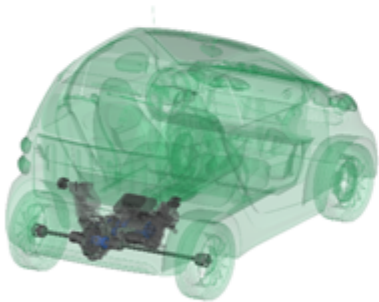


Drivetrain simulation for the assessment of the NVH-behavior of electric vehicles

Pascal Drichel, Mark Mueller-Giebeler, Markus Jäger
Joerg Berroth, Georg Jacobs, Kay Hamayer, Michael Vorländer
Simpack 4th Wind & Drivetrain Conference 2018
Hamburg, Germany, 2018/04/19



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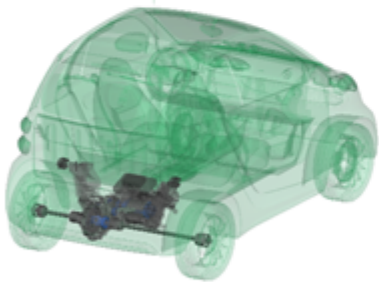
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Summary and outlook

Drivetrain simulation for the assessment of the NVH-behavior of electric vehicles

Motivation and objective

- Increasing electrification in all vehicle classes, e. g.



e Go



VW E-Golf



Tesla Model 3

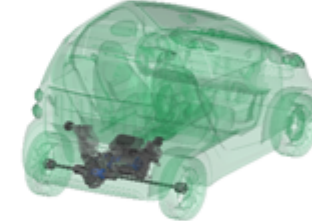
- New challenges regarding nvh behavior
 - Tonal electric motor noise at higher frequencies
 - No broadband ICE masking



- Handling through the use of methods of virtual product development



Real car

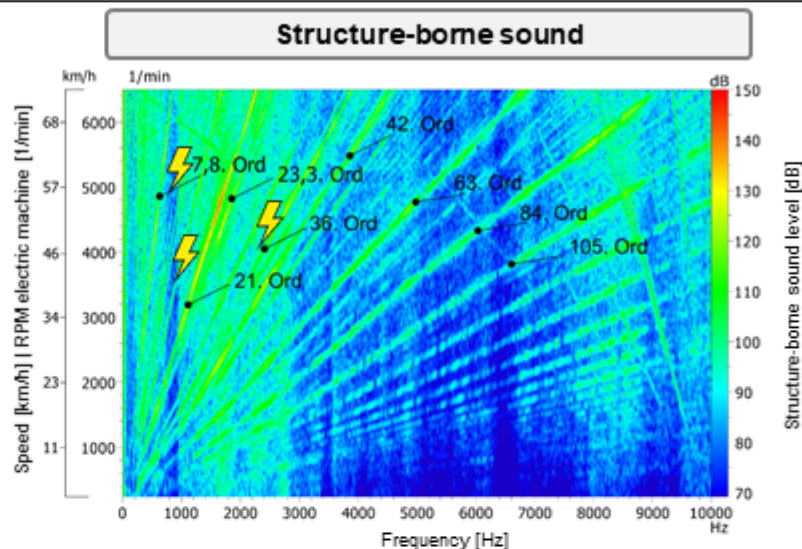
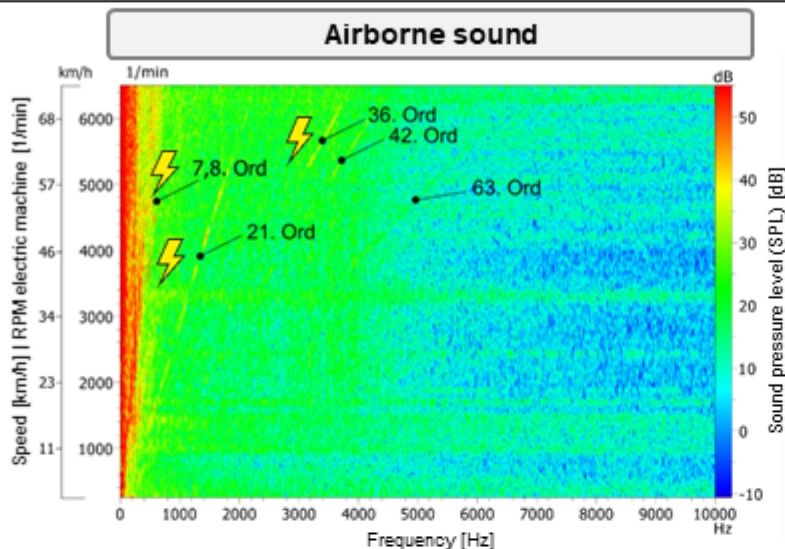


MBS model

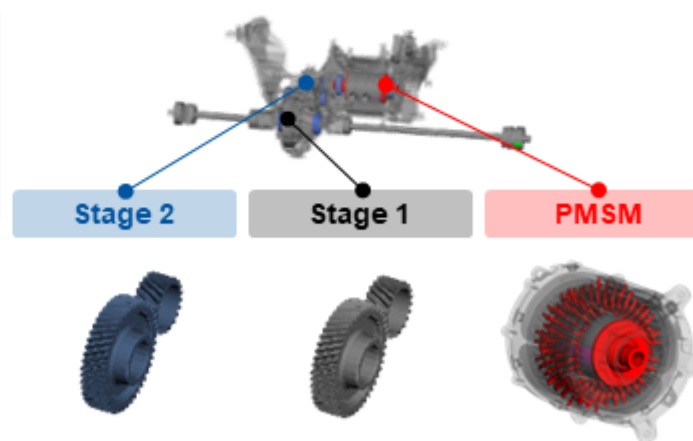
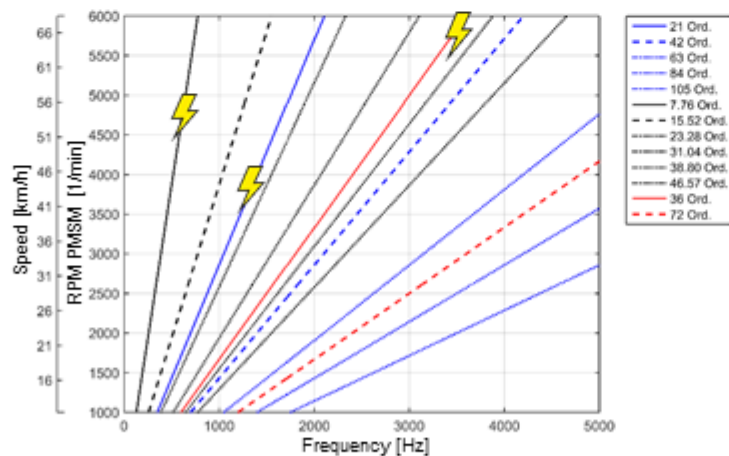
- Further development of tools for the assessment, optimization of drivetrain variants necessary

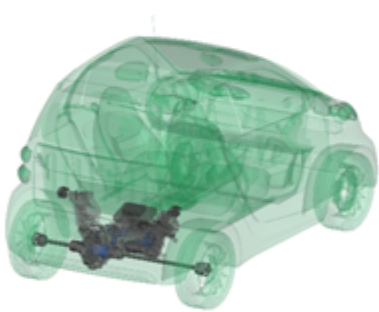
Drivetrain simulation for the assessment of the NVH-behavior of electric vehicles

