and optimal testing productivity thanks to its versatility, flexibility and high performance. The range includes compact mobile units, autonomous smart recorders up to high-channel count laboratory systems.

LMS Test.Lab Structures and GVT Structural Dynamics Testing	LMS Test.Lab Acoustics and General Dynamic Data-Acquisition	LMS Test.Lab Rotating and Turbine Testing	LMS Test.Lab Vibration Control and Environmental
Small-scale and large-scale modal tests in hours rather than days	Data acquisition and analysis for noise, vibration and other dynamic phenomena	All-digital, advanced solution for complex turbine testing processes	Advanced and complete environmental testing solution range
• Complete GVT testing for aeroelastic certification • Identify root causes of vibration problems and engineer the best solution	• Cabin comfort • Interior acoustics • Fly-over noise • Advanced aircraft noise and vibration	• Data acquisition • Data storage and management • Online monitoring alarming • Analysis and reporting • Updating	• Basic component vibration qualification testing • Advanced 3D multi-shaker vibration control • Closed loop shaker control and real-time monitoring of shakedown tests • Safe operation

LMS Engineering

The technology and process know-how for success



LMS™ Engineering services counts on its globally minded team of over 100 multi-lingual engineers to help customers optimize product designs and address tough engineering challenges. This highly mobile and diverse team of experts supports engineering departments across the globe in deploying the most up-to-date engineering processes successfully in a variety of complex domains.

A unique combination of skills, experience and knowledge

LMS Engineering includes troubleshooting, design refinement, technology transfer and development support through all stages of the development cycle. Dedicated aviation experts combine solid industry experience with multidisciplinary technology and know-how in a variety of areas including landing gear analysis, shimmy, aircraft mechanism, ground vibration testing, noise and vibration analysis, strength analysis of metallic and composite structures, environmental control systems, thermal management and systems engineering.

A proven approach to late-development troubleshooting

Our teams are specialists in generating highly accurate models of aircraft systems, using the best available assumptions in the concept stage or integrating the most relevant test data in the later stages. Furthermore, LMS Enginering delivers an integrated and proven approach to late-development troubleshooting, using a mix of test and simulation techniques to avoid inefficient and time-consuming trial and error methods. The impact of different possible solutions is analyzed upfront and the optimal design change is validated through final prototype testing.

Open technology sharing

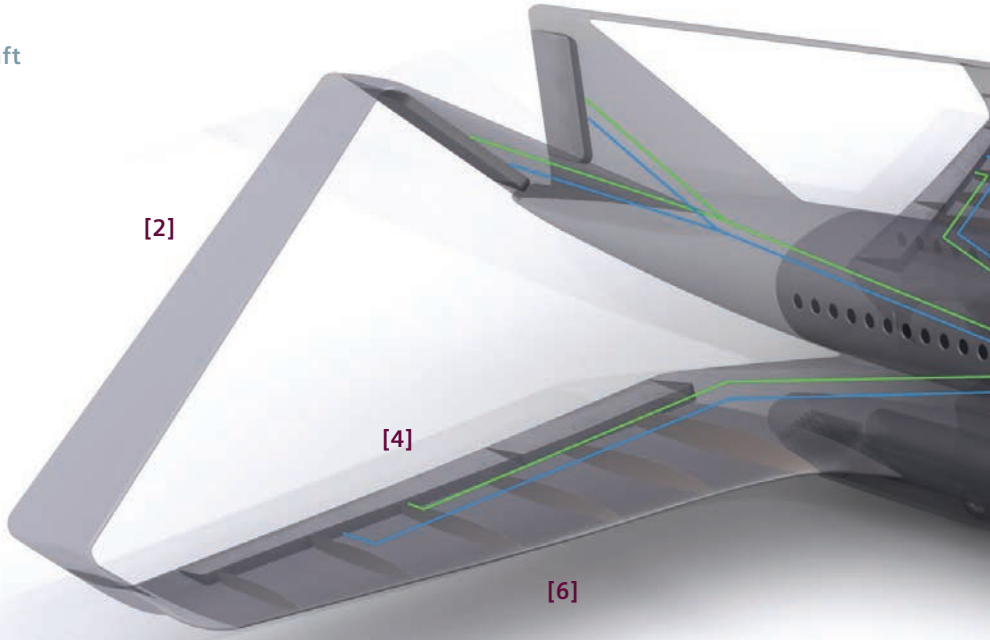
LMS Engineering has a culture of open technology sharing including models, data and milestone reports. The team organizes regular onsite technology exchanges. This process of cooperation not only helps reach the project targets, but it also deploys a simulation-based, system-level methodology with a complete technology transfer. Most importantly, LMS Engineering firmly believes in on-the-job involvement, securing a trusted customer relation-ship, which is key to the success of the program.

