Live webinar

Address NVH Engineering issues of Hybrid and Electric Vehicles

Wednesday February 28, 2018

Electrification is here to stay

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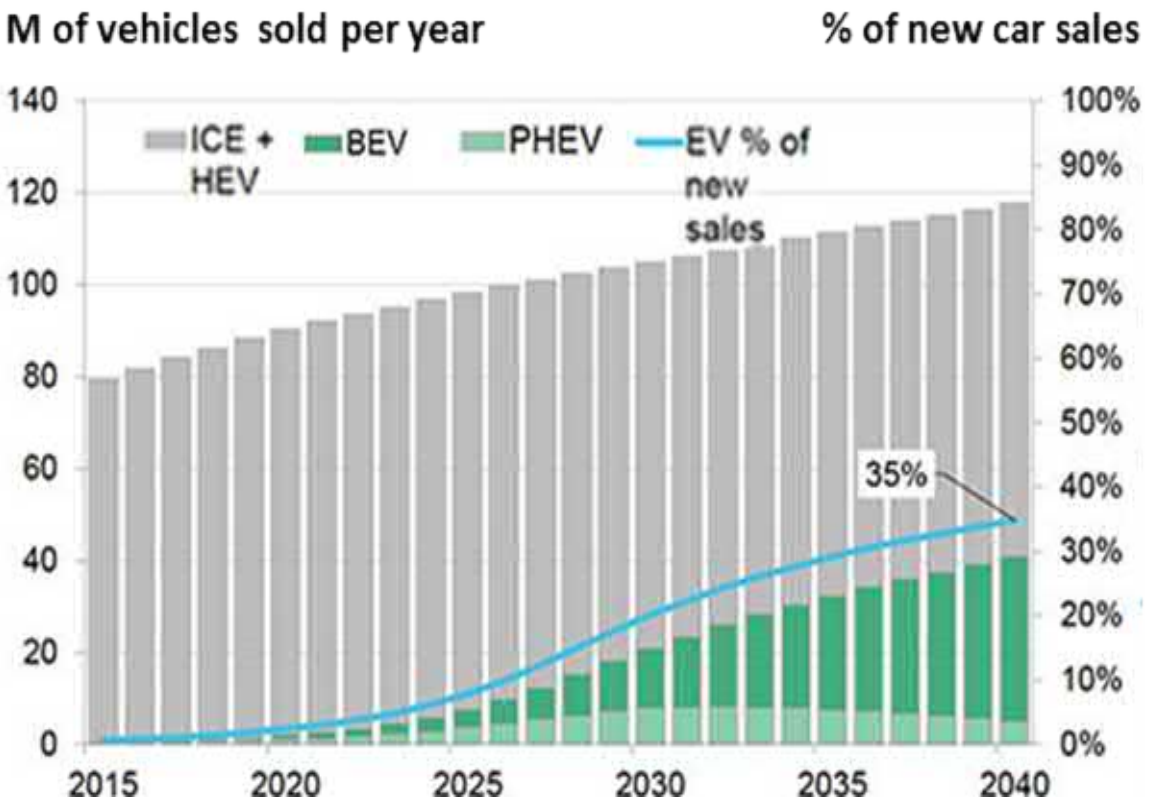
Hybrid and electric vehicles share could range from 10-50% of new vehicle sold in 2030

Source: Bloomberg New Energy Finance



Electrification
Trends & Engineering implications

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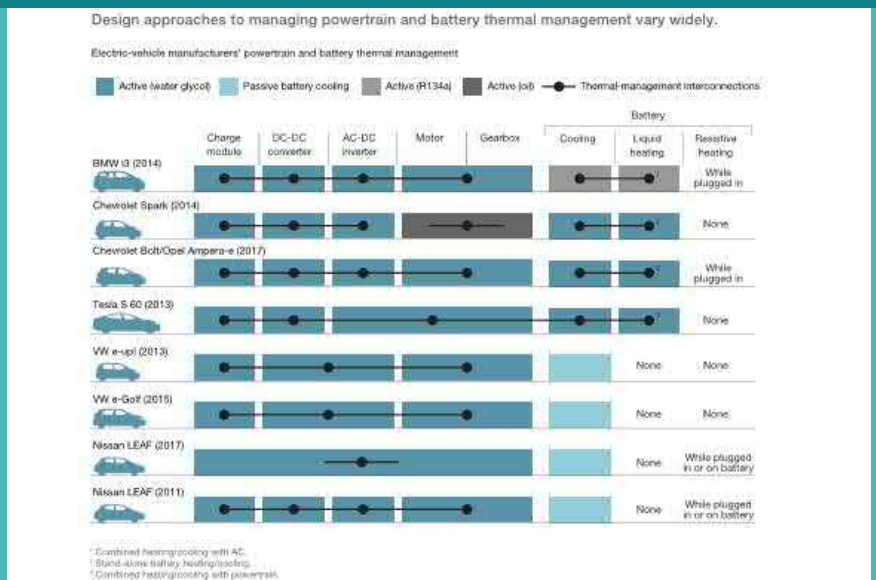
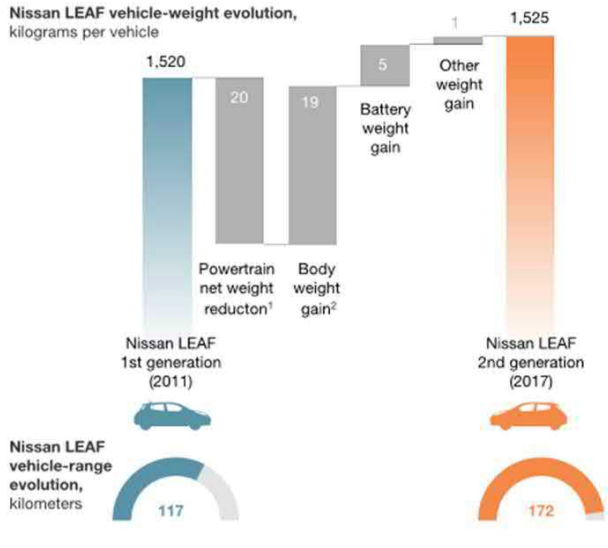
No convergence yet on battery, cells and thermal management system



… Many architectures possible with optimal trade-off cost/performance required

Weight reduction an important design driver for range



… yet cost of weight reduction plays important role

Source : McKinsey – Trends in Electric Vehicle Design

Electrified Powertrain
Solution areas

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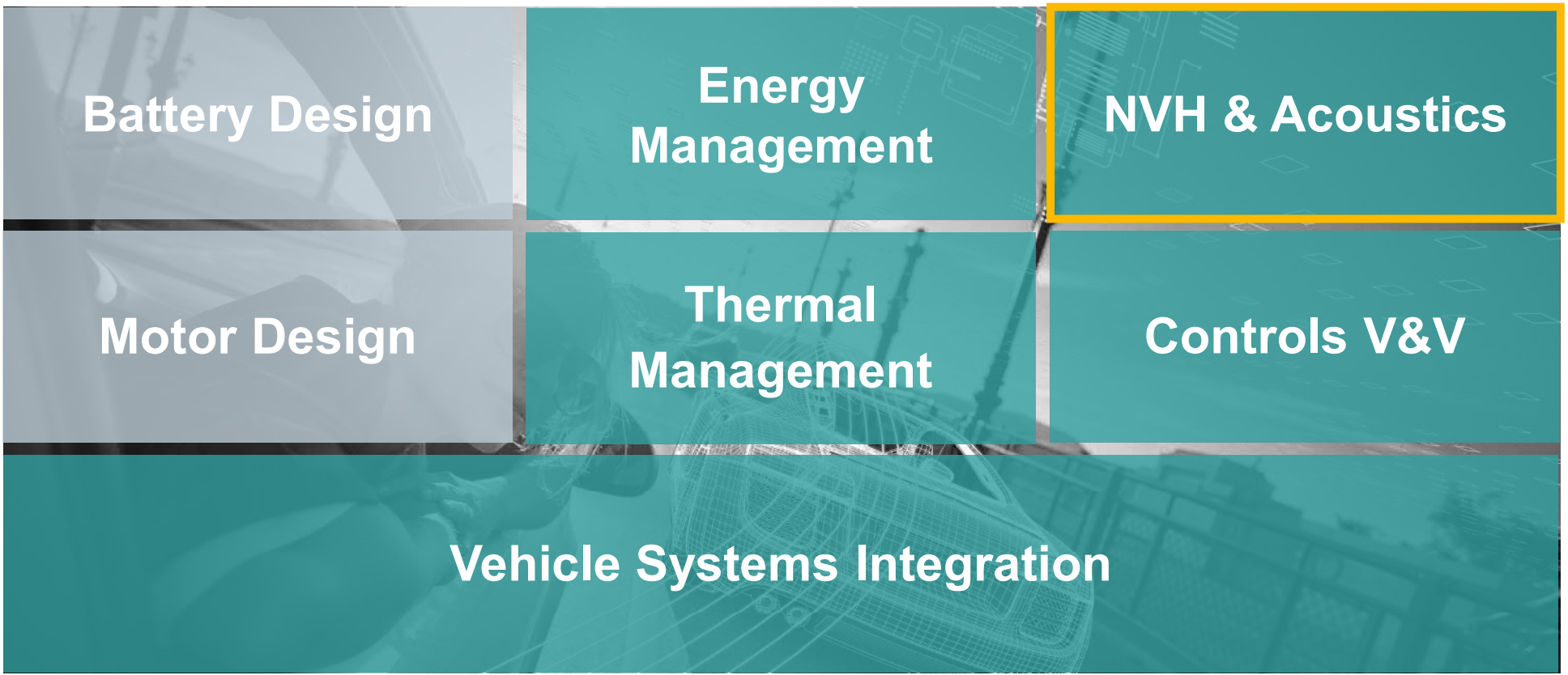

