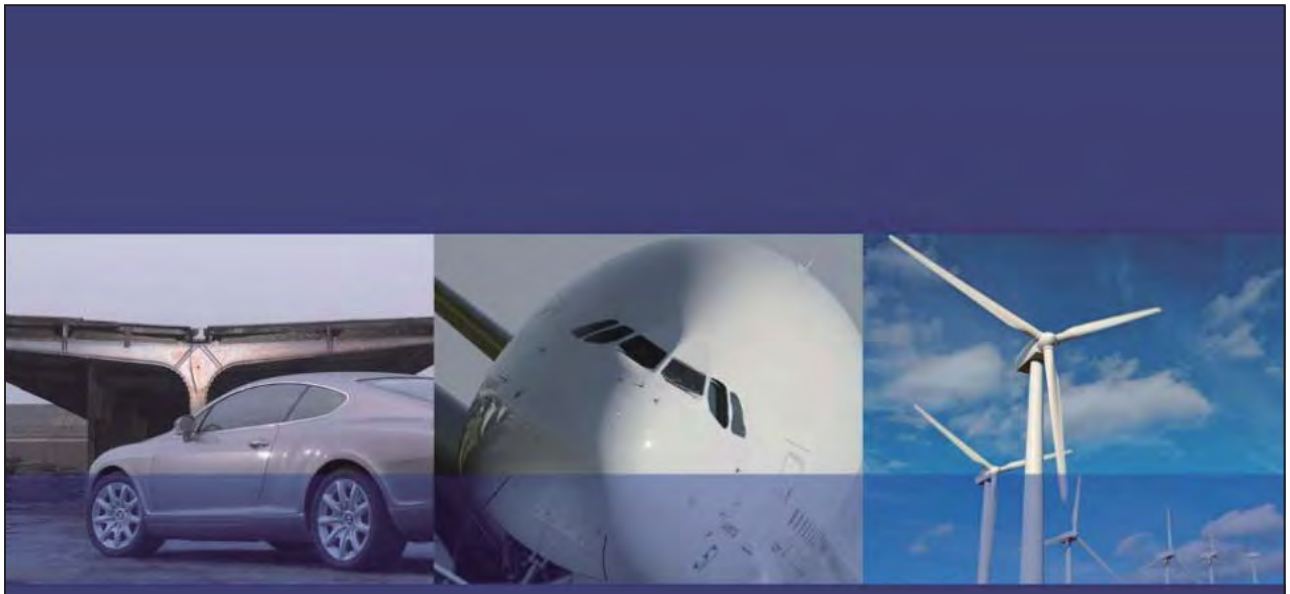
Latest advancements in noise and vibration simulation in support of electrical motors and power electronics.

Koen De Langhe
LMS International

Abstract :
Electrical Motors specifically and Power electronics in general are mechanical systems that produce noise and vibrations. In most cases, the noise and vibration is unwanted for environmental, functional or comfort purposes. The presentation will address the different aspects of the noise, including cooling fan noise, unbalance noise and Electromagnetical noise. It will be demonstrated how recent technologies in acoustics can be applied to simulate, analyse and address the noise of electrical machinery.
In a second part of the presentation the scope of the collaboration between JSOL and LMS will be highlighted in view of interfacing JMAG and Virtual.Lab products, resulting in a premier solution for Noise and Vibration analysis.



LMS Virtual.Lab Acoustics

Noise and Vibration prediction from Electrical Motors with JMAG and Virtual.Lab

Dr. Koen De Langhe
JMAG Users Conference – Tokyo December 2010

LMS ENGINEERING INNOVATION

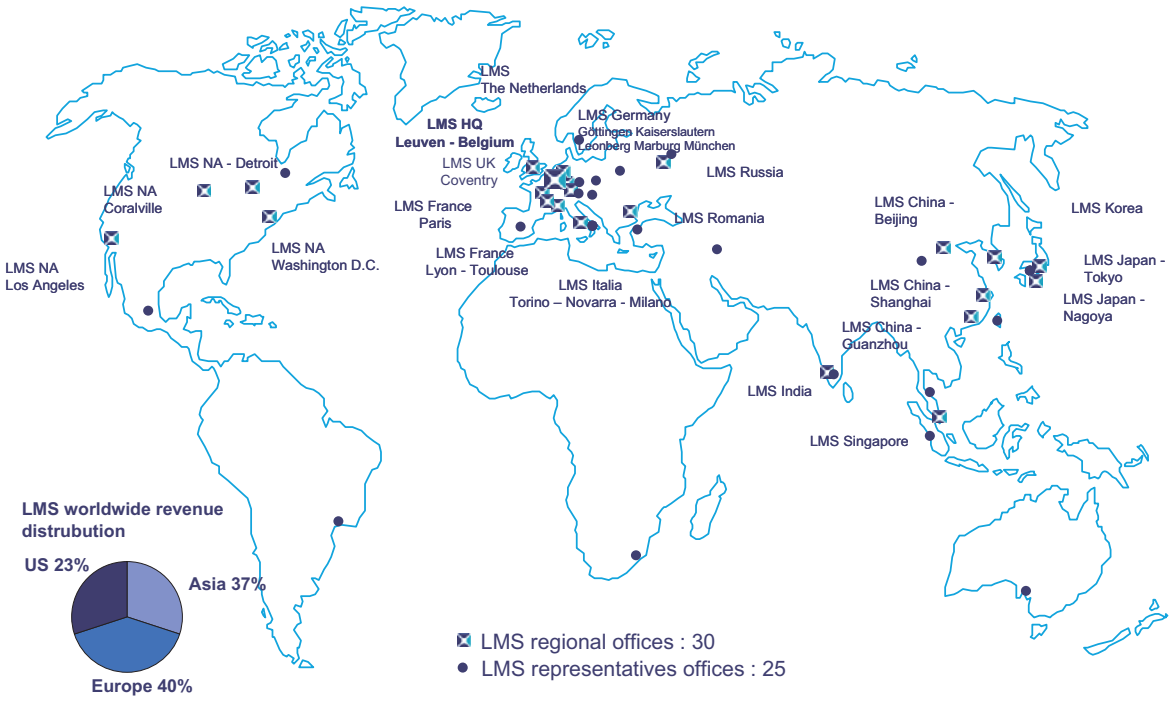
LMS, 30 years of engineering innovation

A unique provider of engineering services, virtual simulation and physical testing solutions