Process deployement	Troubleshooting	Technology transfer	Extended resources
Define and deploy improvements to your development processes	Troubleshoot your product issues	Increase your internal knowledge	Extend your team and let LMS do the job for you
• Very good understanding of aircraft development process and engineering processes • Identify bottlenecks and define improvements using new technologies, improvements in the way of working, closer integration of Test/CAE	• Unique approach source – transmitter – receiver model	• Transfer our technologies and best practice, teaming through projects • Delivering the know-how together with the results	• Unique combination of skills - 1D-3D; Test – CAE; mechanical – controls - Technology deployment – problem solving • Tailored projects to accomodate your needs

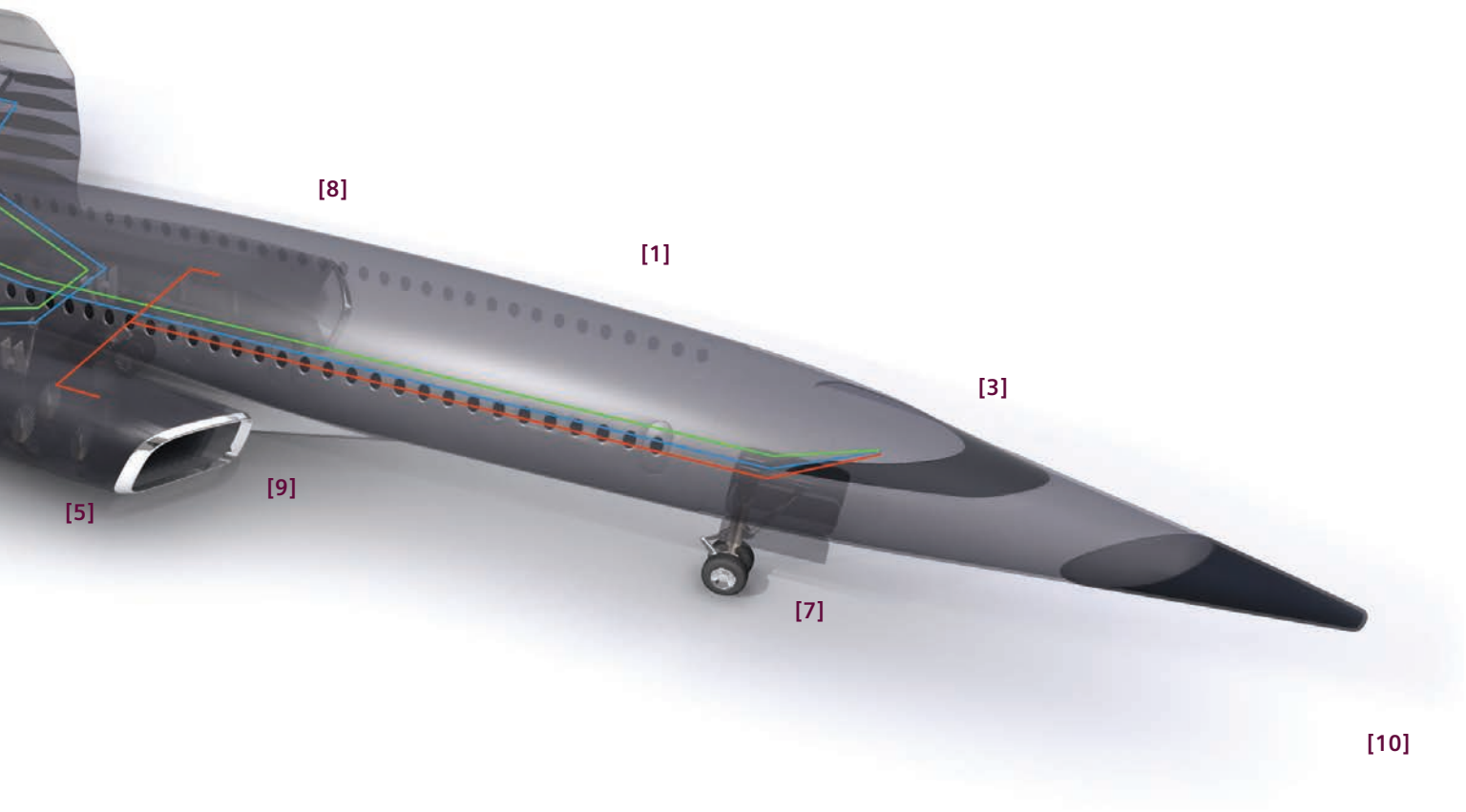
Unrivaled portfolio of structural and mechatronic system simulation and testing solutions

LMS solutions for the next-generation aircraft

- Structural presizing and certification
- Noise and vibration
- Structural dynamics
- Acoustics
- Virtual testing
- System design and optimization
- Structural and failure analysis
- Composites optimization
- Kinematics, dynamics and loads
- Power management
- Engine modeling
- Rotor dynamics
- Thermal and mechanisms analysis
- Virtual integrated aircraft
- Virtual iron bird
- Ground vibration testing



From both the mechatronic simulation and testing perspective, we are evolving our solutions and services to support all stages of an aircraft program from defining aircraft architecture and system requirements to confirming integration and validation testing.



[1] ATA 21
Air condititioning

[2] ATA 27
Flight controls

[3] ATA 24
Electrical power

[4] ATA 28
Fuel

[5] ATA 29
Hydraulic power

[6] ATA 30 – 36 - 75
ICE protection
Pneumatic power
Air systems

[7] ATA 32
Landing gear

[8] ATA 53 – 55-57
Fuselage
Stabilizers – wings

[9] ATA 71 – 72 – 73 – 79 – 76 – 83
Powerplant – turbine
Engine fuel and control
Engine oil
Engine controls
Engine accessory gearbox

[10] Non-ATA related
Aircraft loads
Cabin comfort and exterior noise
Aircraft energy/thermal (VIA)
Aircraft integration testing (VIB)
Structural dynamics

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.

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