Shifting focus in NVH development effort

From powertrain towards road noise and aero-acoustic noise reduction

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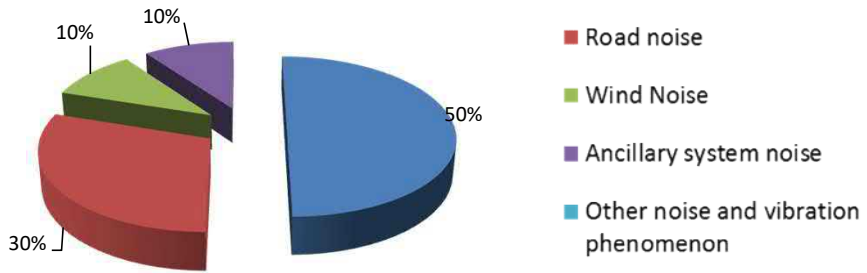
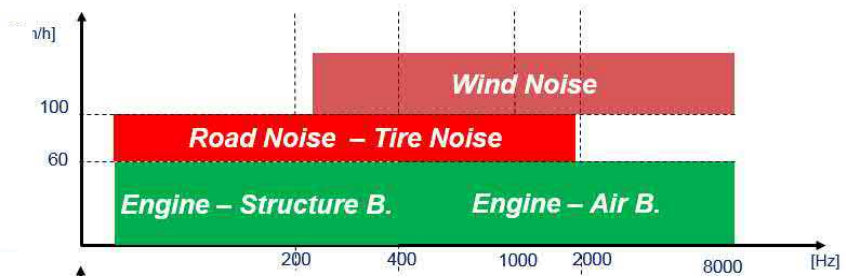
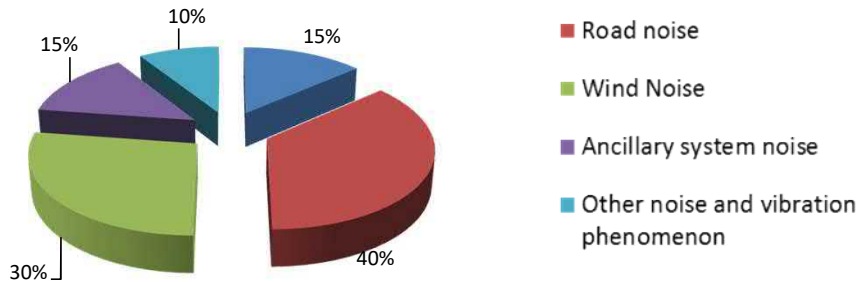
ICE vehicle



Source: Leading the Charge – The Future of Electric Vehicle Noise Control
Greg Goetchius, Sound & Vibration, April 2011



Electric Vehicle



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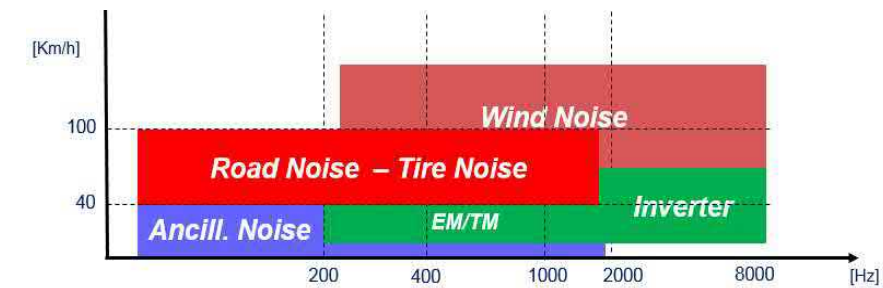

Vehicle NVH & Acoustic Innovation Area

Electric and hybrid electric vehicles – Challenges

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Electric motor

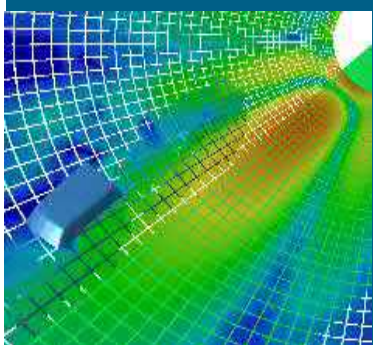
Wind Noise

Road Noise

Other,

HVAC, battery cooling, steering systems, …

Warning sounds



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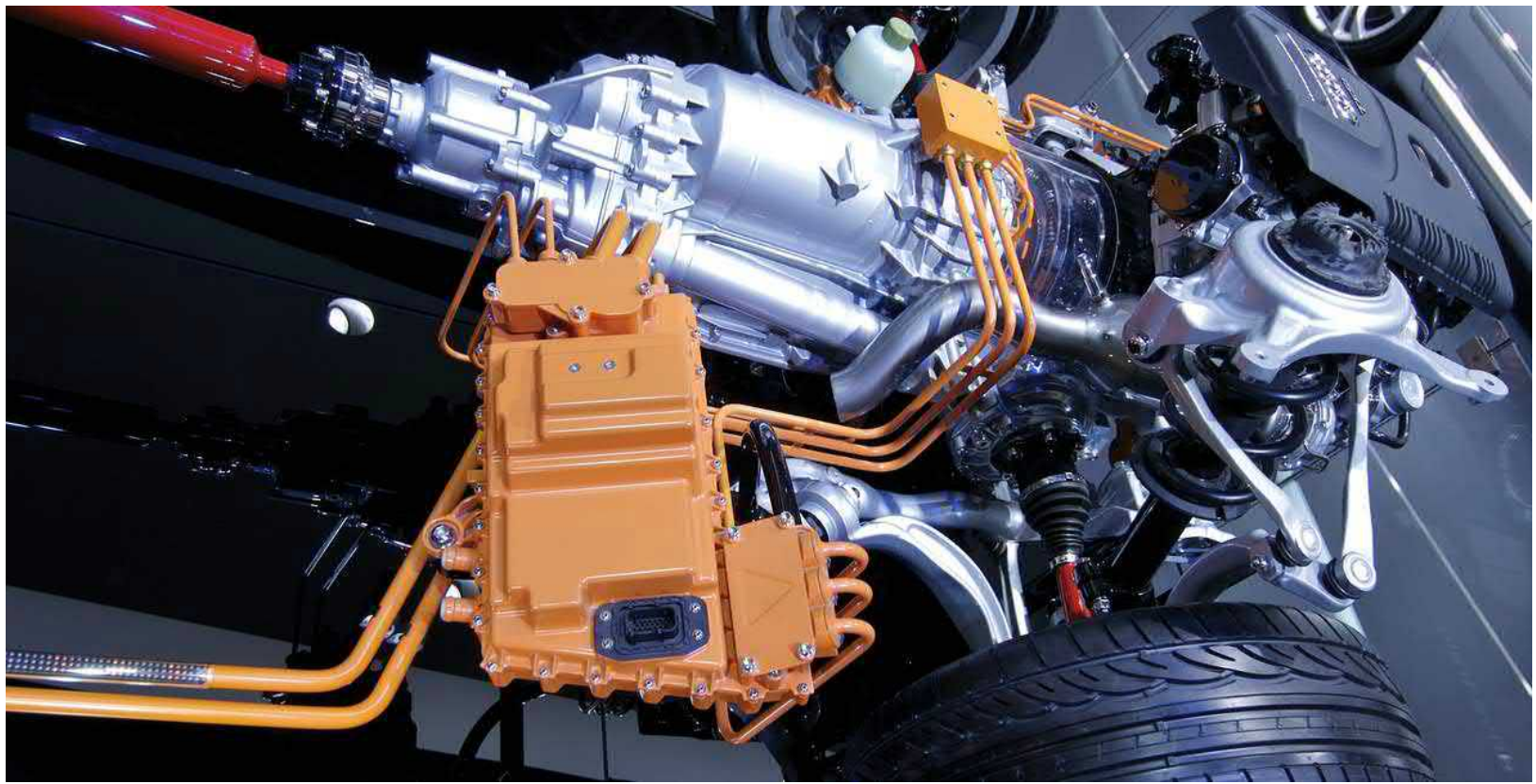
Electric motor

Sound levels may be lower but the high frequency tonal components make them quite annoying