Motivation and objective



Excitation of gears and electric machine





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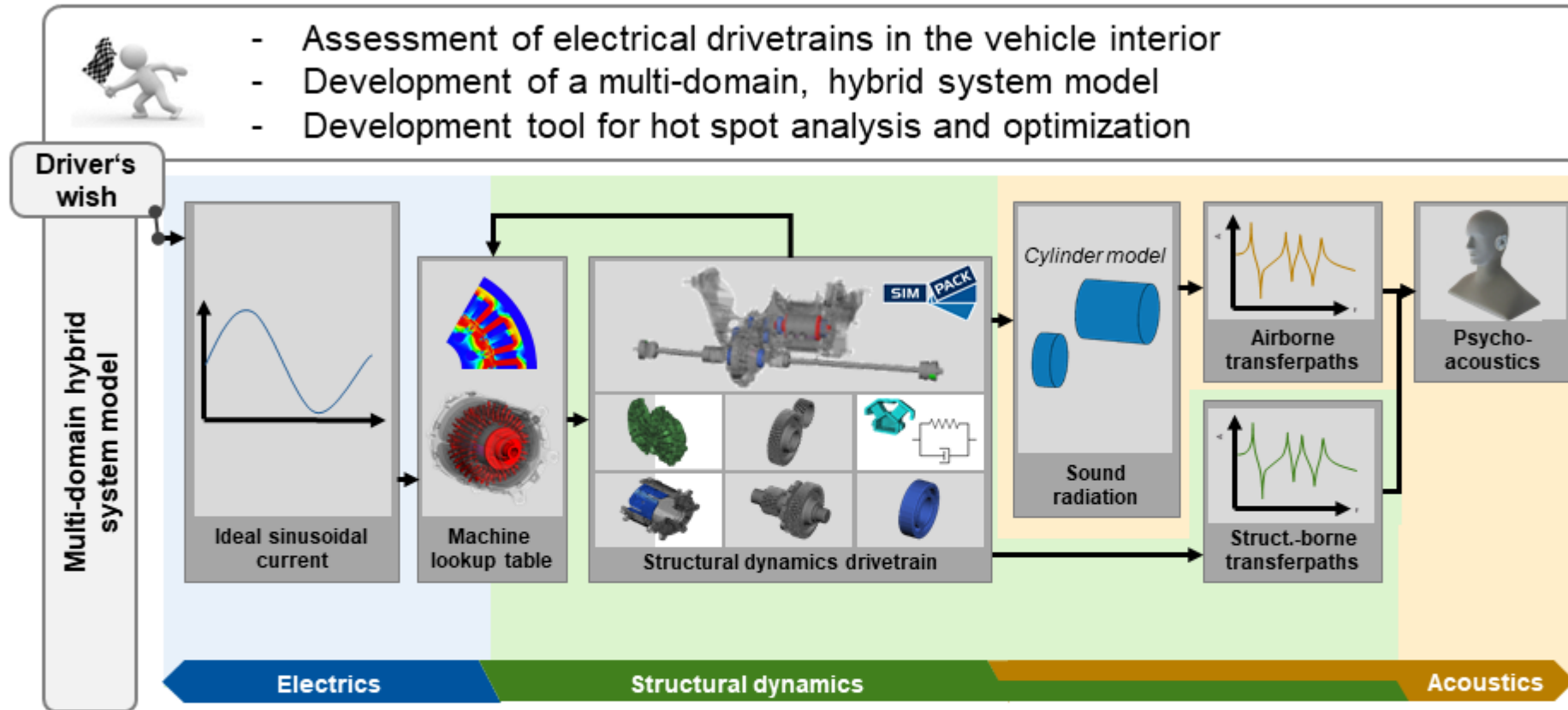
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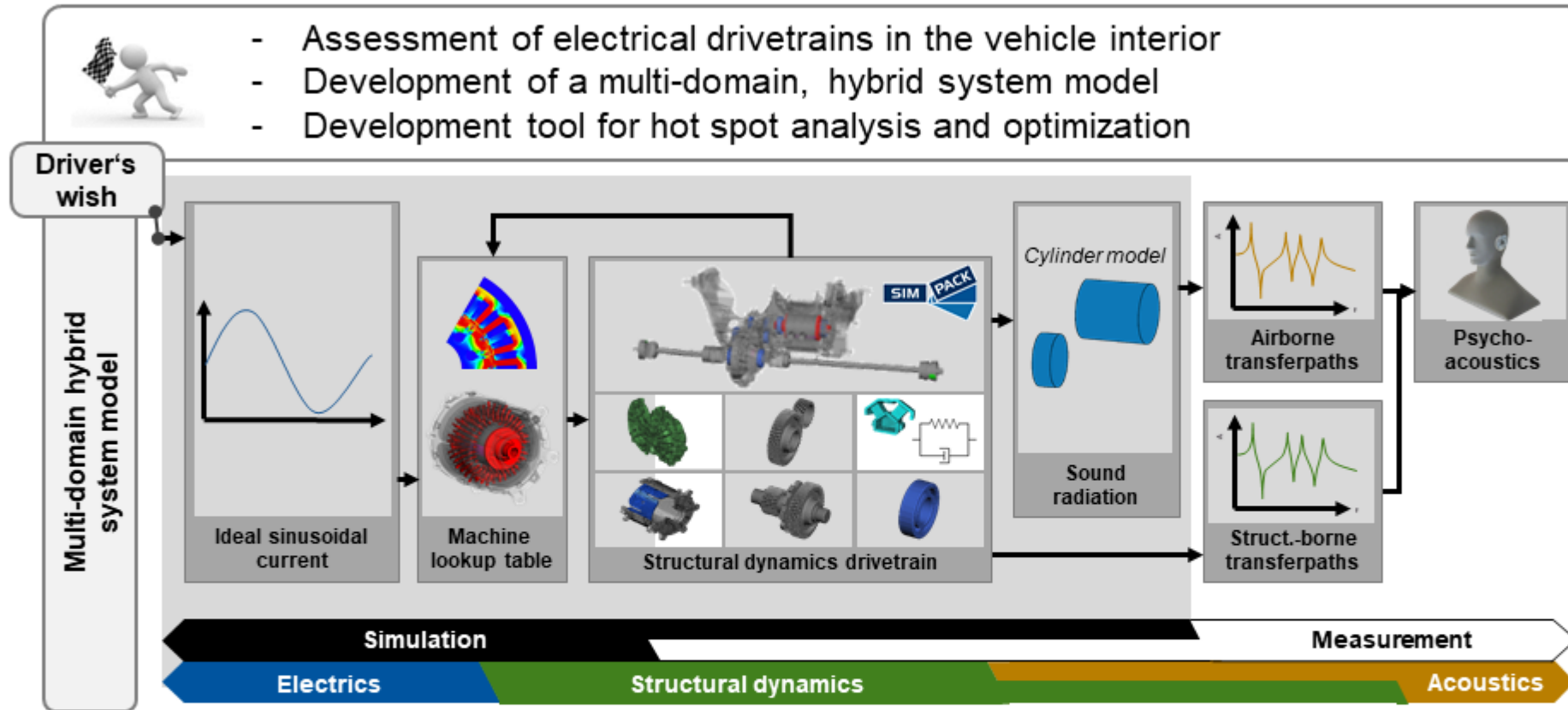
Drivetrain simulation for the assessment of the NVH-behavior of electric vehicles