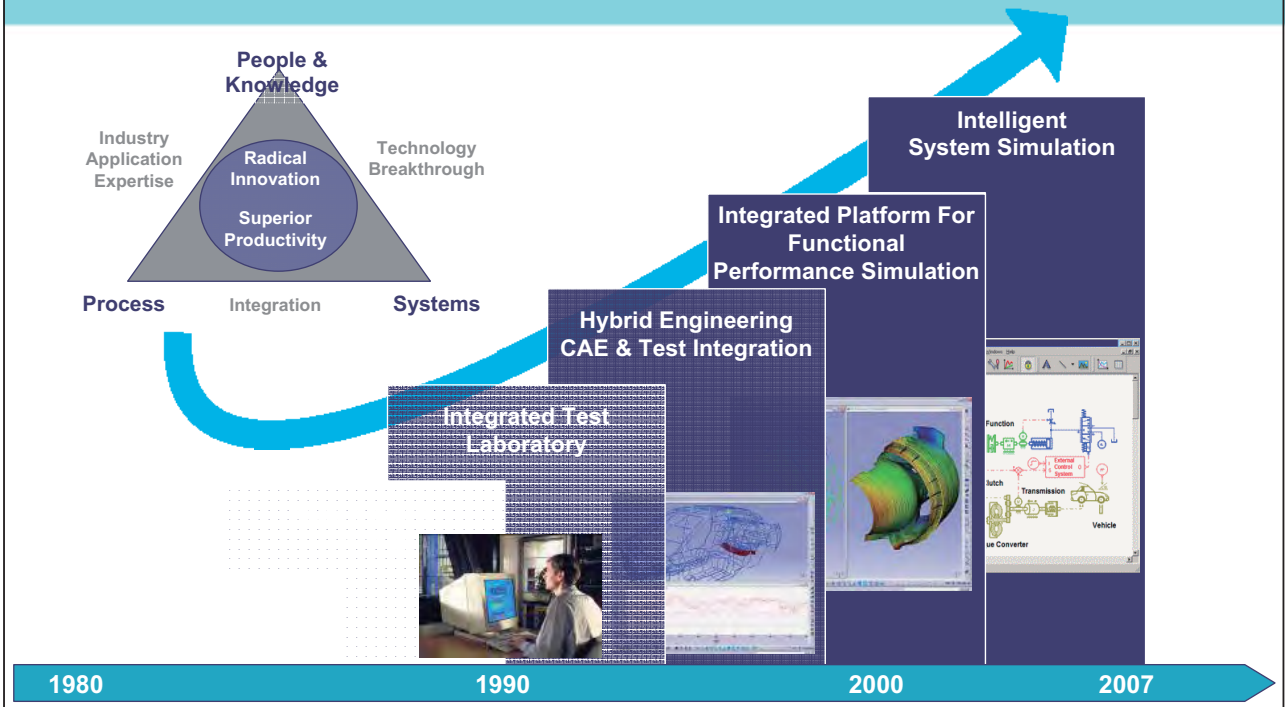
- Global Engineering Innovation Partner for
  … more than **100.000** R&D engineers in **5.000** manufacturing companies
- Top talent in 30+ offices in Europe, US en Asia
  … more than **850 employees**
- The industry largest commitment to technology development and innovation… **30 % of budget in R&D**
- Strong financial track record
  … double digit **profitable growth** for +25 years

LMS ENGINEERING INNOVATION

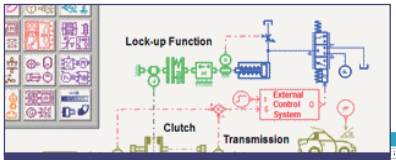
LMS, a global response to customer needs



LMS, delivering engineering innovation since 1980

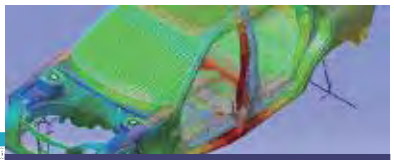


LMS, a unique portfolio of engineering innovation solutions



LMS Imagine.Lab
1D simulation solution

Engineering Collaboration
Simulation Integration in PLM



LMS Virtual.Lab
3D simulation solutions

LMS Engineering and Deployment Services

LMS Test.Lab
Test-based engineering solutions

LMS SCADAS
Mobile – Recorder – Lab

LMS Tec.Manager
Test data management

LMS Test.Xpress
Analyzer testing solutions

LMS SCADAS
Mobile – Recorder – Lab

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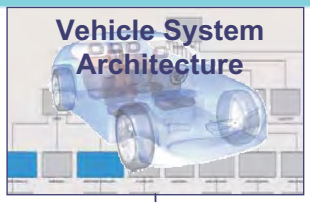
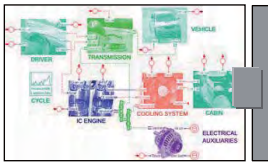
Towards "Model Driven" Product Development Enabled by Model Based System Engineering

"Multi-physics" models
Thermal, Mechanical, Electrical…



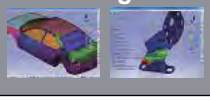
Vehicle System Architecture

"Controls" models
Electrical, Electronics, Software…



Concept Engineering

Detailed Design



Vehicle Integration

Manufacturing

Concept Engrg - System **Synthesis**	Optimization of system architecture & committed cost
Detailed Design – System **Verification**	High fidelity simulation - minimize reliance on Test
Vehicle Integration – System **Validation**	Frontload subsystem validation – "Virtual/Physical"

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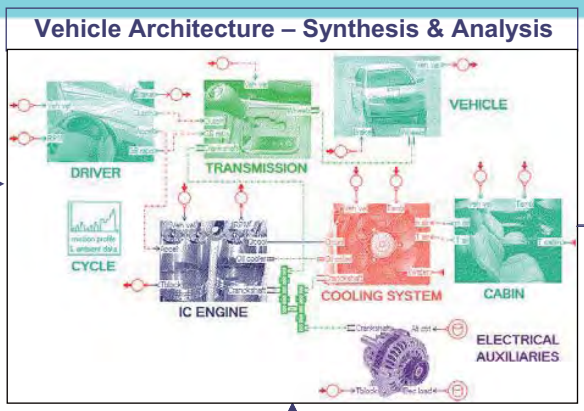
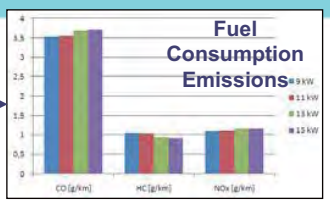
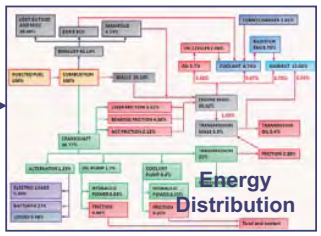
Vehicle Energy Management – Concept Engineering
Optimization of hybrid vehicle architecture for fuel economy