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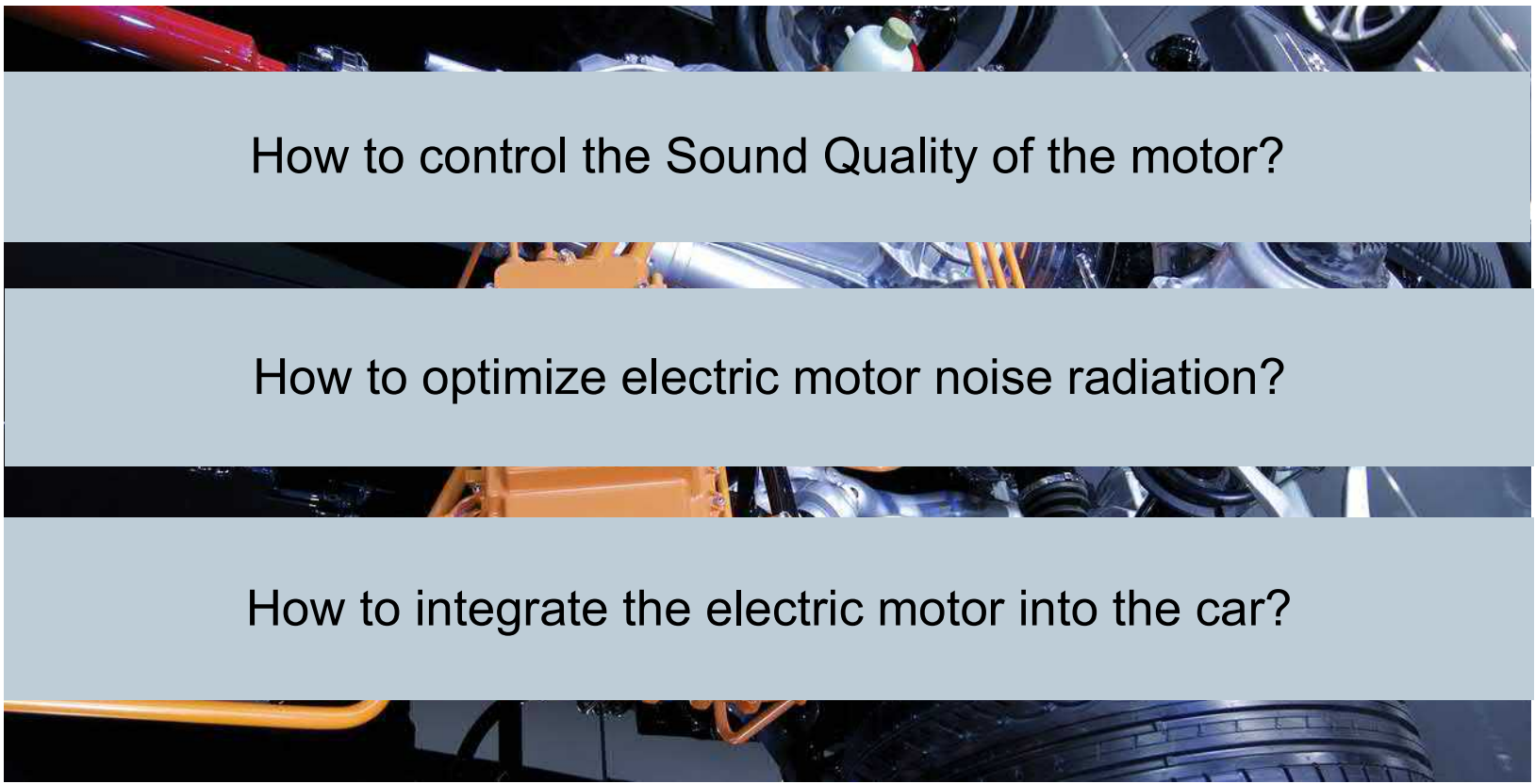

How to control the Sound Quality of the motor?

How to optimize electric motor noise radiation?

How to integrate the electric motor into the car?

What is Sound Quality?

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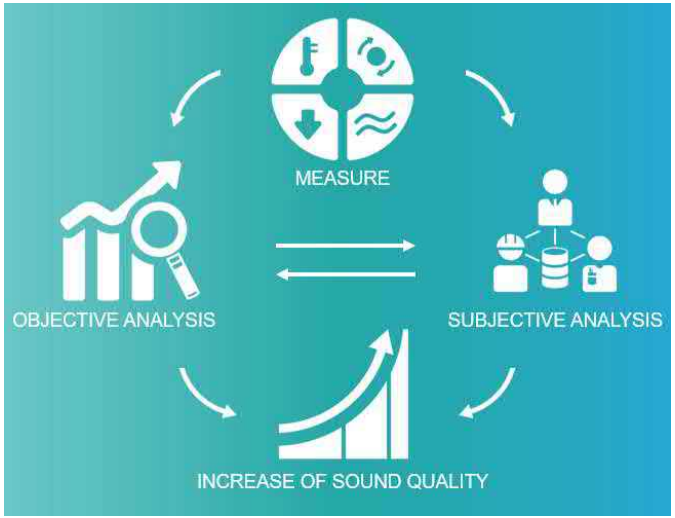
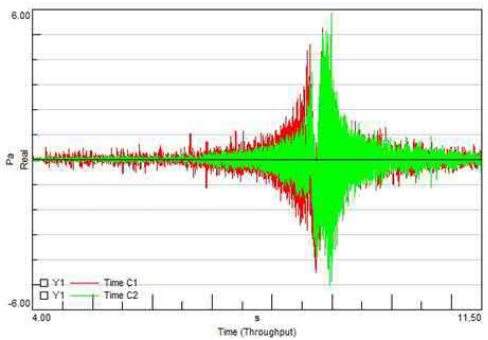


Objective assessment

Analyze your sound with measures that can be quantified

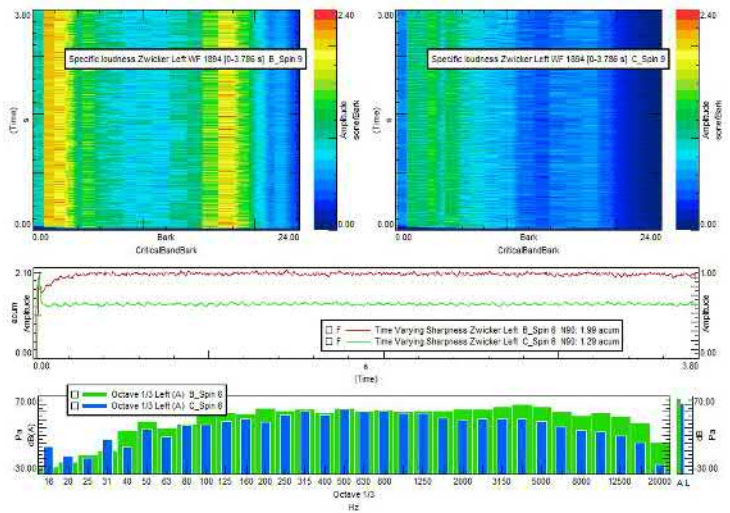


Subjective assessment

Study the *perception* of the sound

What are the positive and negative contributors to your products sound

Psychoacoustics is the science of sound perception. It studies the psychological and physiological responses associated with sound



Benchmarking & Target Setting
Interior noise replay, overall levels, sound quality metrics

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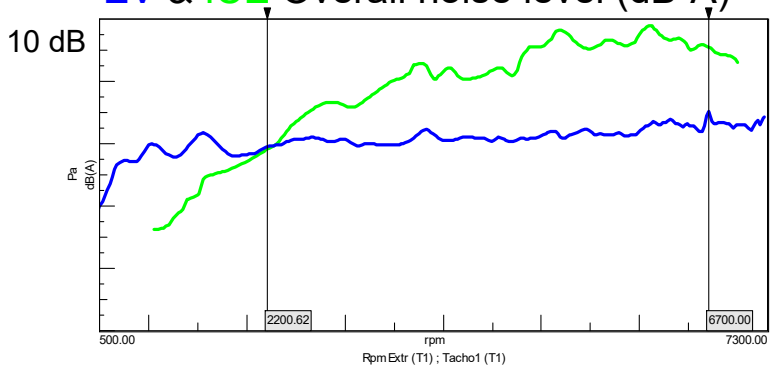
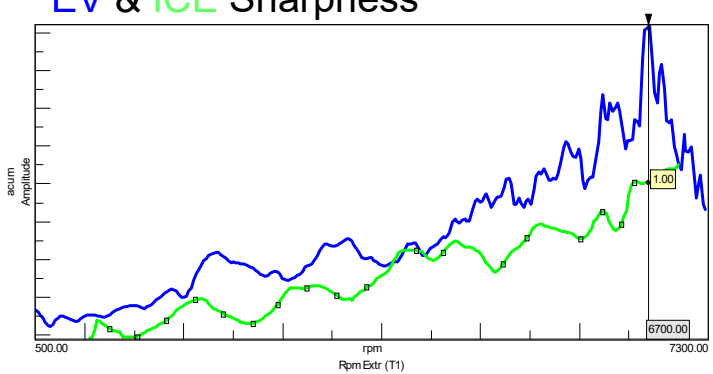
EV & ICE Overall noise level (dB-A)