Approach



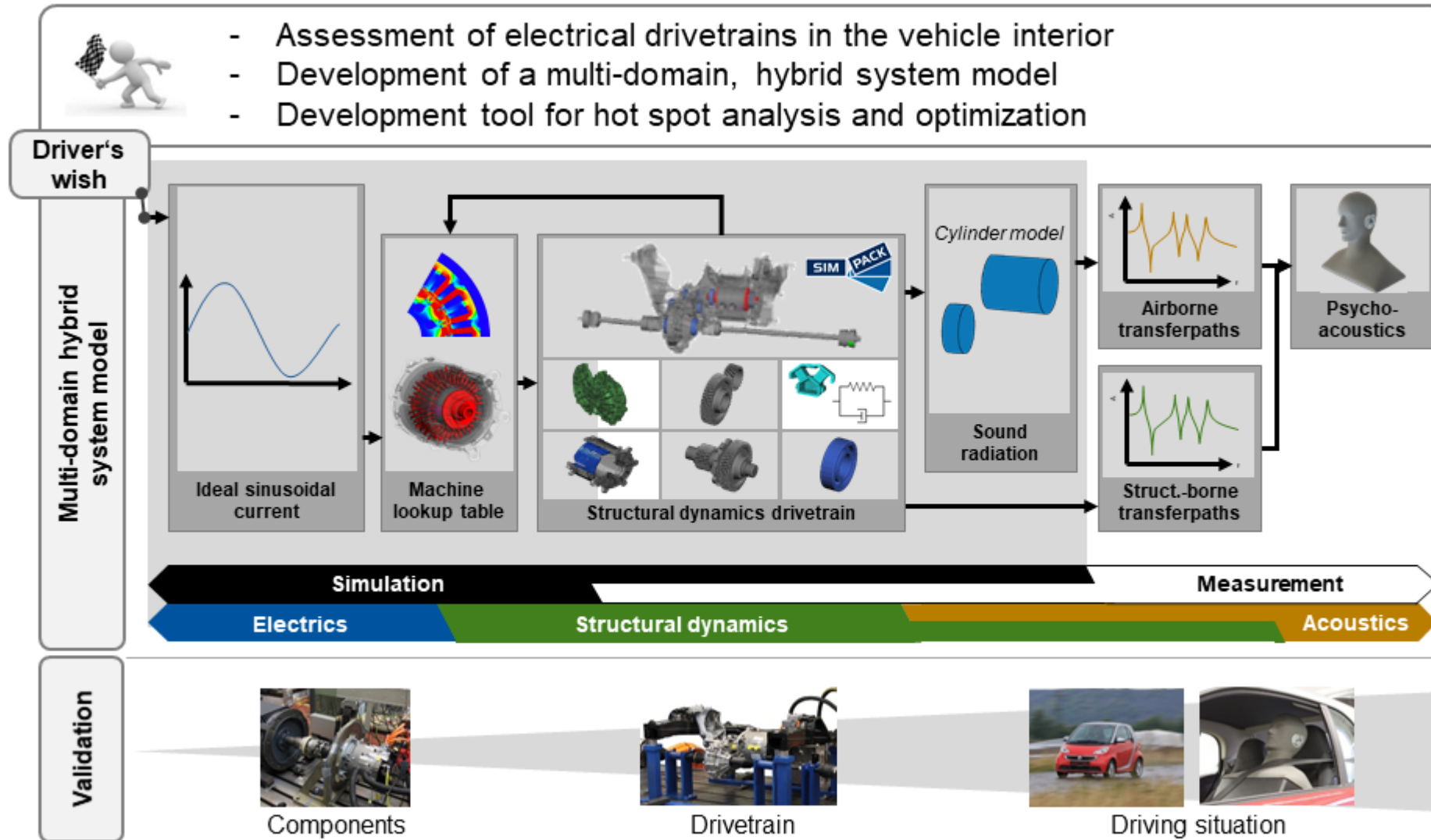
Drivetrain simulation for the assessment of the NVH-behavior of electric vehicles

Approach



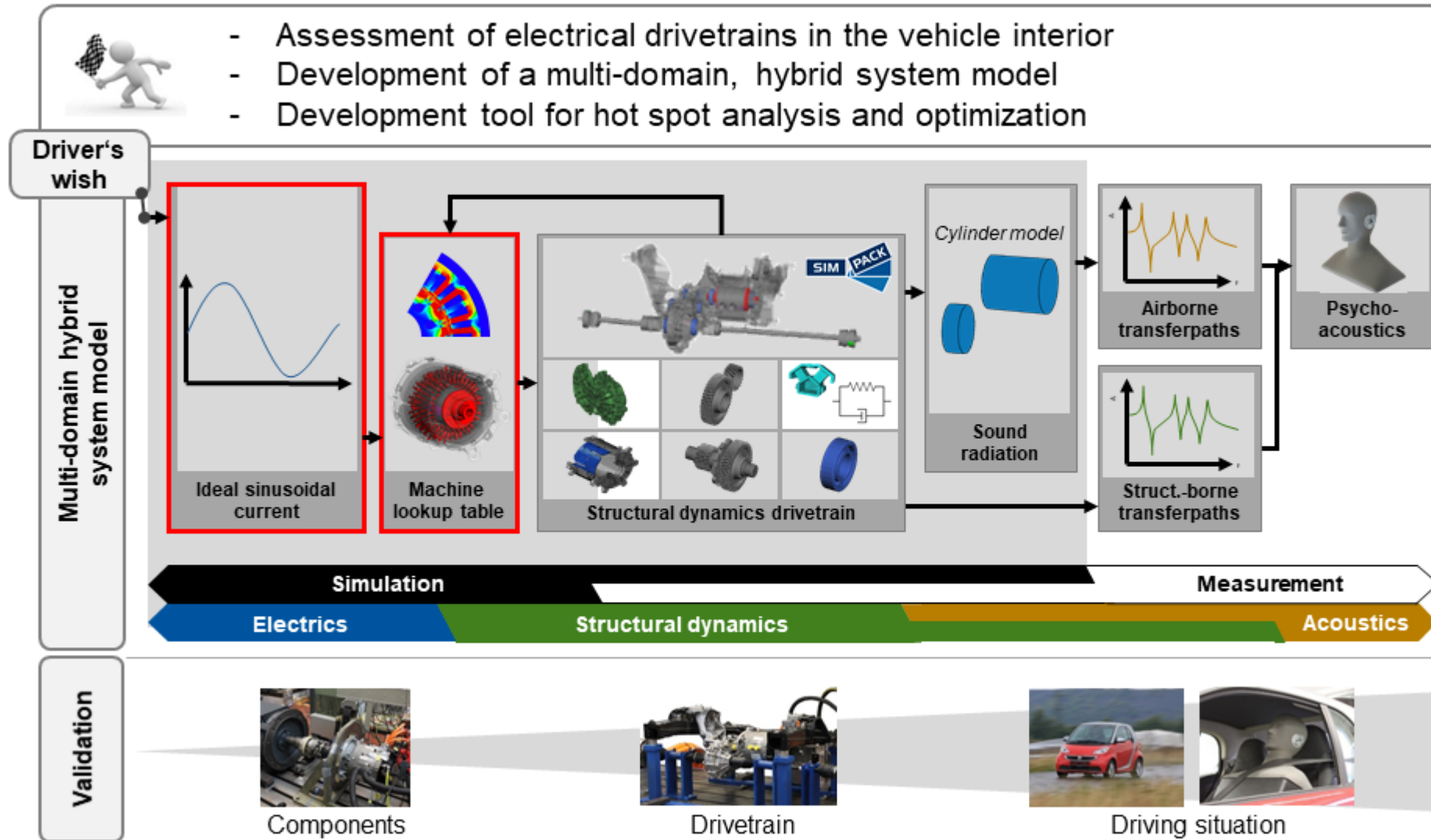
Drivetrain simulation for the assessment of the NVH-behavior of electric vehicles

Approach



Drivetrain simulation for the assessment of the NVH-behavior of electric vehicles

Approach



Drivetrain simulation for the assessment of the NVH-behavior of electric vehicles

Electrics



3D-modeling of electric machine
cumbersome and resource intensive



Efficient 3D-modeling
with 2D-precalculation

- Abstraction of the machine:
Axial discretization with slices

- Transformation of 2D-results:
 - Individual operating point calculation
 - Spatial shift of excitation