Example

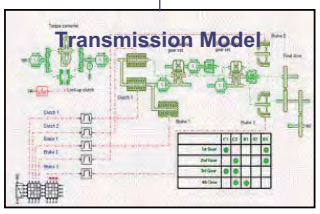
Tip-in, Tip-out
Gearshift, WOT, Stop & Start
Incidental maneuver
Std & Realistic cycle
…

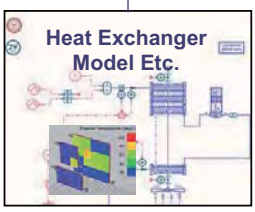


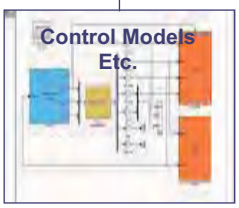




Sub-Systems Models







LMS ENGINEERING INNOVATION

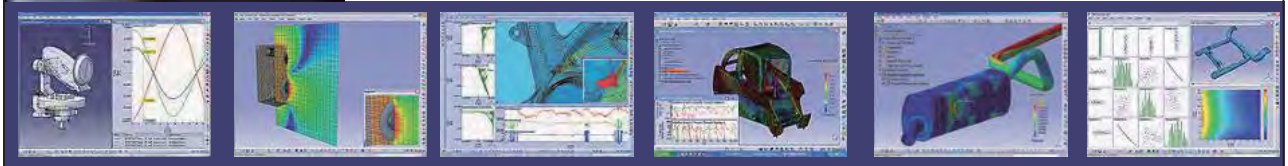
Virtual.Lab: a unified simulation platform

Engineering the right product…

- Simulate real-life behavior of mechanical designs → **Rich Attributes**
- Deliver a balanced performance → **Multi-Attributes**
- Tackle the root causes of design weak spots → **Engineering**

… Accelerating the development process

- Accelerate model creation in a unified environment → **One model**
- Capture and automate simulation processes → **Automation**
- Combine the best of testing and 1D/3D simulation → **Hybrid**



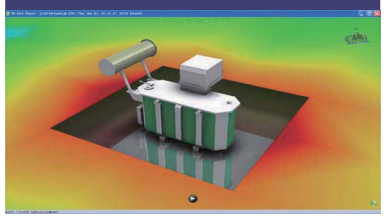
Motion | Acoustics | Durability | Noise & Vibration | Structures | Optimization

LMS ENGINEERING INNOVATION

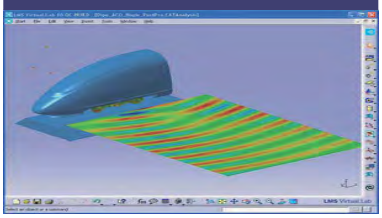
LMS Virtual.Lab Acoustics

Comfort / quality

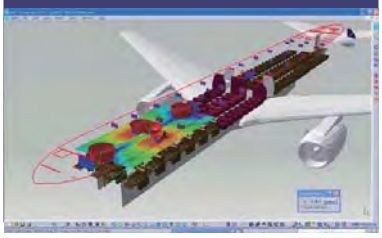
Legislation Noise machinery



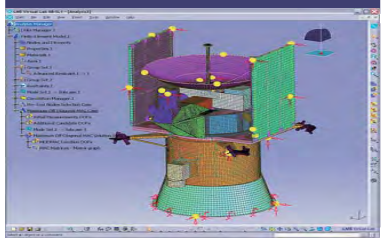
Legislation Environmental



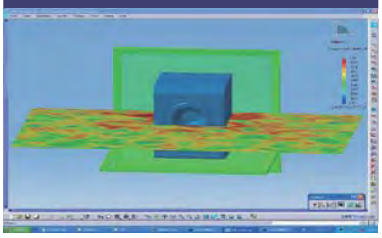
ECO Friendly



Risk reduction



Cost reduction

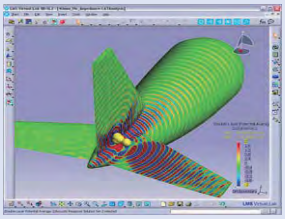


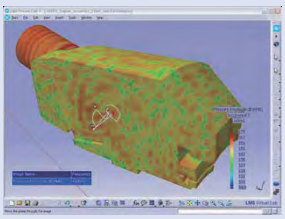
LMS ENGINEERING INNOVATION

The Premier Vibro-Acoustic Simulation Tool

SOLVER SPEED

Tremendous value running
1 hour
versus
1 day





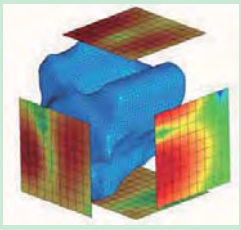
PROCESS EFFICIENCY

Tremendous value for
End-to-end process
versus
scattered tools

REALISTIC SIMULATION

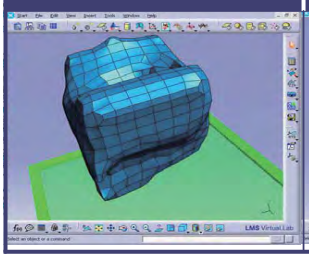
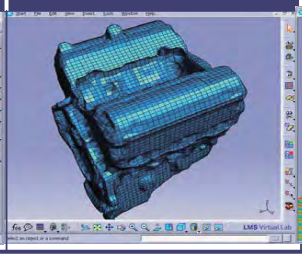
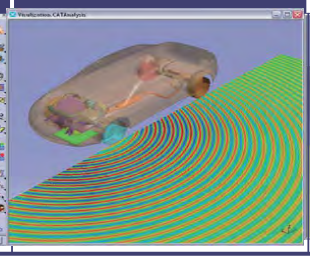
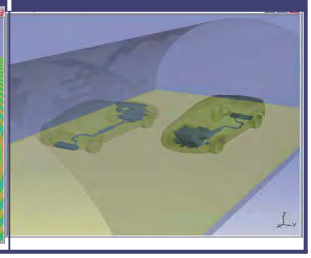
Tremendous value for a
"**3 dB**" accuracy
versus
"**20 dB**" accuracy