EV & ICE Sharpness



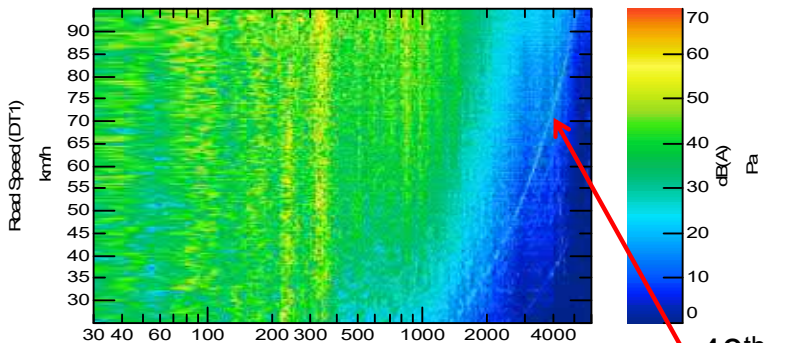
Objective assessment

Analyze your sound with measures that can be quantified

ICE

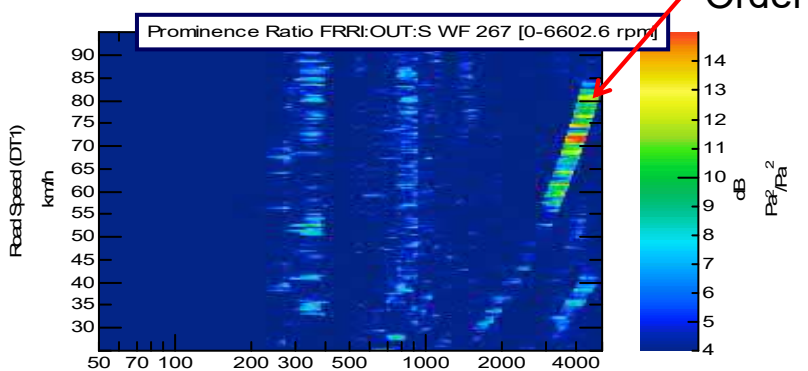
EV

EV - Sound Pressure Level



48th Order

EV - Prominence Ratio



Sound Quality - Subjective Analysis - Jury Testing

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SUBJECTIVE ANALYSIS

- Gather subjective opinions on your product
- Benchmark competition
- Consistency and statistical analysis
- Automated reporting

Understand the *expectations* of your customers and design the product that *exceeds* them

Listening tests

NVH & Acoustic solution areas
Electric and hybrid electric vehicles

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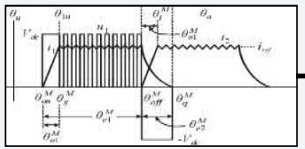
Design space

Motor Design

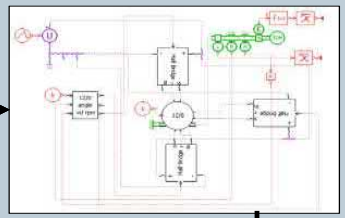
Electric Design

Controls Design

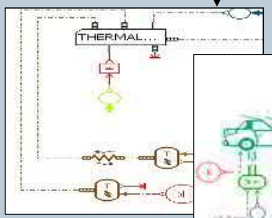


1D Simulation

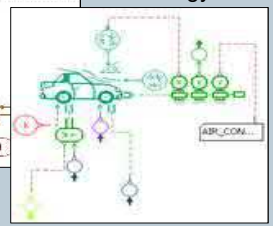
Functional Motor Model



Thermal Model

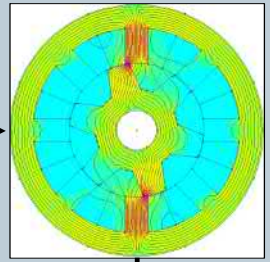


Vehicle Energy Model



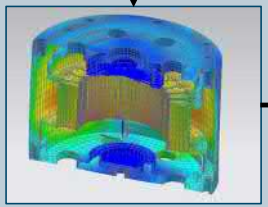
Electric system models including controls and extendable to thermal and energy management

3D Simulation



Electro-Magnetic simulation

Vibro-Acoustic Model



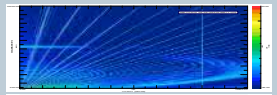
Vibro-acoustic models based on electro-magnetic loads calculation

Test

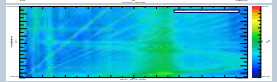
Full vehicle diagnostics

Acoustic characterization

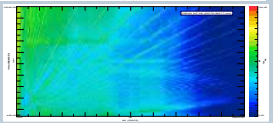
Phase current



Acceleration



Sound



From sub-system characterization to full vehicle diagnostics using TPA, ODS, OMA,…

Electric Motor Noise Radiation Optimization
Punch Powertrain cut time-to-market by factor 2

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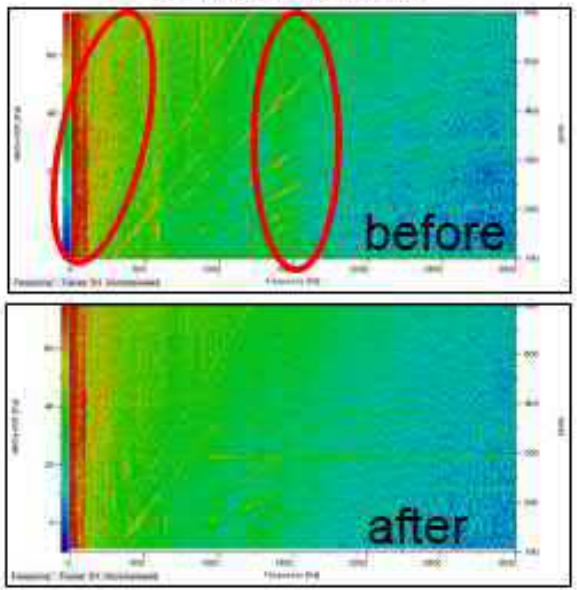
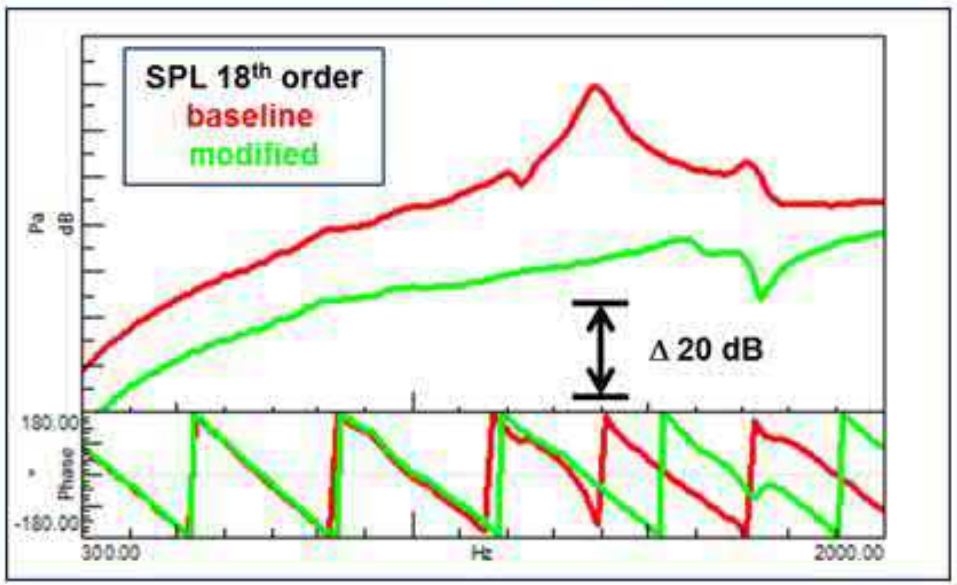
Effect of Optimized
Control Strategy



Effect of
Structural Modifications



"Thanks to Simcenter Engineering services and the optimization process they used with Simcenter 3D software, we are now working on a new generation of commercially competitive switched reluctance motors for automotive propulsion."

Diederik Brems, Mechanical Engineer

Hybrid and electric drives call for new testing and analysis techniques

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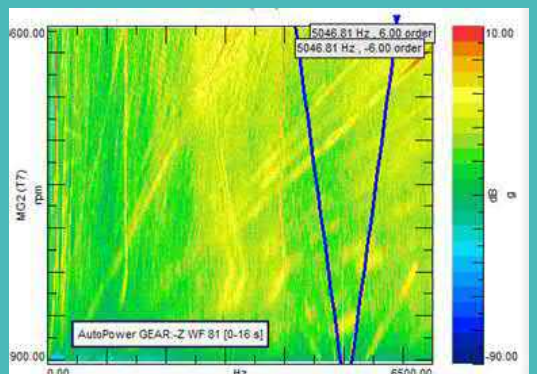
Support to handle new sound signature



- Support high-frequent off-zero orders coming from power electronics
- Support to switch RPM axis between different shafts (for HEV)

Support of new sensors

e.g. ability to derive rotational speed from available resolver

- Reuse resolver that is already present at electric motor
- Derive rotational speed and shaft position from electric motor without any additional sensors

Handling new important noise sources

- Gear whine analysis
- Battery cooling system noise
- Electric Motor TPA analysis
- …

Investigation of electrical motor noise
Source-Transfer-Receiver methodology

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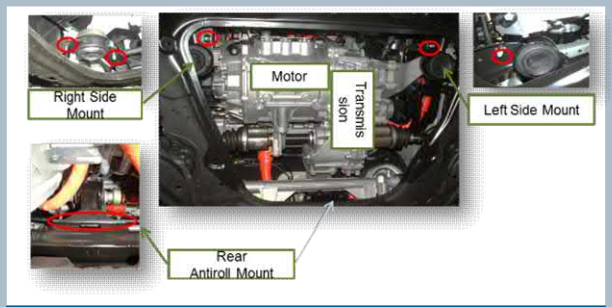
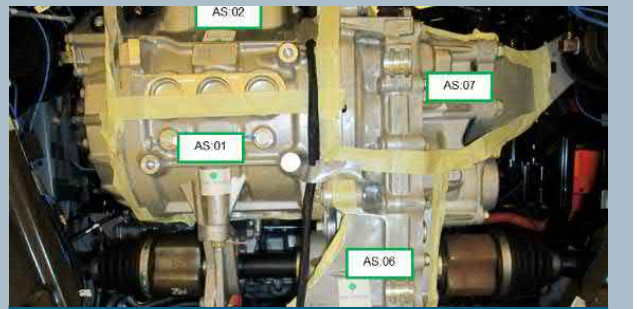
- **Traditional TPA technology applied to electric vehicles**
- **Identification of major noise contributors up to high frequency (up to 100th engine order)**
- **Electro-magnetic forces, gear whine and PWM switching as noise generating mechanisms**

Applying TPA and ASQ methodologies on an electric vehicle



Structure borne TPA



Airborne TPA

Investigation of airborne and structure borne source contributions from the powertrain to the interior by applying common TPA technologies .