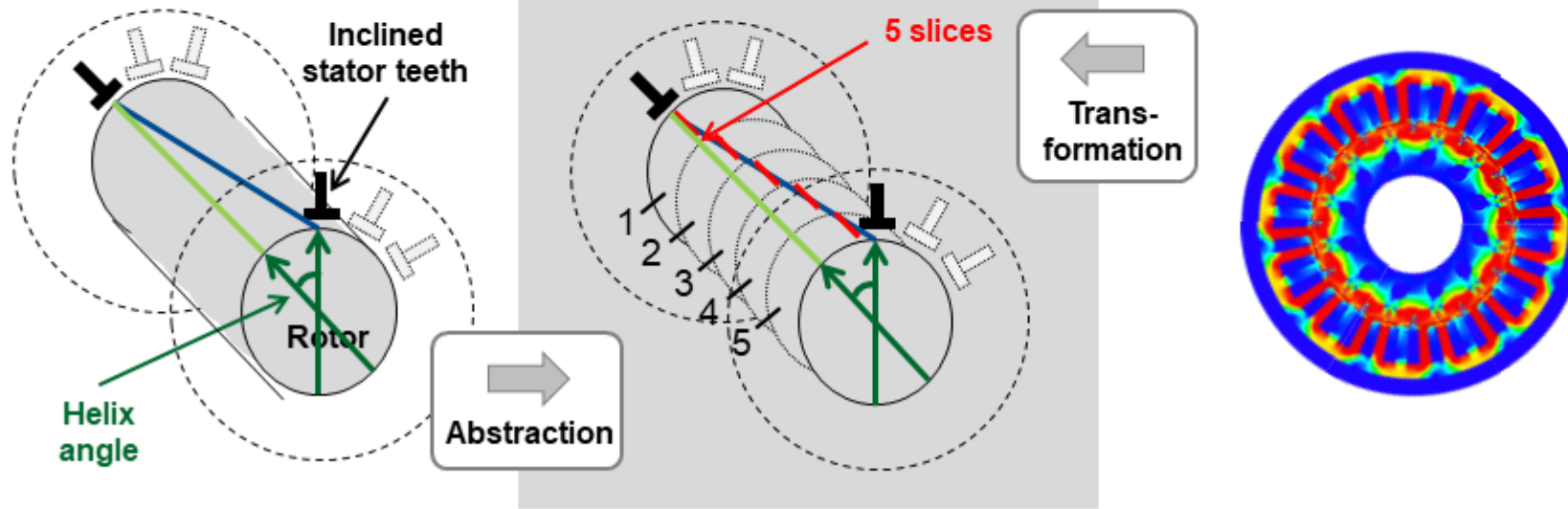
Inclined electric machine

MBS model
with „multi-slice“-method

FEM model

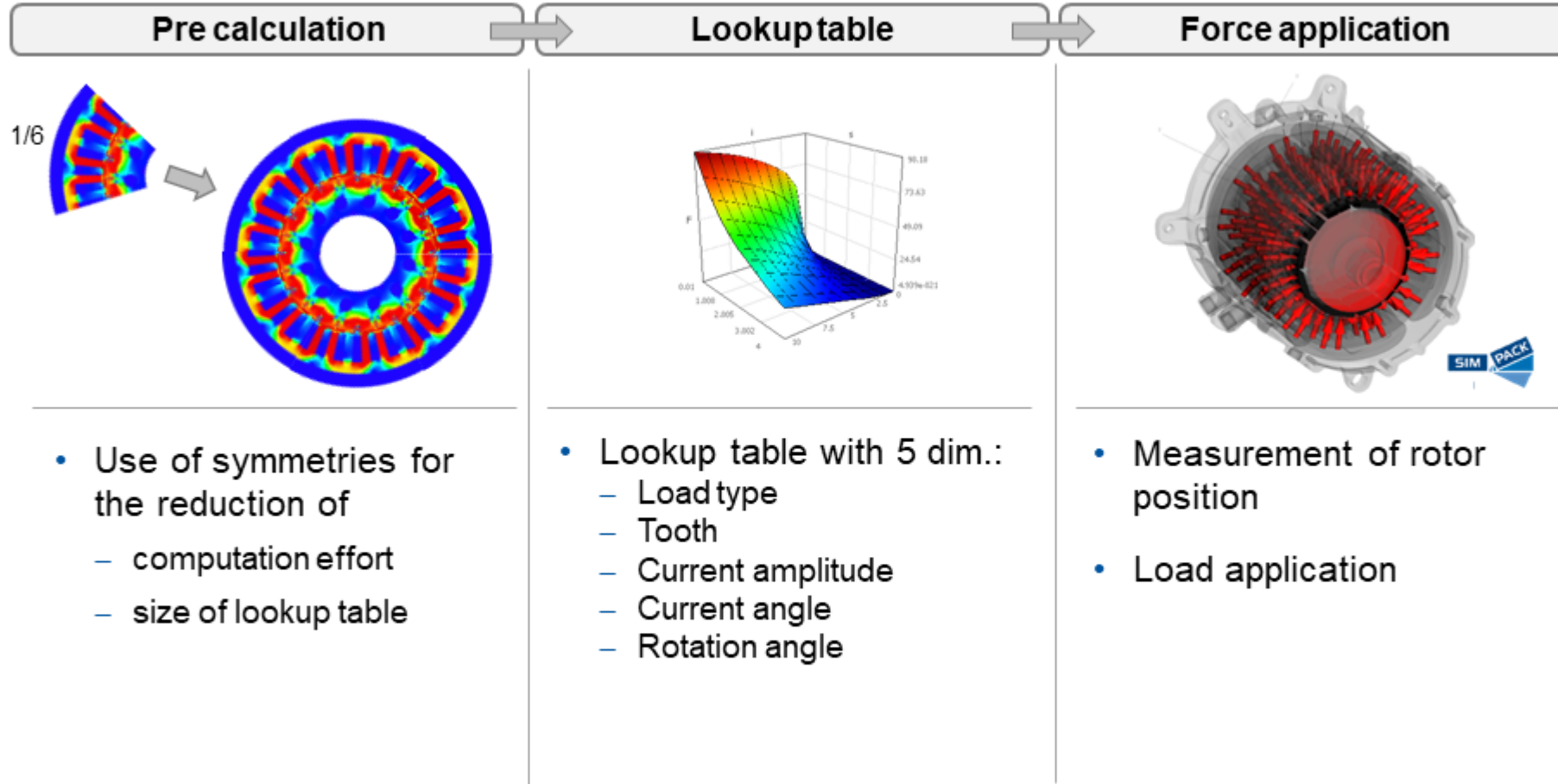
3D

2D



Drivetrain simulation for the assessment of the NVH-behavior of electric vehicles