Tremendous value when
doing high fidelity
REAL STRUCTURE
versus
SIMPLE PLATE



LMS ENGINEERING INNOVATION

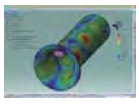
Evolution in Realistic Acoustic Simulation

1990	2000	2010	From now onwards
			
Low Fidelity Component level	High Fidelity Component level	High Fidelity System-level	High Fidelity Full System including the "environment"

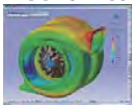
A systematic approach for N&V engineering

Source

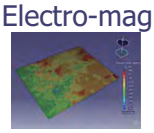
Flow-based



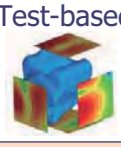
Mechanical



Electro-magnetics

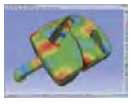


Test-based



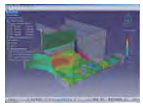
System

FEM-Acoustics



BEM-Acoustics

RAY-Acoustics

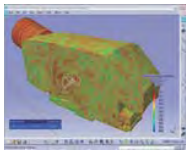


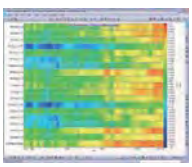
SEA

Receiver

Standard

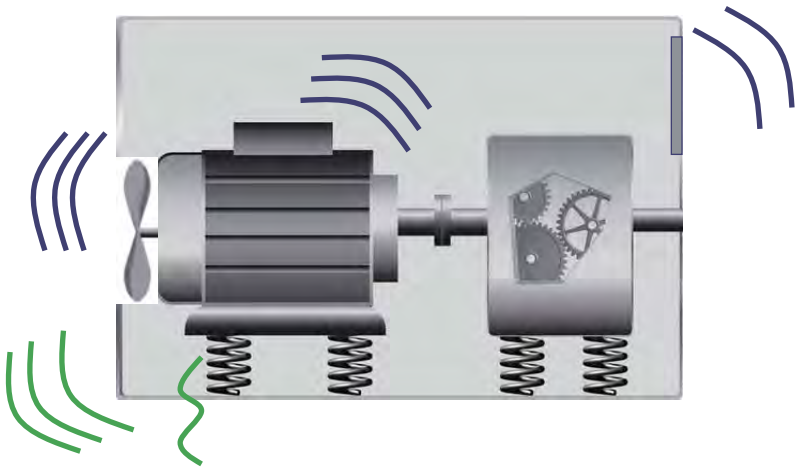
Advanced





Electrical Motor Noise and Vibration

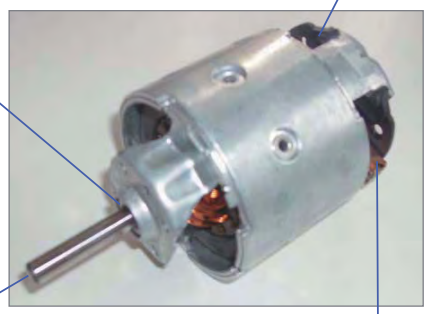
Source	Cooling Fan	Mechanical	Electro-magnetic