Traditional TPA methodologies prove well capable of investigating high frequency noise content as seen in electric vehicles if measurements and analysis are done with appropriate care.

Vehicle NVH & Acoustic Innovation Area

Electric and hybrid electric vehicles – Applications

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Electric motor

Analyze sound quality

Simulate and/or test electric motor noise from current to ear

Integrate the electric powertrain into vehicle

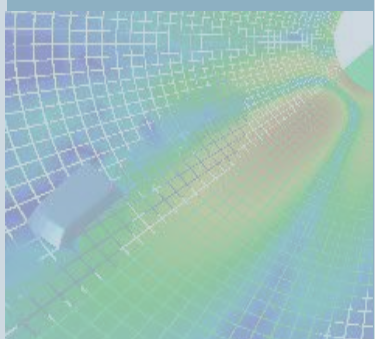
Wind Noise

Road Noise

Other,

HVAC, battery cooling, steering systems, …

Warning sounds



Vehicle NVH & Acoustic Innovation Area

Electric and hybrid electric vehicles – Challenge

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Wind Noise

Lower powertrain noise lets wind noise become apparent from lower speeds

This results in new investments in Aero-acoustic testing

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Challenges:

- Increase further the return out of each test
- Get more work done in the wind tunnel
- Reduce the number of iterations and modifications made to the vehicle

Layout example of next generation aero-acoustic wind tunnel

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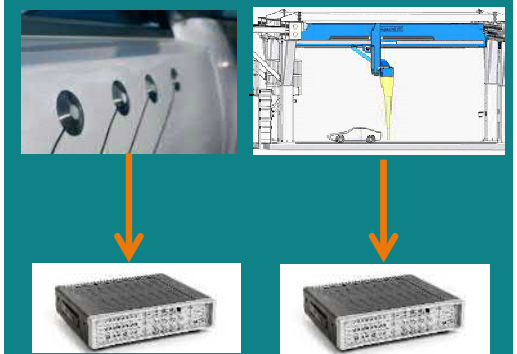
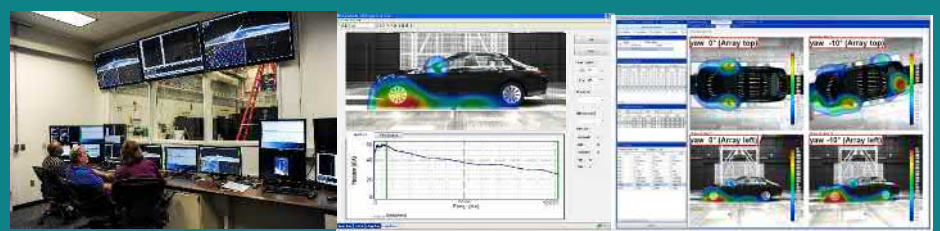
In vehicle

Turntable & Traverse



4 exterior Arrays

Wind tunnel control room



Online and offline Analysis system

- Integrated with wind tunnel controller
- Automatic processing
- View & analyze processed results in 10 seconds
- Data management

Wind noise simulation offering in Simcenter

Combined expertise on flow and acoustics

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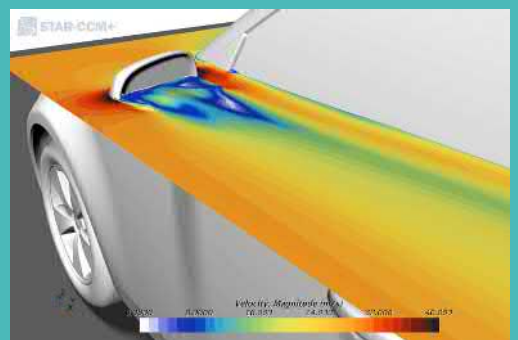
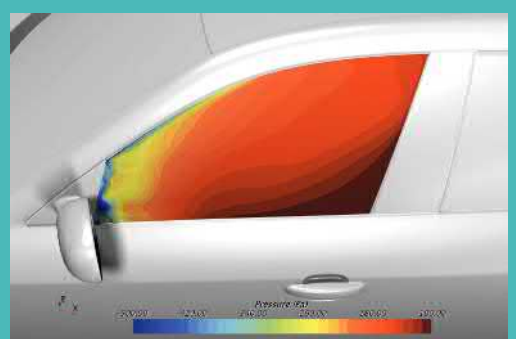
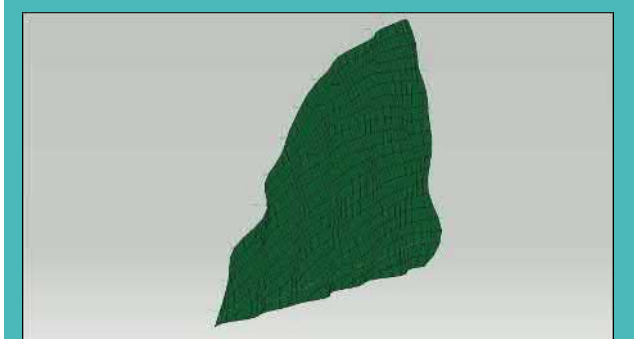
Source

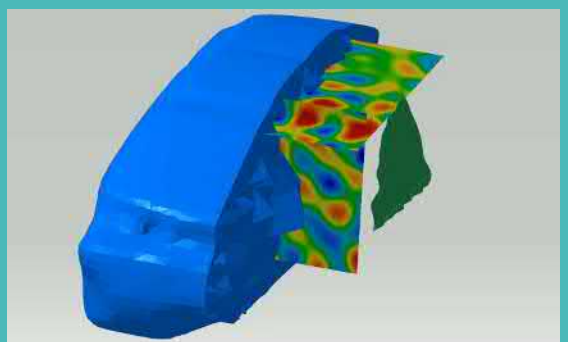


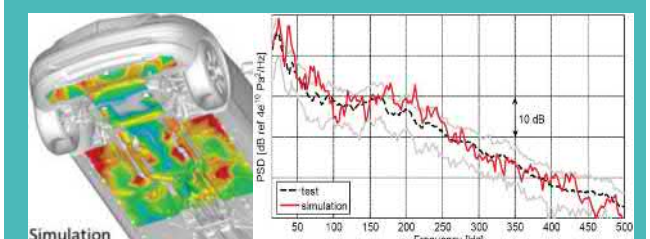


Transfer



Receiver





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Test or Simulation?

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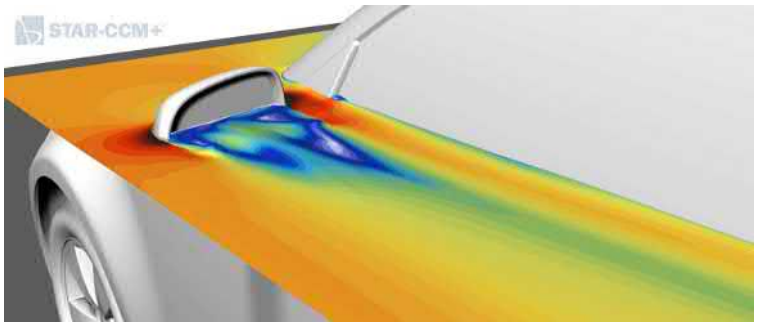
Test:

+ Testing 100's of configurations/campaign
+ Results in few seconds
+ Any frequency range
– Only once prototype available
– Expensive



Simulation

+ Early predictions
+ Without expensive wind tunnel
– 1 week to finish one simulation
– Challenging for high frequencies

INCREASE EFFECIENCY & EFFECTIVENESS by combining TEST & SIMULATION:

- Use more and more simulation to simulate before prototypes
- Reduce pressure on testing time in wind tunnel by reduction of prototypes thanks to simulation
- When you test, highly increase the outcome

Vehicle NVH & Acoustic Innovation Area

Electric and hybrid electric vehicles – Applications

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Electric motor

Analyze sound quality

Simulate and/or test electric motor noise from current to ear

Integrate the electric powertrain into vehicle

Wind Noise

Test the right thing in an efficient way

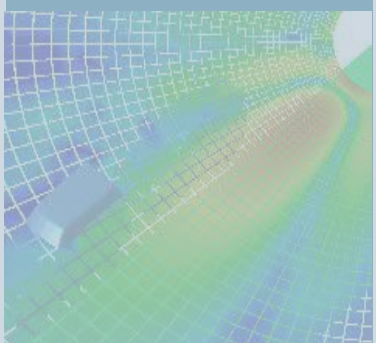
Simulate as much as you can prior to prototypes