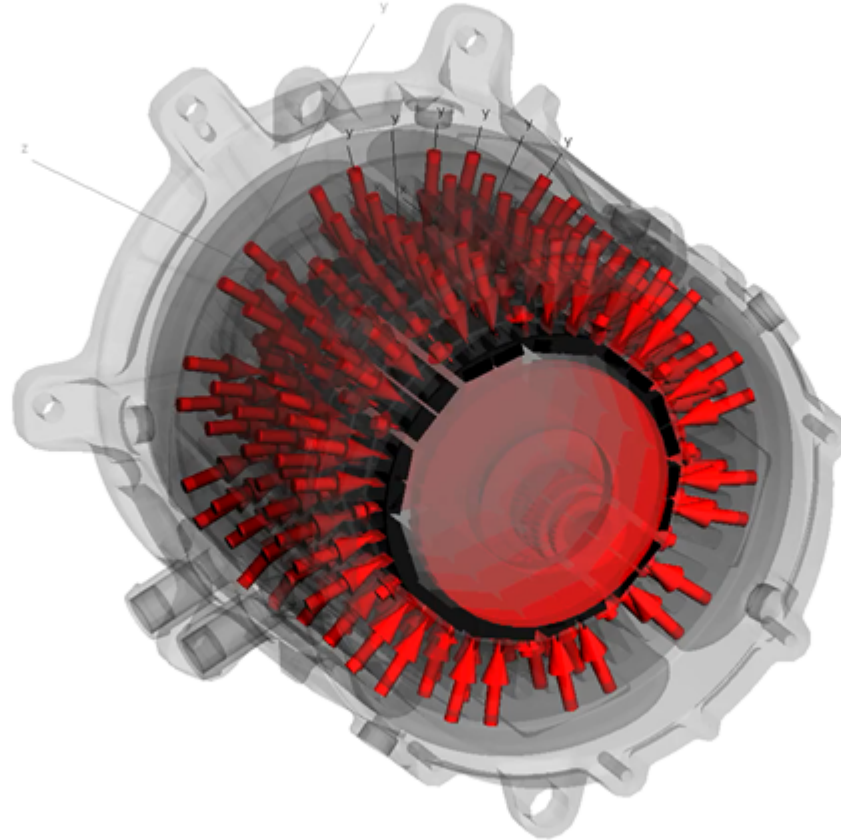
Electrics



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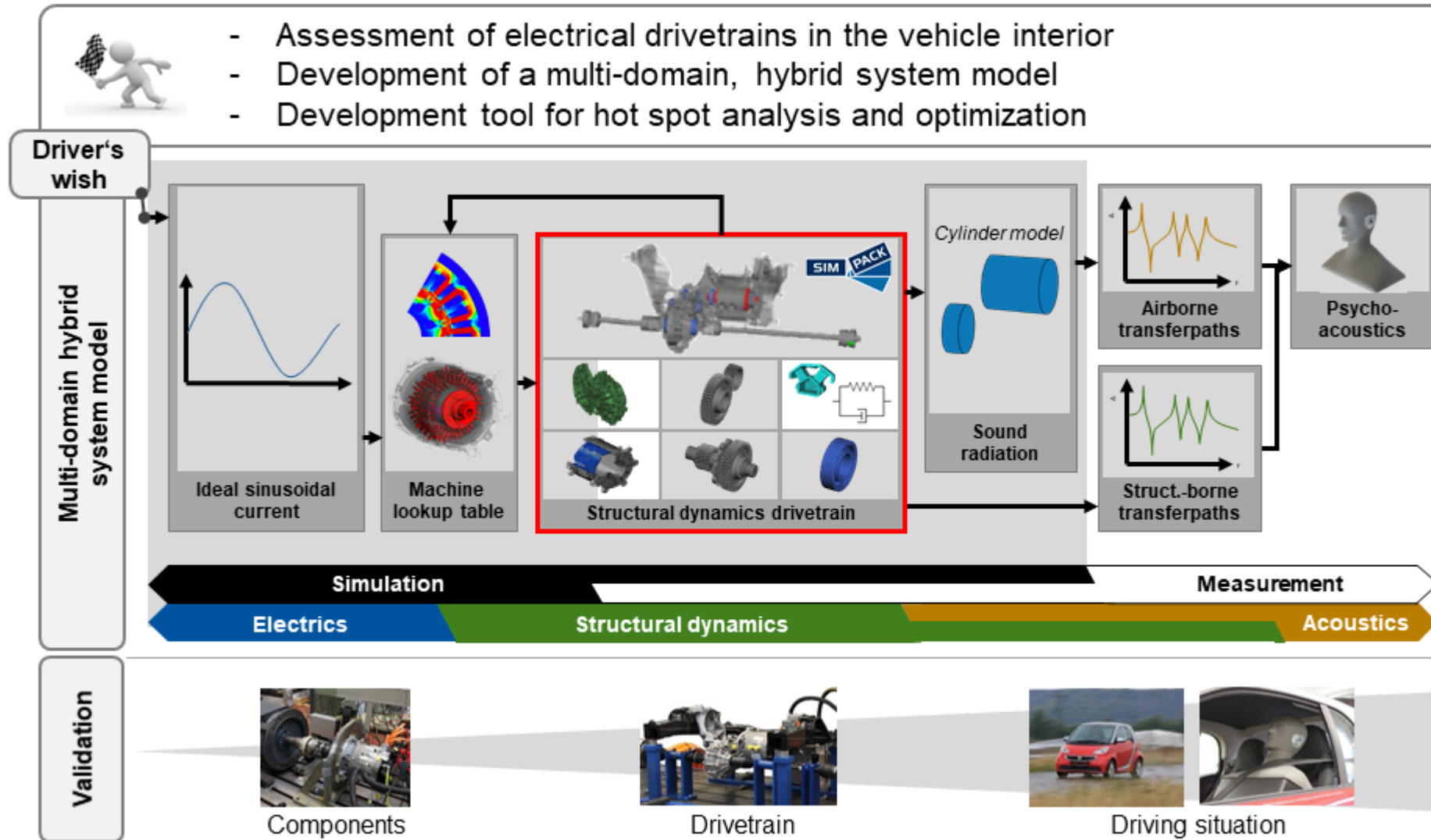
Electrics

Force application



Drivetrain simulation for the assessment of the NVH-behavior of electric vehicles

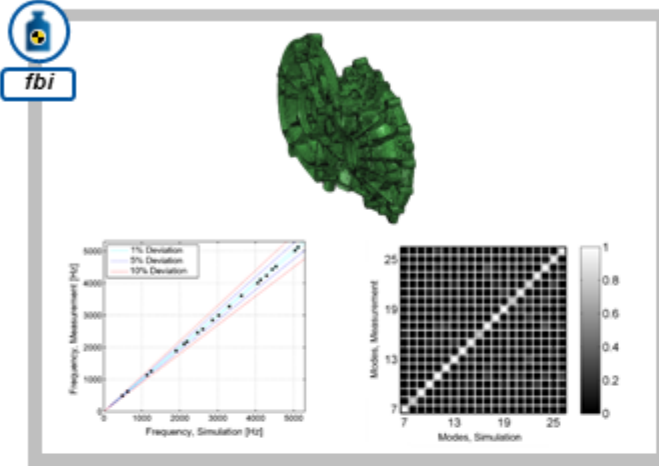
Approach – Structural dynamics



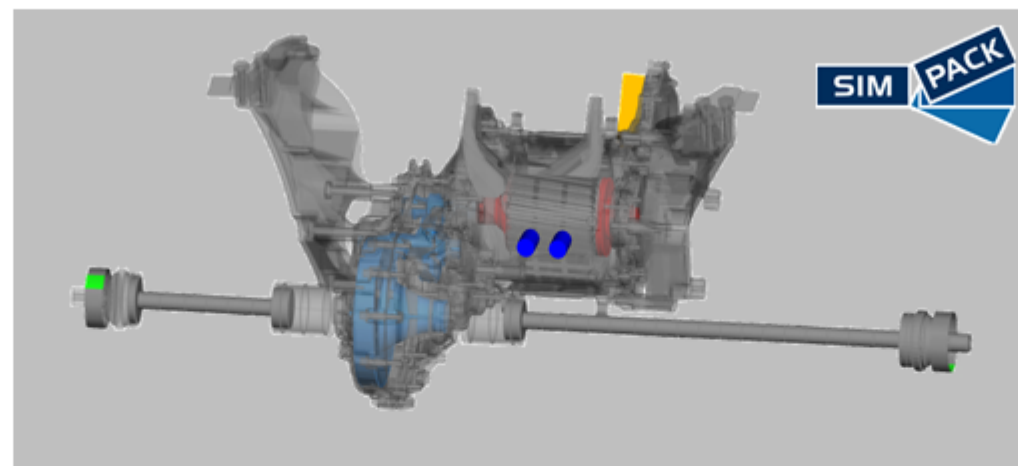
Drivetrain simulation for the assessment of the NVH-behavior of electric vehicles