Transfer	Air-borne	Structure-borne

LMS ENGINEERING INNOVATION

Example: DC Electric Motor Mechanical noise



Mechanical Commutation
- Bar-to-bar variations
- Run-out

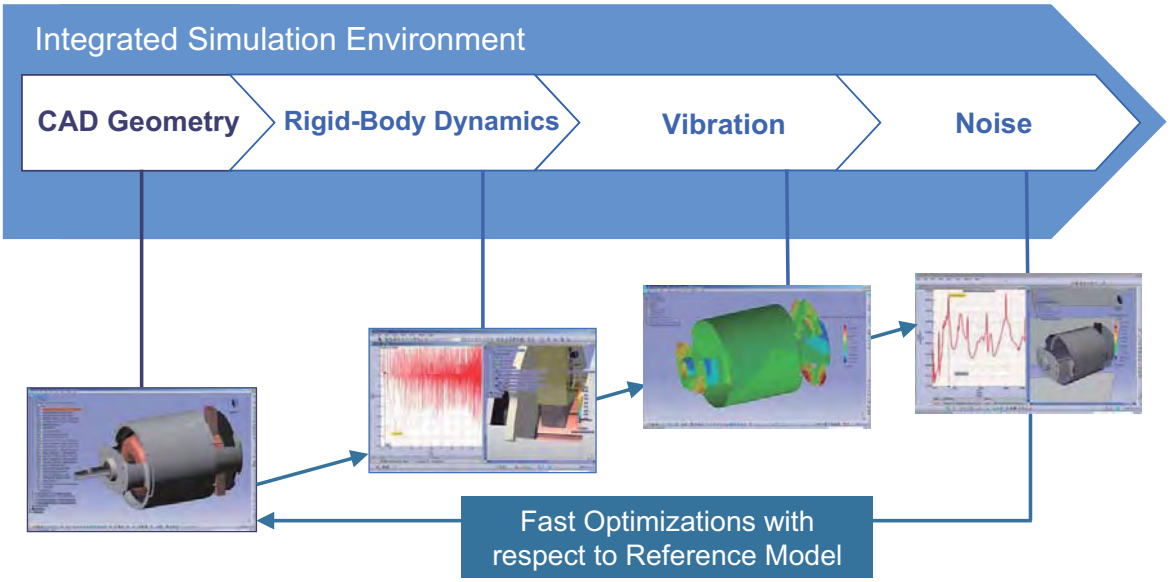
Bearing
- Clearance
- Oil
- Moment

Armature/Shaft
- Unbalance
- Run-out
- Surface

Brushes/Brush-Card
- Spring type and force
- Stabilization scheme

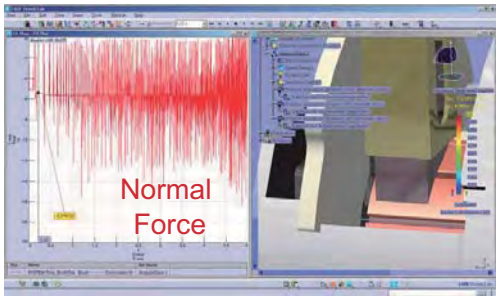
LMS ENGINEERING INNOVATION

DC Electric Motor
Implementation of Simulation Software

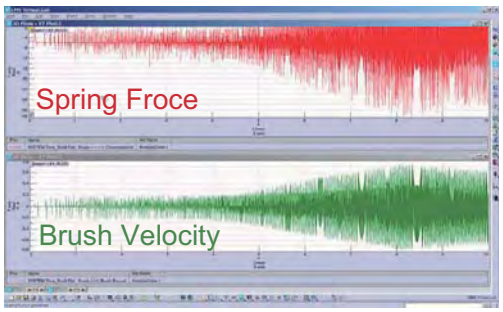


DC Electric Motor

Commutation

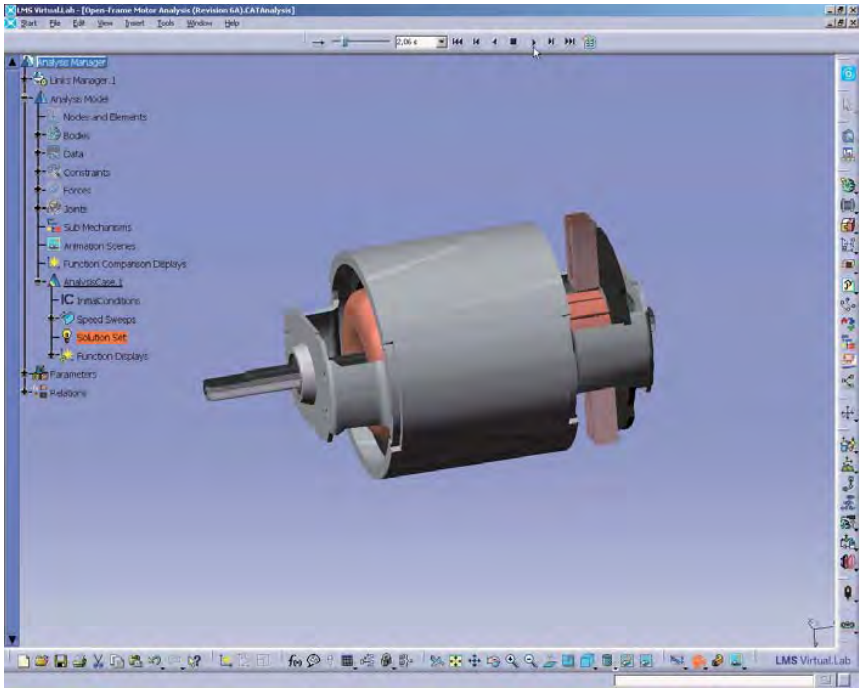


- **Normal Contact Force on Commutator**
  - Speed-ramp 0-3000min^{-1} in 10s (5s span)
  - DC offset of 5.5N (by design)
  - Variations ~±5N
  - Cannot be measured
  - Force impulses cause noise



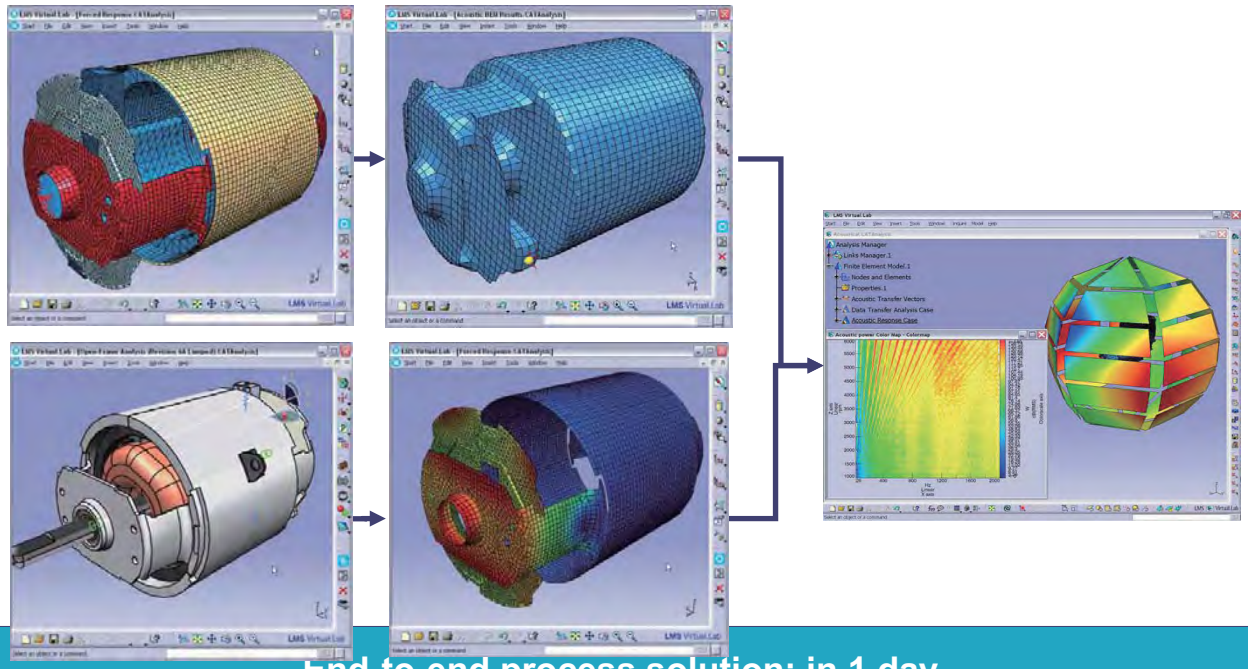
- **Brush Radial Force and Velocity**
  - Speed-ramp 0-3000min^{-1} in 10s (10s span)
  - Brush force mirrors contact force (logical)
  - Brush velocity variations of ±0.8m/s – can be measured with laser Doppler vibrometer