Road Noise

Other,

HVAC, battery cooling, steering systems, …

Warning sounds



Vehicle NVH & Acoustic Innovation Area

Electric and hybrid electric vehicles – Challenge

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Road Noise

Less masking and low rolling resistance tires make road noise more important

Road and Tire noise

Types of noise resulting in exterior and interior noise

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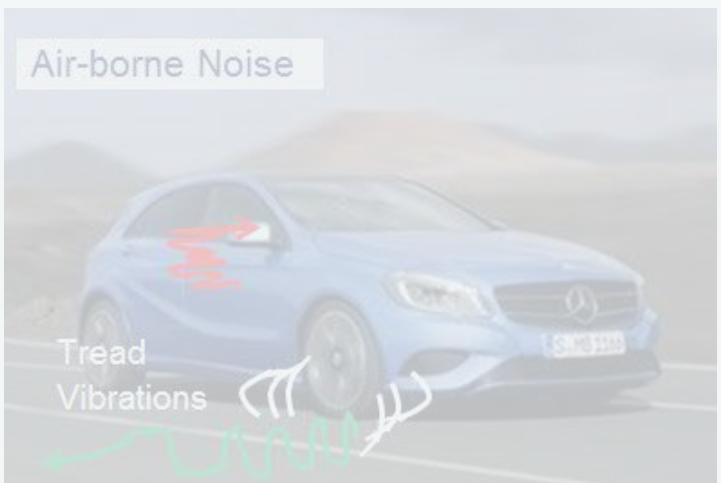
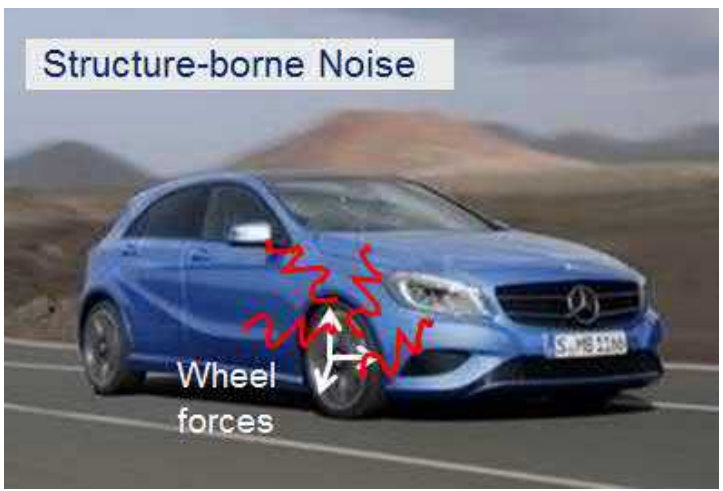
TIRE NOISE = airborne

Originates from tire surface vibrations
and aeroacoustic events



ROAD NOISE = structure borne

Originates from tire patch forces
→ wheel hub → car body → **occupants ears/passenger compartment**



Road and Tire noise

Lower road noise levels by combining test and simulation

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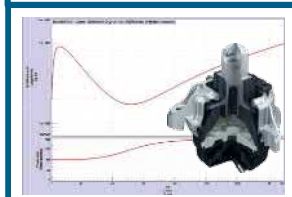
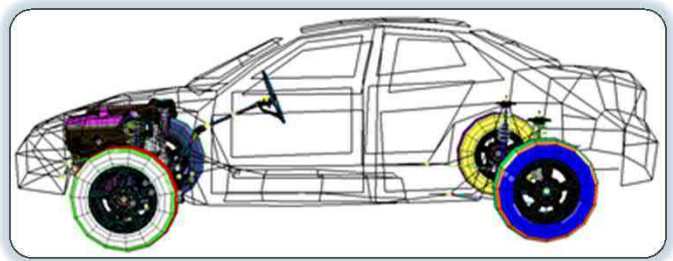
Test models
Body, Tire



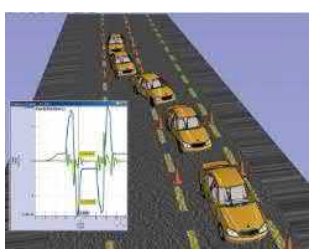
FE/Test
Mount
description

FE model for subframe

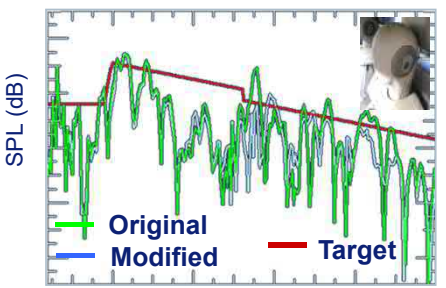
Test/FE model
(solved in NX Nastran)

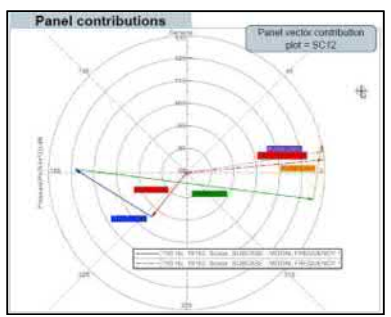


Operational Forces from
Test or **Simulation**



Minimize SPL by
optimizing mounts, sub-systems &interaction





Fiat Group Automobiles SpA

Delivering extraordinary NVH performance across product lines

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Ingenuity for life

- **Optimized design validation with minimal errors**
- **Achieved all NVH performance targets**
- **Now delivering solutions to road noise problems in days instead of weeks**

Eliminating annoying road noise

Road noise transfer path analysis

Competition creates the need for much shorter timeframes

- Use Simcenter simulation and testing solutions to deliver a robust, virtual validation process and develop the best-in-class NVH performance

“ All Simcenter solutions help us prove that our NVH performance is solid in regards to the chassis and underbody. This is a clear benefit if you look at the number of variations we do.”

Roberto Mangiantini, NVH Manager for Vehicle Concepts and Integration

Vehicle NVH & Acoustic Innovation Area

Electric and hybrid electric vehicles – Applications

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Electric motor

Analyze sound quality

Simulate and/or test electric motor noise from current to ear

Integrate the electric powertrain into vehicle

Wind Noise

Test the right thing in an efficient way

Simulate as much as you can prior to prototypes

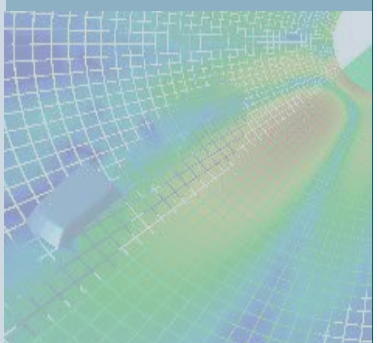
Road Noise

Identify the root causes and verify chassis and body modifications to increase passenger comfort

Other,

HVAC, battery cooling, steering systems, …

Warning sounds



Vehicle NVH & Acoustic Innovation Area

Electric and hybrid electric vehicles – Challenge

SIEMENS
Ingenuity for life

Other

‘New’ noise sources, such as HVAC, battery cooling, steering systems, wiper motors,… are more noticeable and pose a complex problem to solve

Mechatronic system integration
Example: Steering Systems

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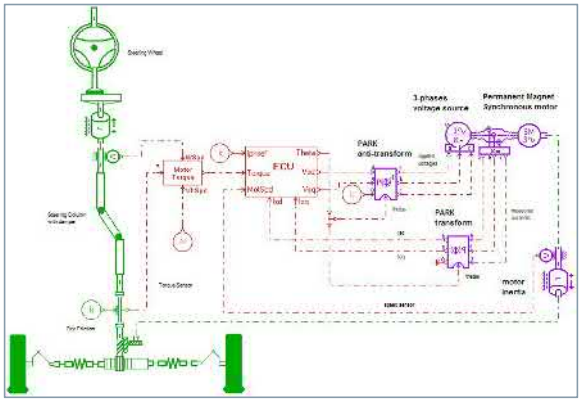