Structural dynamics subsystem model

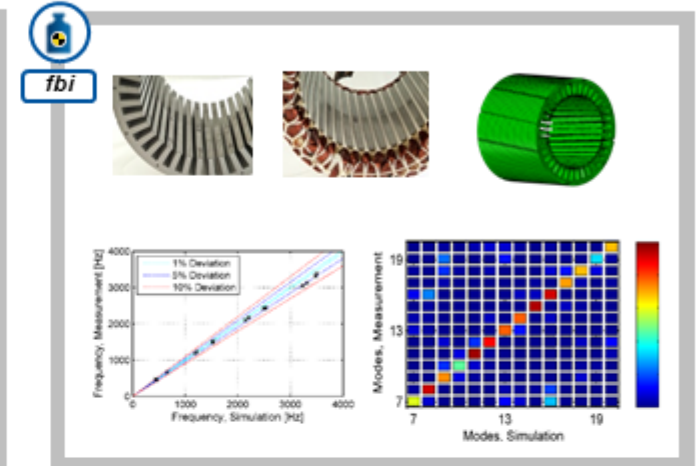
Elastic housings



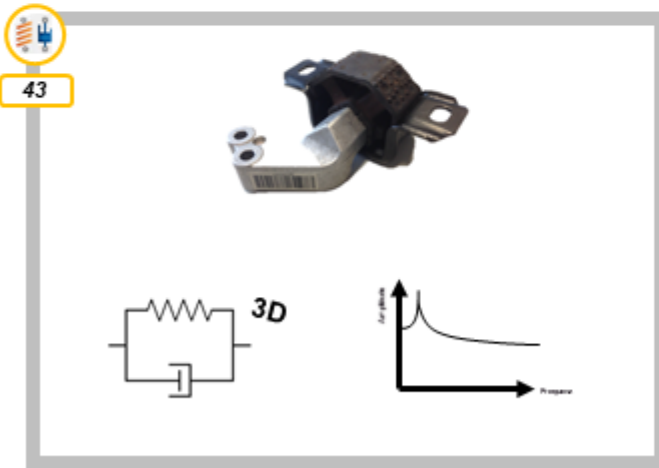
Elastic Multi-body-simulation model



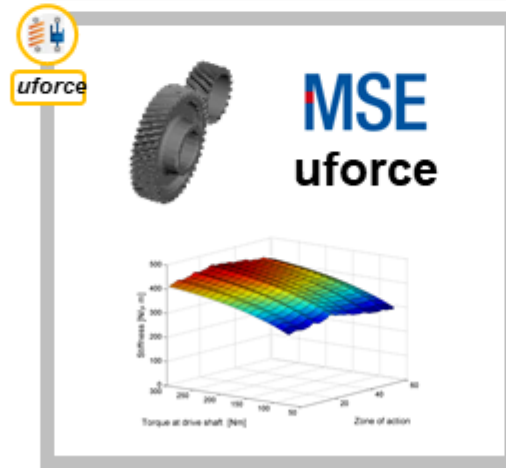
Laminar Stator mit Wicklungen



Elastomeric mounts



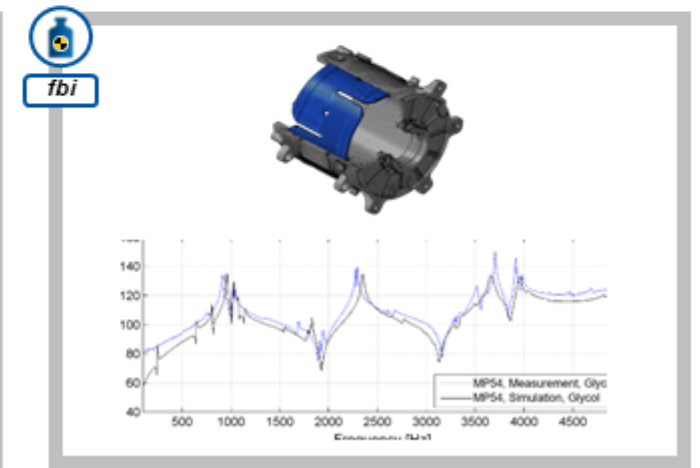
Gear mesh excitation



Bearings



Fluid-Structure-Interaction



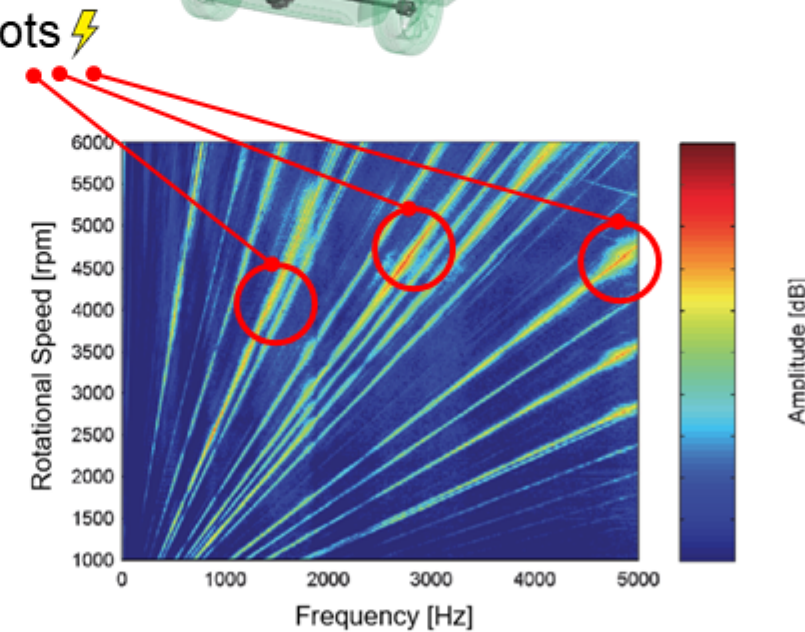
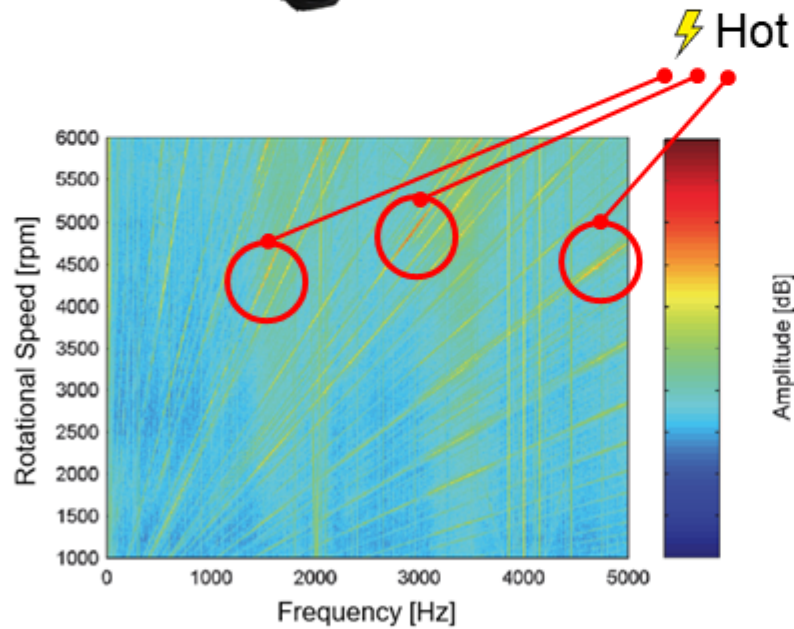
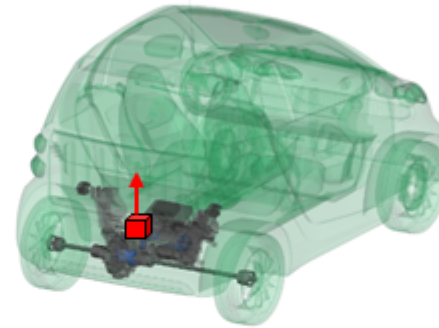
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Structural dynamics subsystem model – Validation