DC Electric Motor



LMS ENGINEERING INNOVATION

LMS Virtual.Lab Acoustics
End-to-end process solution

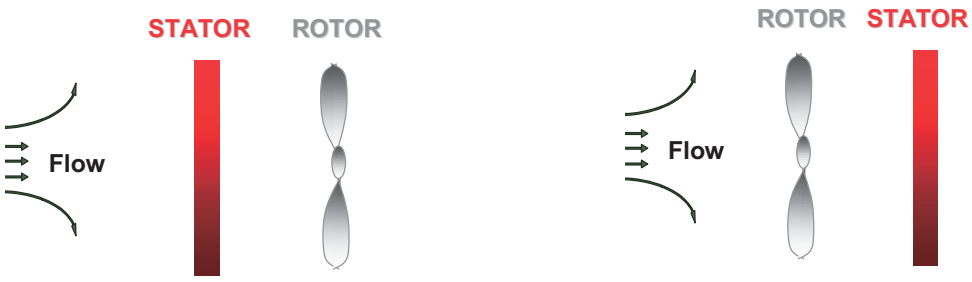


End-to-end process solution: in 1 day

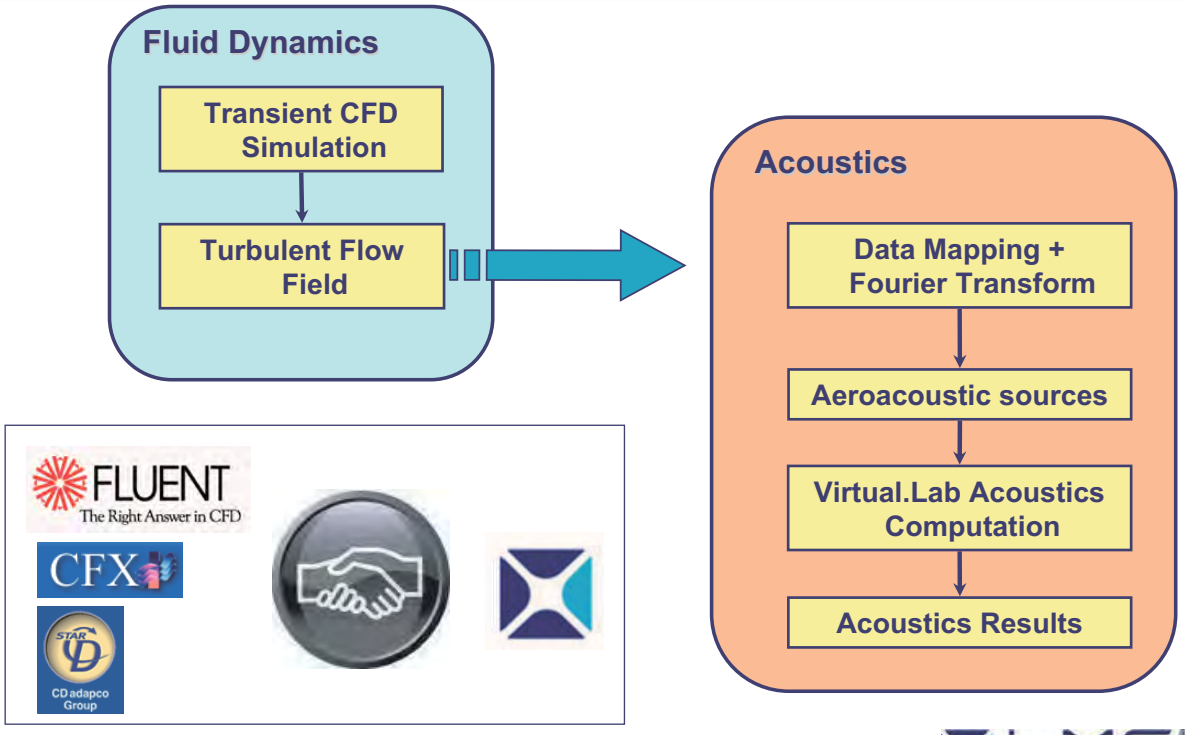
LMS ENGINEERING INNOVATION

Electrical Motor Cooling Noise

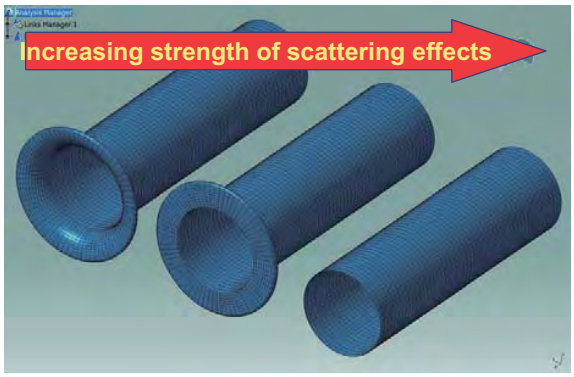
- The loading noise produced by a rotating machine has two main characteristics:
  - The **broadband** noise
  - The **tonal** noise
- The discrete frequency noise is due to the periodic interaction of the incoming air with the blades of the rotor. The noise is at the blade passing frequencies and harmonics (**BPFH**).
  → Handled by FWH formulation