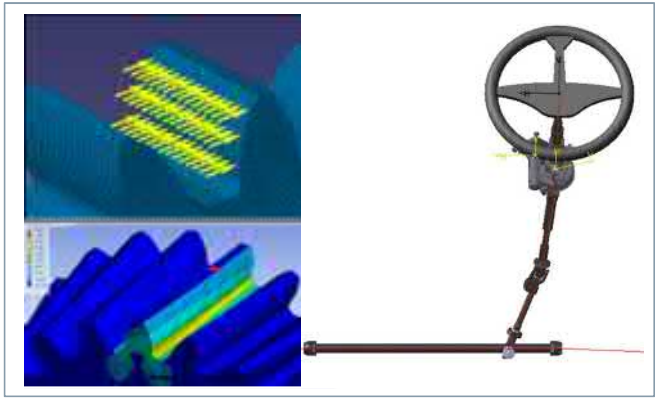

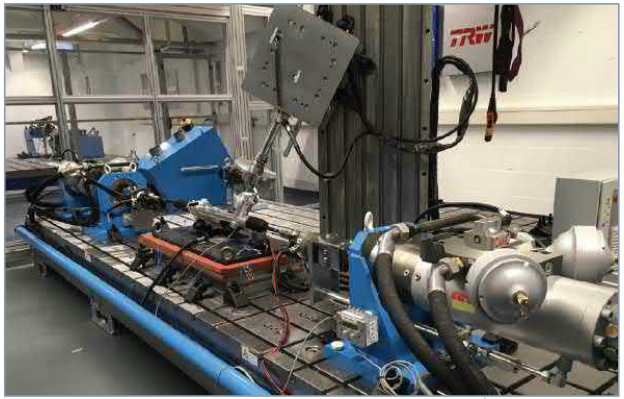

System level integration
Component Sizing
Controls integration

Detailed component models
1D and 3D simulation for NVH
and acoustic optimization

System validation
Test rig or full vehicle testing

Multi-domain engineering supporting all aspects of development

ZF TRW

Positioning steering systems NVH at the front of the development cycle

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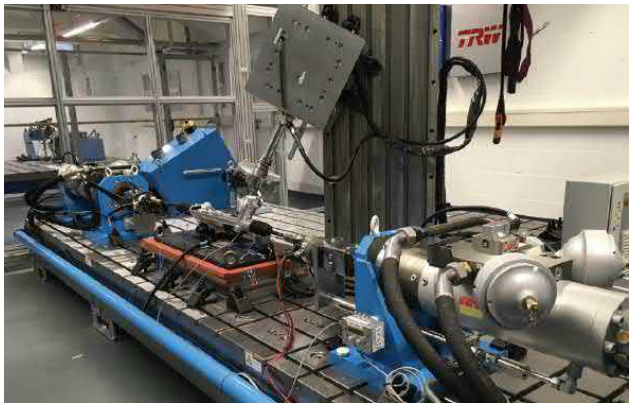
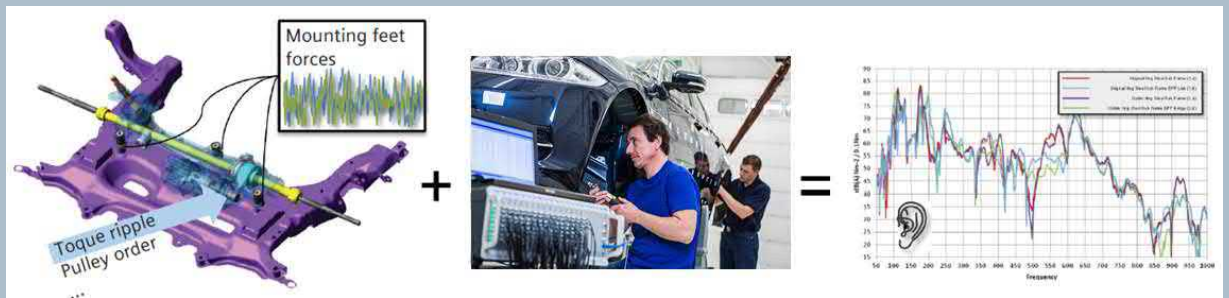


- **Reduced overall resources to solve NVH-related issues**
- **Accurately estimated resources for NVH resolution upfront**
- **Received positive feedback from customers, who appreciate the output data as well as the approach used to gather it**

Development of the world's first NVH steering system bench



Developing a powerful partnership

- Translate NVH recommendations into real and objective requirements and targets
- Integrate test and simulation to determine and resolve the root causes of problems

"We can establish exactly how much force we are allowed to introduce to a particular car to stay below a given NVH target, and we find that our customers appreciate this approach a lot."

Christian Landsberg, Global Chief Engineer NVH

HVAC Noise

Optimizing driver comfort in terms of climate control and acoustics

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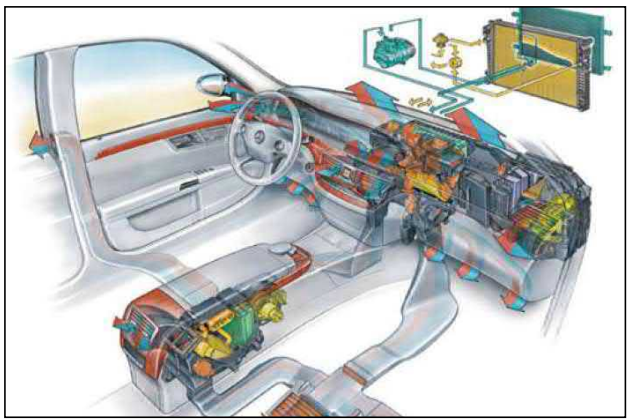


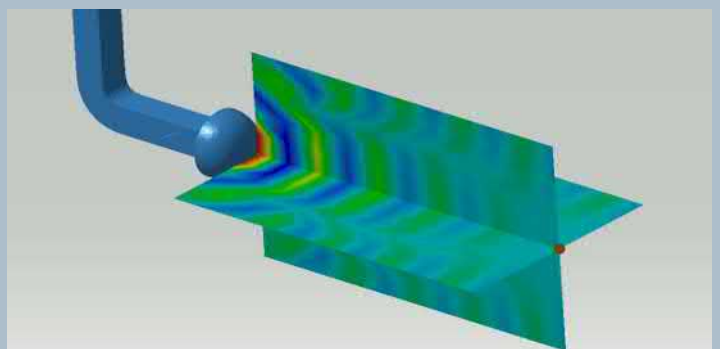
- Obtain accurate noise sources using CFD, focusing on the flow problem
- Switch to Acoustic FEM for fast prediction of the noise propagation part

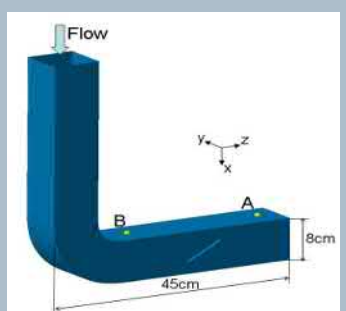
Fast and precise HVAC noise simulation: hybrid CFD - Acoustic FEM

Acoustic Response matching Experiments Simcenter 3D Acoustics

Flow Results ➔ Acoustic Sources Simcenter 3D Acoustics

Flow Simulation - CFD StarCCM+





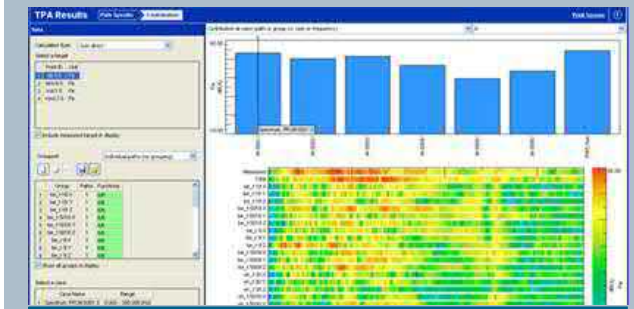
Denso

Releasing products 3 times faster by using Simcenter Engineering services

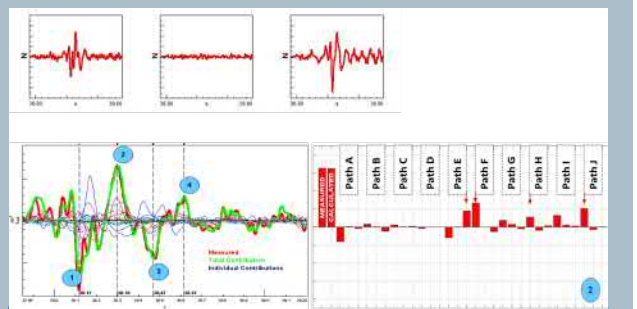
SIEMENS Ingenuity for life

- **Released products 3 times faster than previously possible**
- **Reduced time it took to measure TPA by 70 percent**
- **Enhanced collaboration with OEMs**

Quantify noise transfer paths in a shorter time



Speeding the release of products



Close cooperation enhances results

- Develop new approach in close cooperation with Simcenter Engineering services
- Deploy LMS testing methods & tools into Denso's HVAC system development process

"OEMs are really satisfied with the input that we deliver using Simcenter tools. Thanks to the Simcenter solutions, we are able to release our new products three times faster than was previously the case."

Tomohiro Sudo, Assistant Project Manager NVH

Battery Cooling NVH

Validate modifications to unit design w/o need for full vehicle validation

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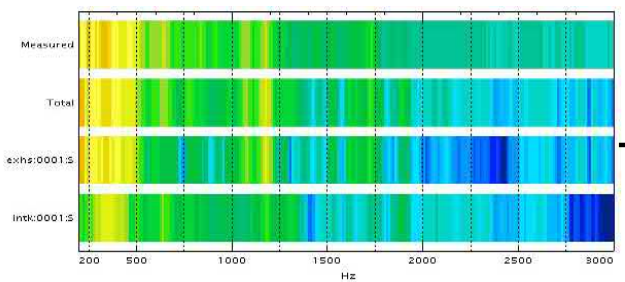
Modification at unit projected to in-vehicle

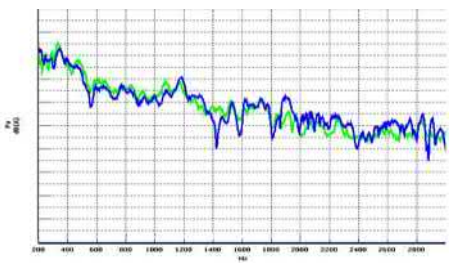
SOURCE
Inlet & outlet ducts located in cabin interior

Transfer
Measured FRF's between sources and cabin microphones

RECEIVER
Cabin sound pressure level



Solution:
In vehicle near field sound pressure levels accurately calculated and correlated from unit level source measurement using Airborne Source Quantification Method



Predict the likely effect on cabin sound pressure levels due to modifications of the battery cooling unit ducts without in-vehicle testing

Vehicle NVH & Acoustic Innovation Area

Electric and hybrid electric vehicles – Applications

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Electric motor

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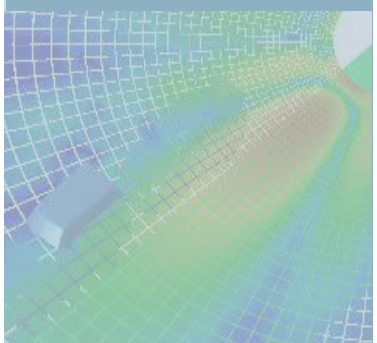
Identify the root causes and verify chassis and body modifications to increase passenger comfort