Measurement

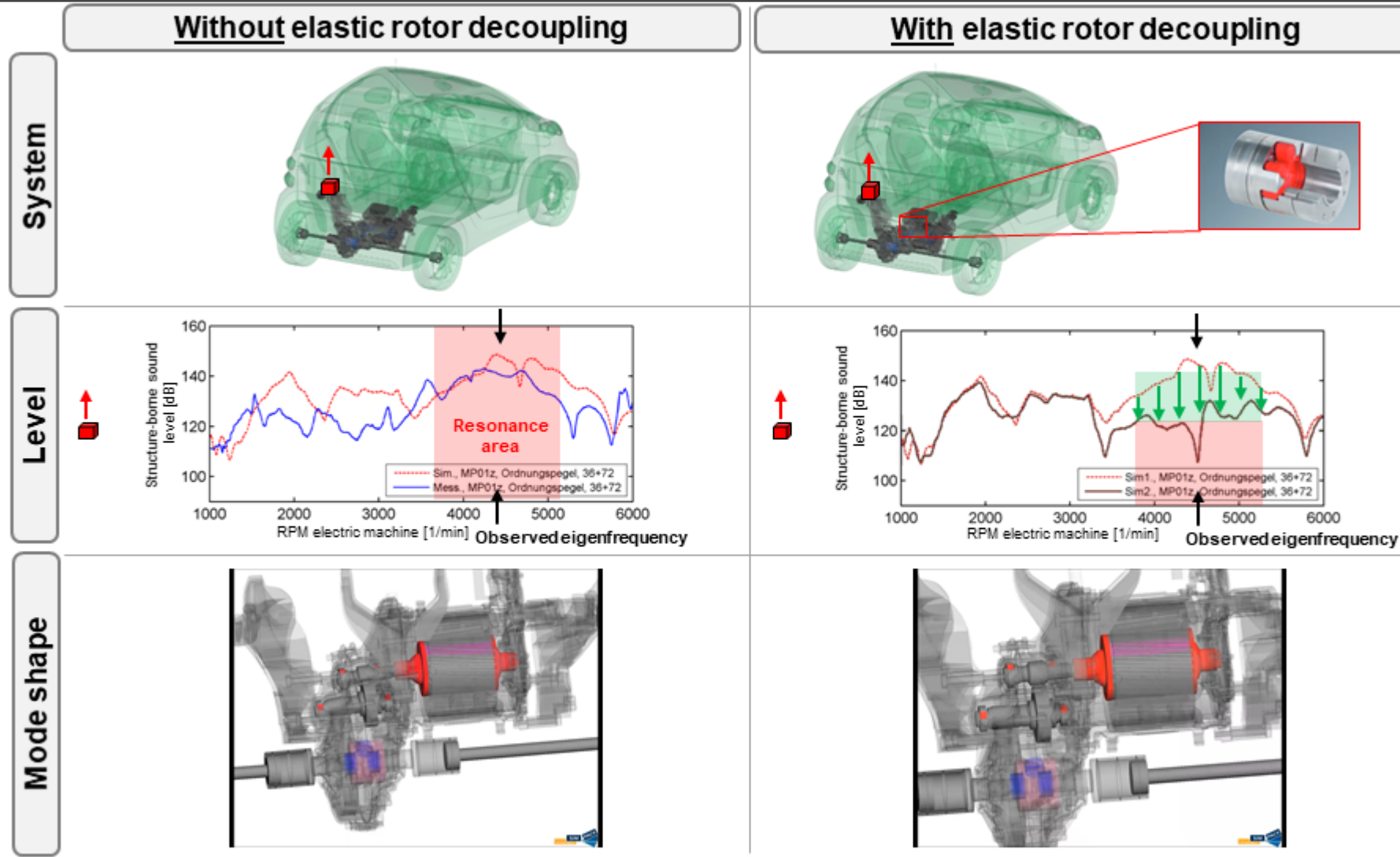


Simulation



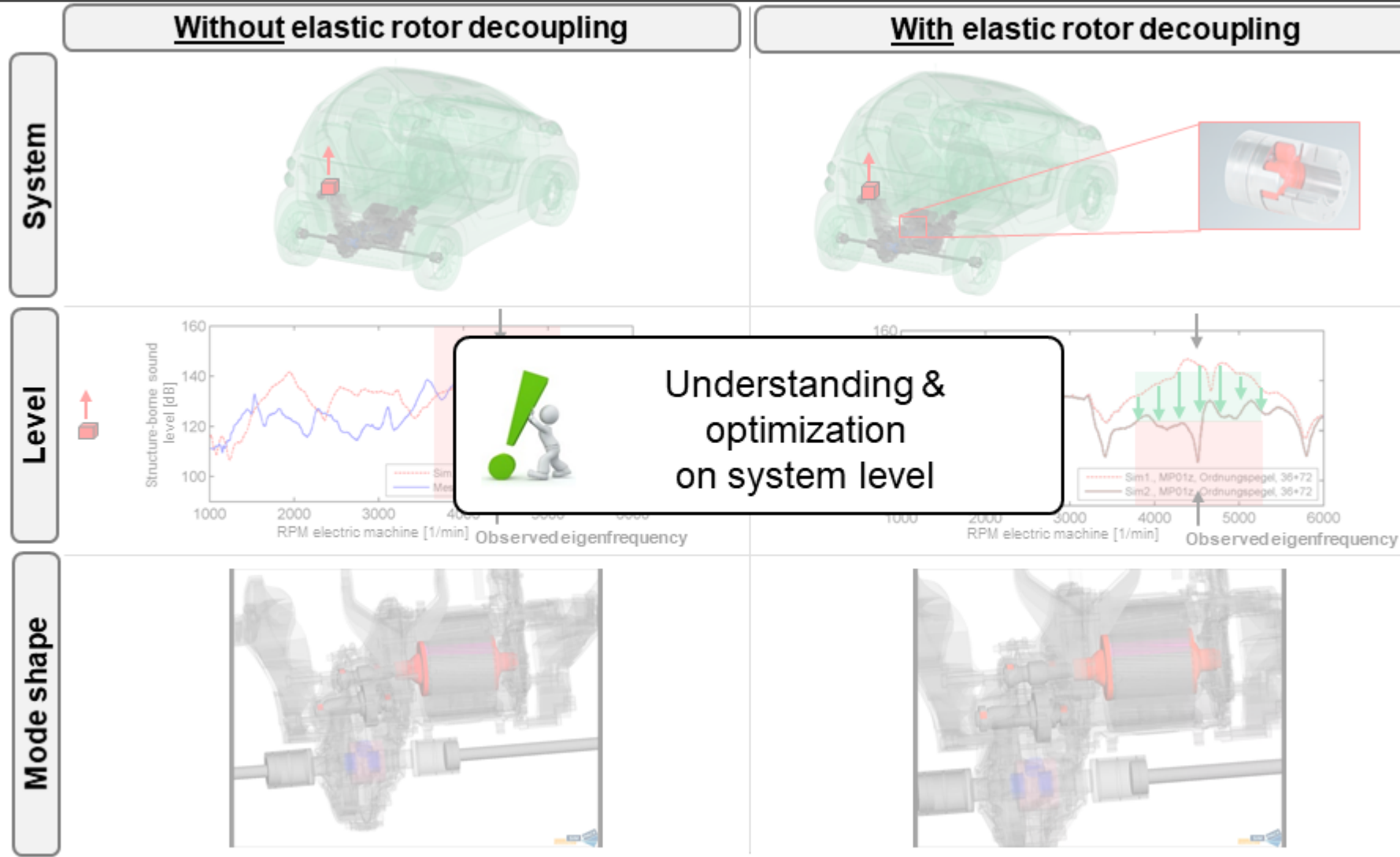
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Structural dynamics subsystem model – Understanding and optimization



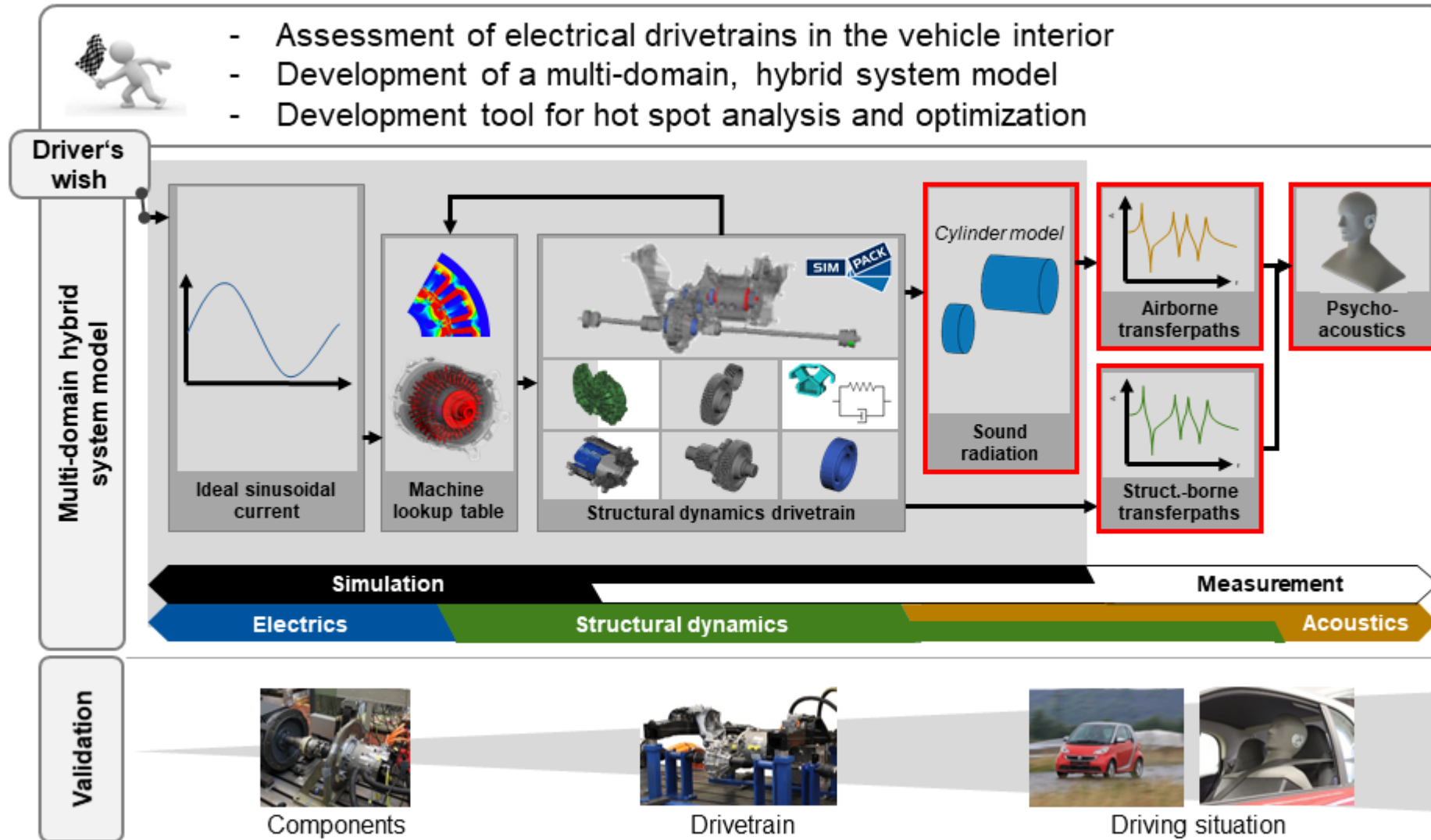
Drivetrain simulation for the assessment of the NVH-behavior of electric vehicles