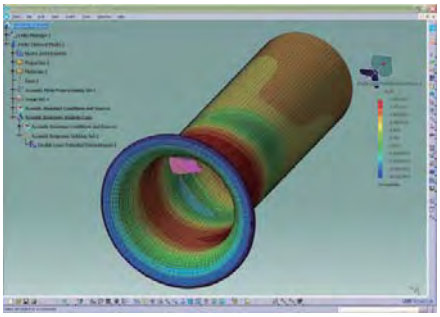


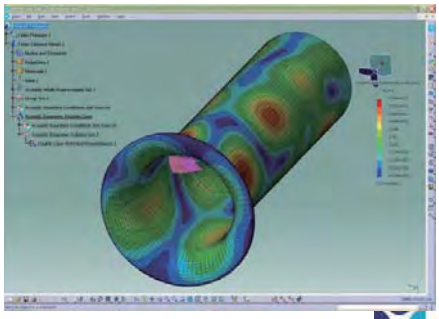
Electrical Motor Cooling Noise



Electrical Motor Cooling Noise







Electrical Motor Electro-Magnetic Noise

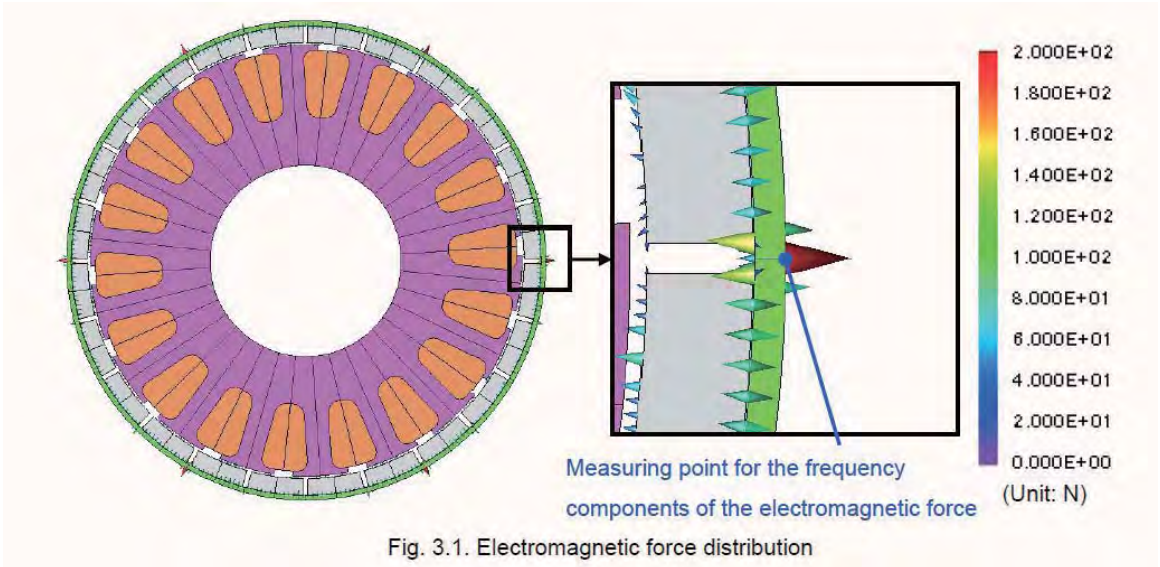
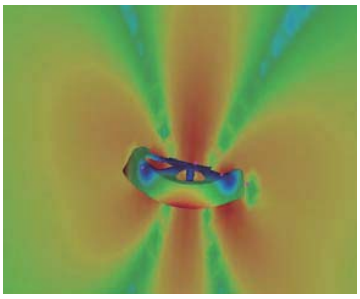


Fig. 3.1. Electromagnetic force distribution

Picture from JSOL

Electrical Motor EM noise

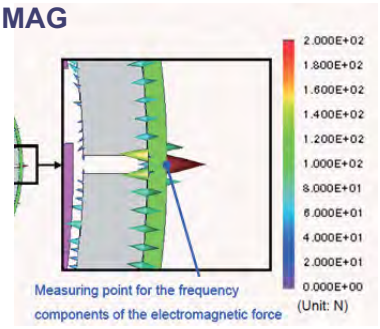
JMAG: Excitation force



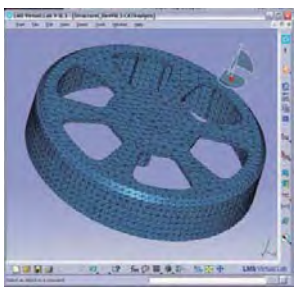
LMS Virtual.Lab: Noise Prediction

Electrical Motor EM noise
JMAG – Virtual.Lab Interface

JMAG



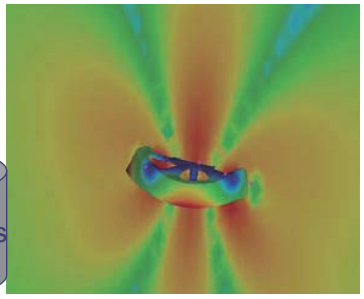
LMS Virtual.Lab



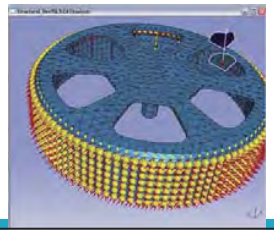
Force mapping tool:
-Time to frequency
-Extrusion
-Geometric mapping

Forces

LMS Virtual.Lab

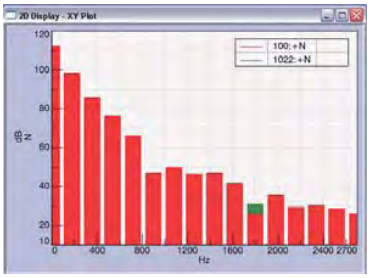


Mesh

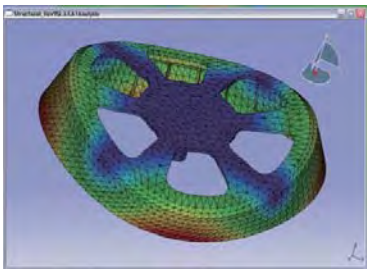


Electrical Motor EM noise
Noise evaluation

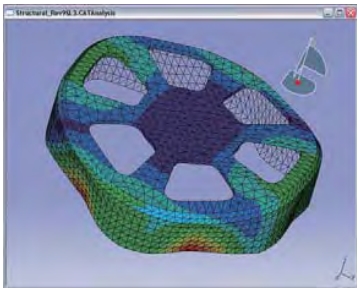
Forces as function of frequency for all surface points