Other

Take control of the variety of 'new' noise sources, such as HVAC, battery cooling, steering systems, wiper motors,… that would have gone unnoticed in the past

Warning sounds



Vehicle NVH & Acoustic Innovation Area

Electric and hybrid electric vehicles – Challenge

SIEMENS
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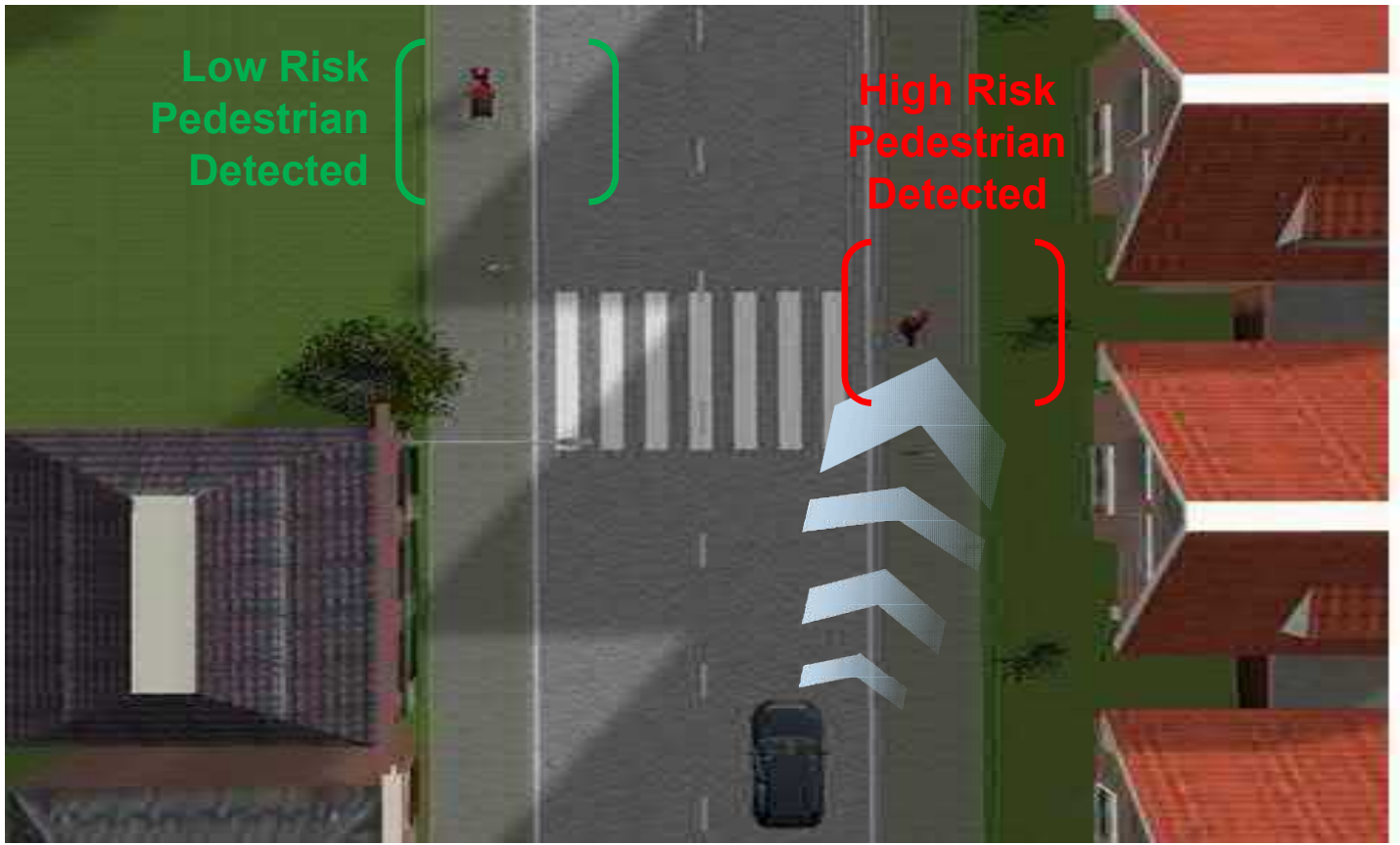
Warning sounds

Legislation is either already in place or is at least soon to come in many regions to protect vulnerable road users from not noticing electric vehicles



Warning sounds
Minimum Noise requirements for EV & HEV

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UNECE suggests minimum noise requirements for silent vehicles

"The US has done some analysis and there is twice the likelihood of an accident under certain low speed scenarios with hybrid cars versus traditional ICE vehicle"

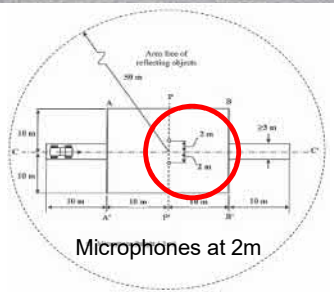
- Minimum noise major concern for **traffic safety**
- Measurement procedures defined in ISO16254 - SAE J2889-1
- US: effective September 2019
- EU: 5 years after final approval proposal of 2014 by member states

Warning sounds

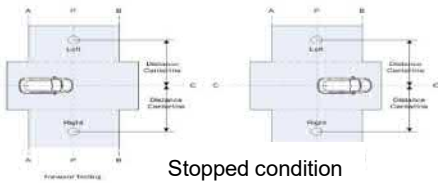
Pass the minimum pass-by noise threshold

Key messages:

- Minimum noise test procedure supported
- Required for homologation
- Test can be done both in-room or exterior

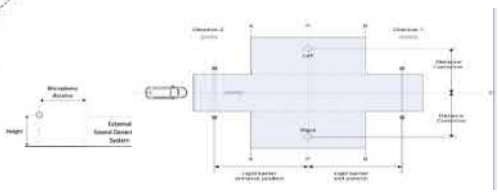


Microphones at 2m

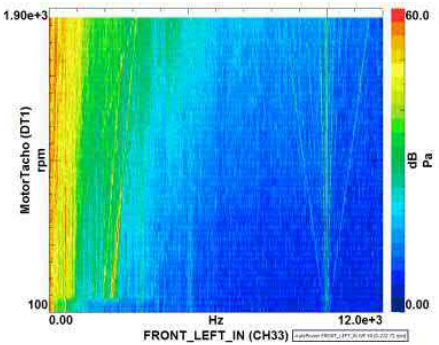


Stopped condition

Frequency shift



Slow speed cruise



eVADER
Studying the exterior sound of electric vehicles

SIEMENS
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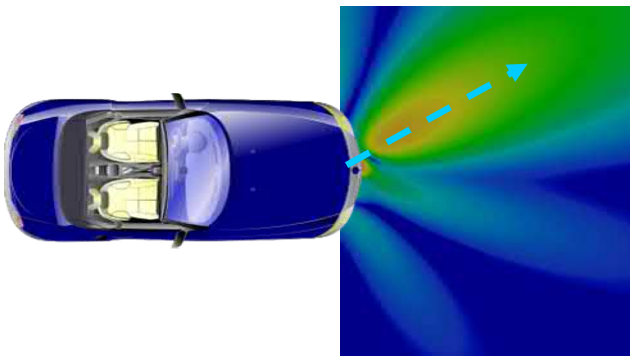
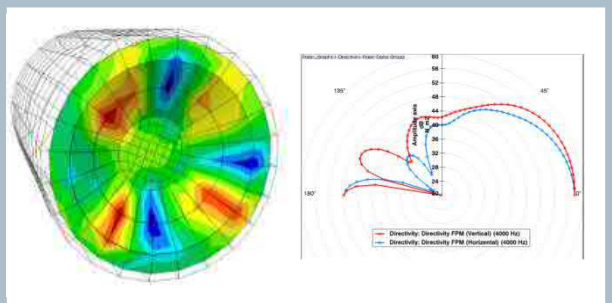
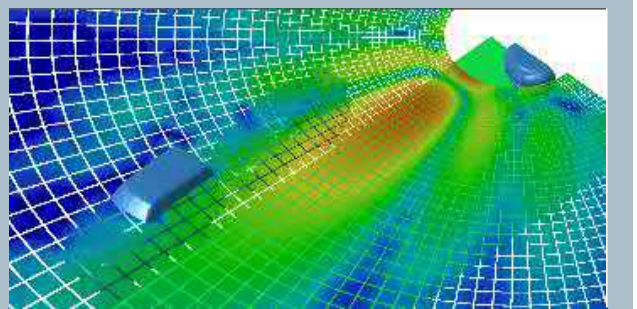


- **Simulate and study the detectability, annoyance and brand sound for sound system devices**
- **Balancing acoustic elements**

System engineering approach - Sound Synthesis & Propagation



Speaker directivity



Sound Reflection and Propagation

- Simulating emitted noise from a speaker array in the front bumper
- Directing the noise at pedestrians that may be in danger

European project to address the road safety concerns that pedestrians will have to face with the future marketing of electrical vehicles in Europe.

EC Project eVADER - SCP1-GA-2011-285095

Vehicle NVH & Acoustic Innovation Area

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Take control of the variety of 'new' noise sources, such as HVAC, battery cooling, steering systems, wiper motors,… that would have gone unnoticed in the past

Warning sounds

Simulate the noise generated by warning systems that are designed to protect pedestrians without creating noise pollution


For more information,
visit our website