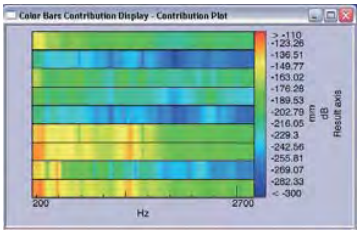


Eigenmodes for the structure

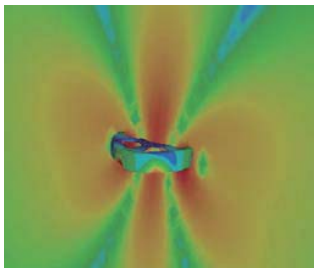


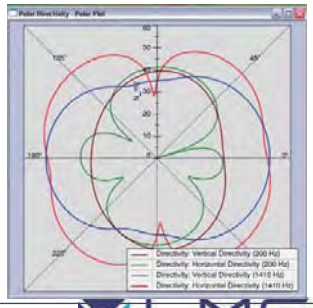
Vibration of structure



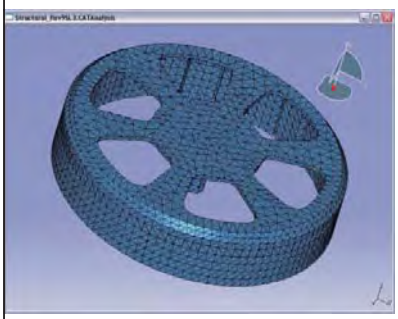


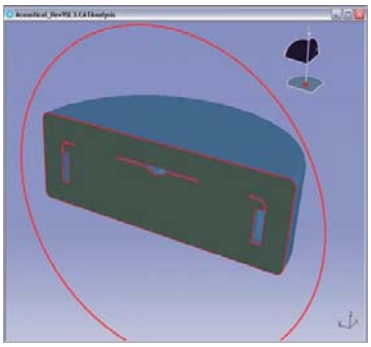
Noise from structure

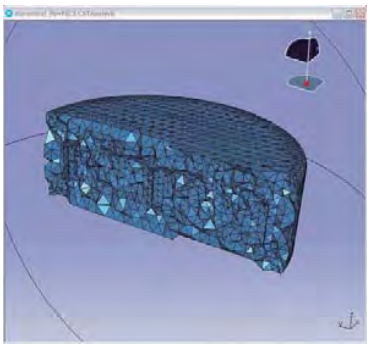




Electrical Motor EM noise
Acoustic model

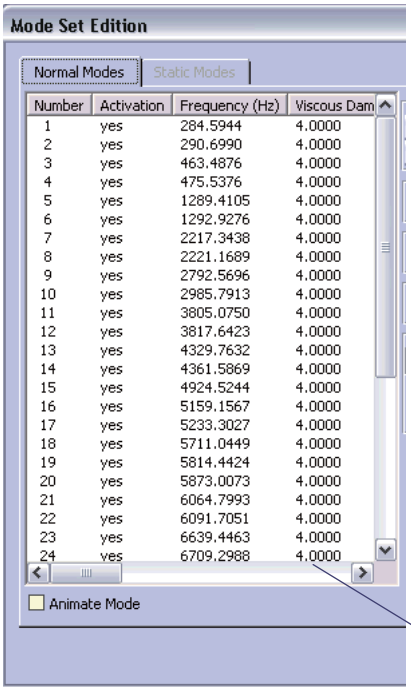


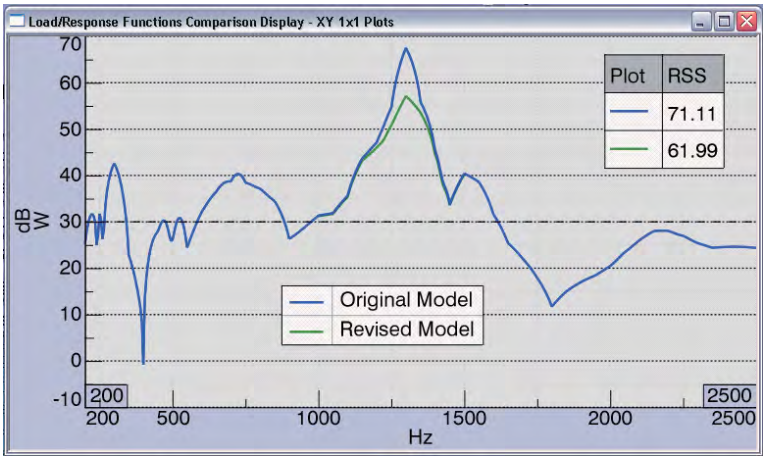




FEM Acoustics model	
Valid up to:	3000 Hz
# nodes	17 600
# elements	88 000 TETRA
HW	4CORE Win64
Calculation time	12 sec / frequency

Electrical Motor EM noise
Refining the system

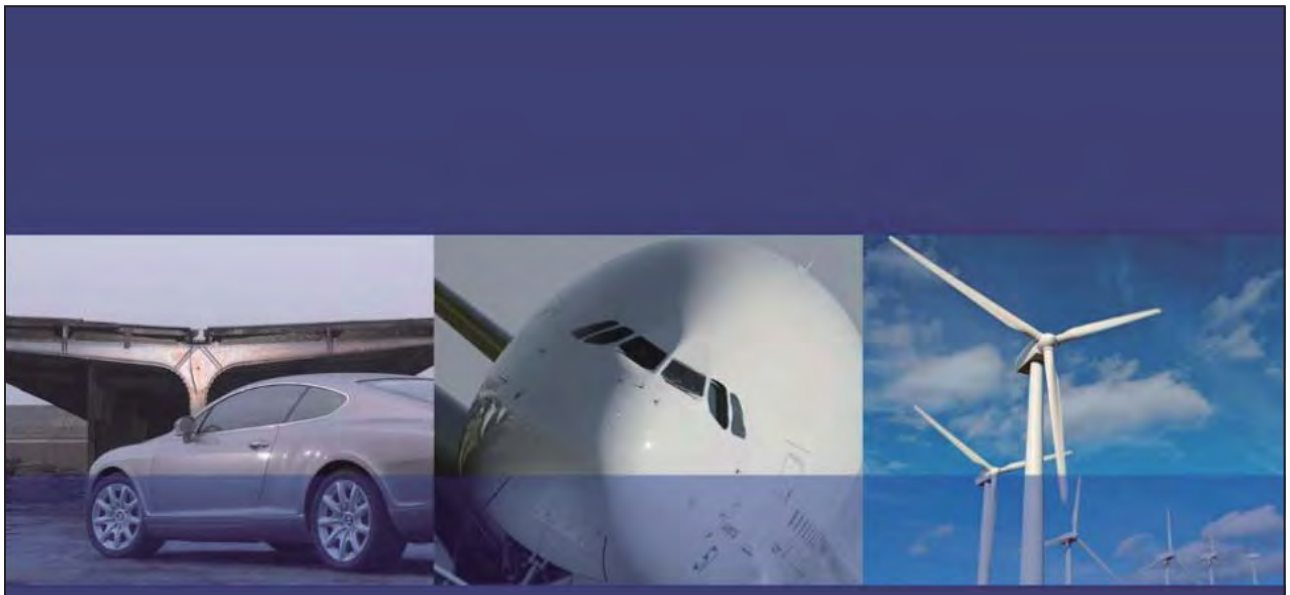




4% viscous damping

Summary

- Virtual.Lab Acoustics allows to address N&V of electrical motors:
  - Mechanical noise: unbalances,…
  - Aerodynamic noise: cooling fan,..
  - Electro-magnetic noise
- For Electro-magnetic noise: JSOL and LMS signed agreement for exploiting synergies between JMAG and Virtual.Lab
  - The interface is available and will be further enhanced



LMS Virtual.Lab Rev 10

Realistic Solutions to Industrial Problems by Efficient Modeling and Fast Solving

Dr. Koen De Langhe
JMAG Users Conference – Tokyo December 2010

LMS ENGINEERING INNOVATION