Structural dynamics subsystem model – Understanding and optimization



Drivetrain simulation for the assessment of the NVH-behavior of electric vehicles

Approach – Structural dynamics

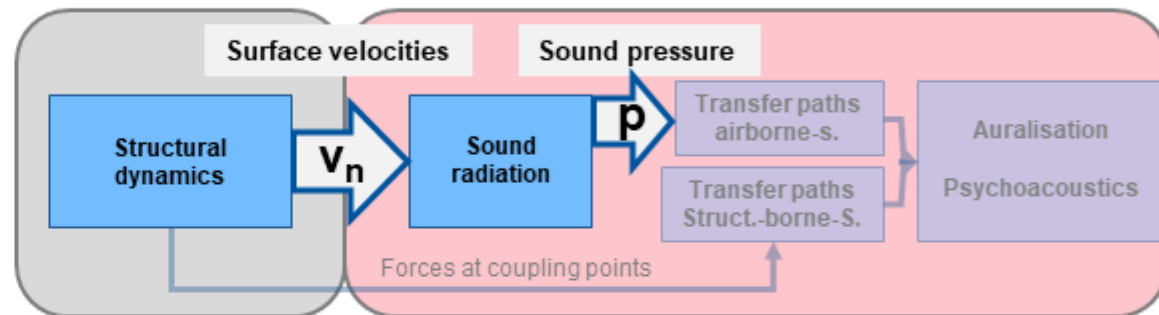


Drivetrain simulation for the assessment of the NVH-behavior of electric vehicles

Acoustics

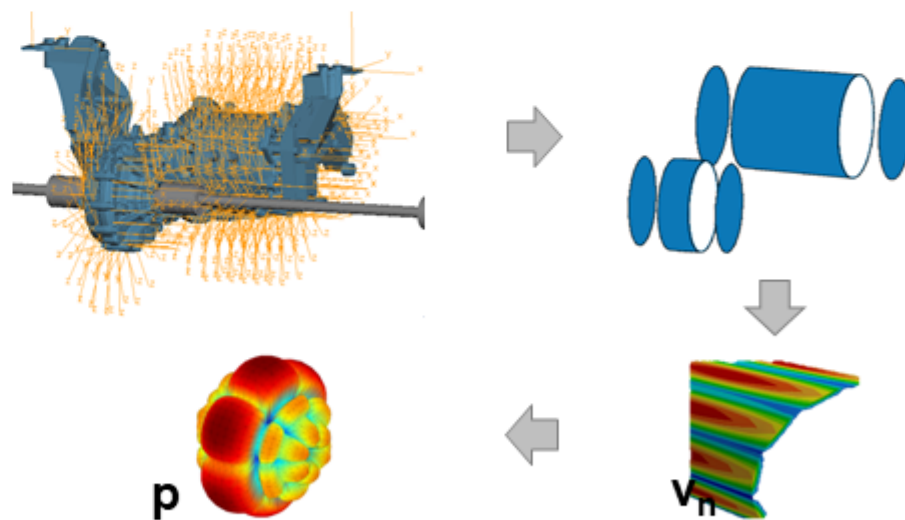
Interface between structural dynamics and acoustic simulation

- Solution of structural dynamics:
Discrete surface velocities v_n
of drivetrain housing
- Solution of wave equation:
Radiated sound pressure p



Efficient calculation of sound radiation

- Abstraction of complex drivetrain geometry
 - Cylinders: Electric machine, gearbox
 - Plate: Sides und bearing plate
- Approximation allows fast analytical computation

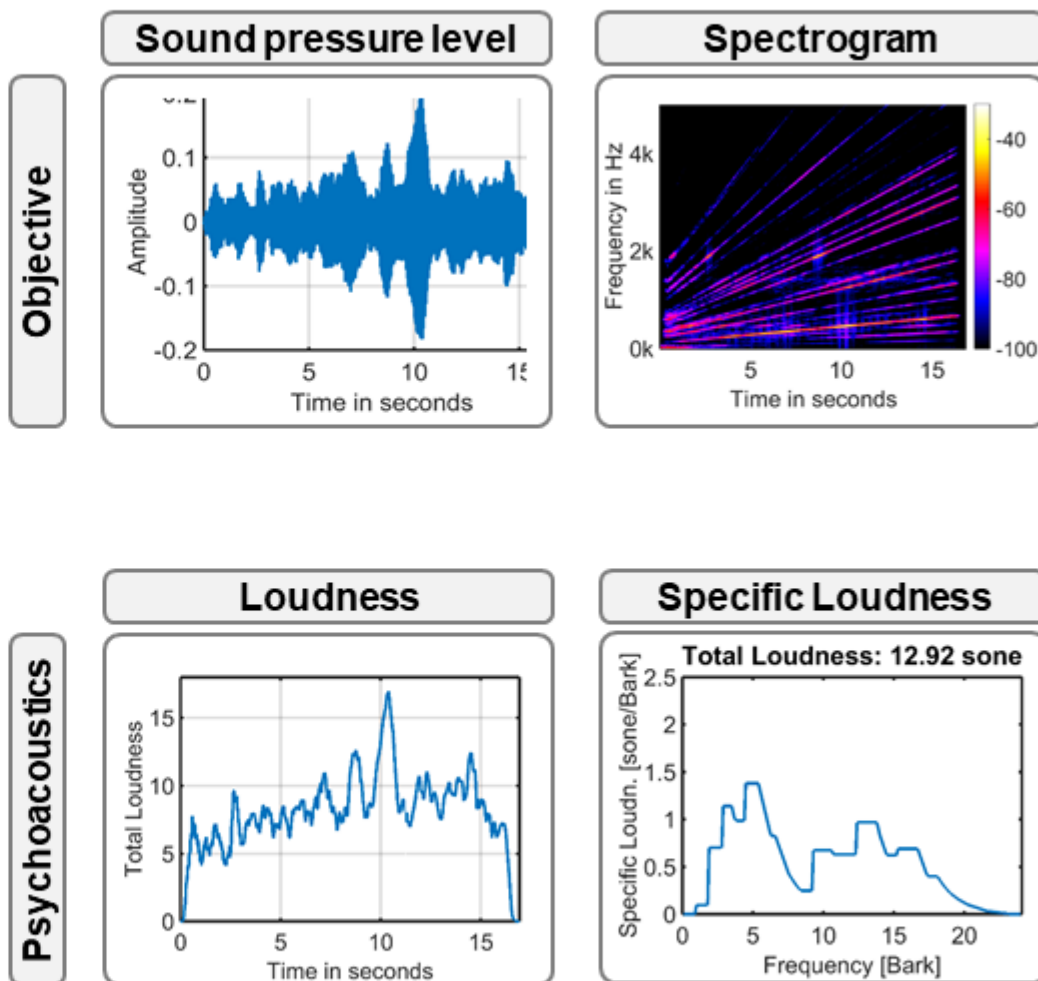


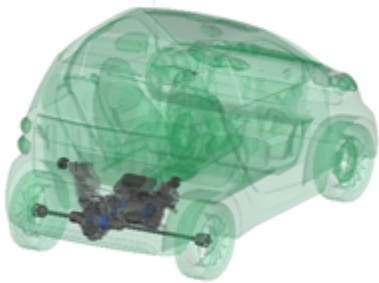
Drivetrain simulation for the assessment of the NVH-behavior of electric vehicles

Acoustics

Acoustic post-processing

- Objective raw data
 - Signal shape (Sound pressure level)
 - Spectrogram
- ↓
- Psychoacoustics
 - Time variant Loudness
 - Specific Loudness
 - ...
 - Allocation of air borne- and structure-borne sound percentages





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Summary and outlook

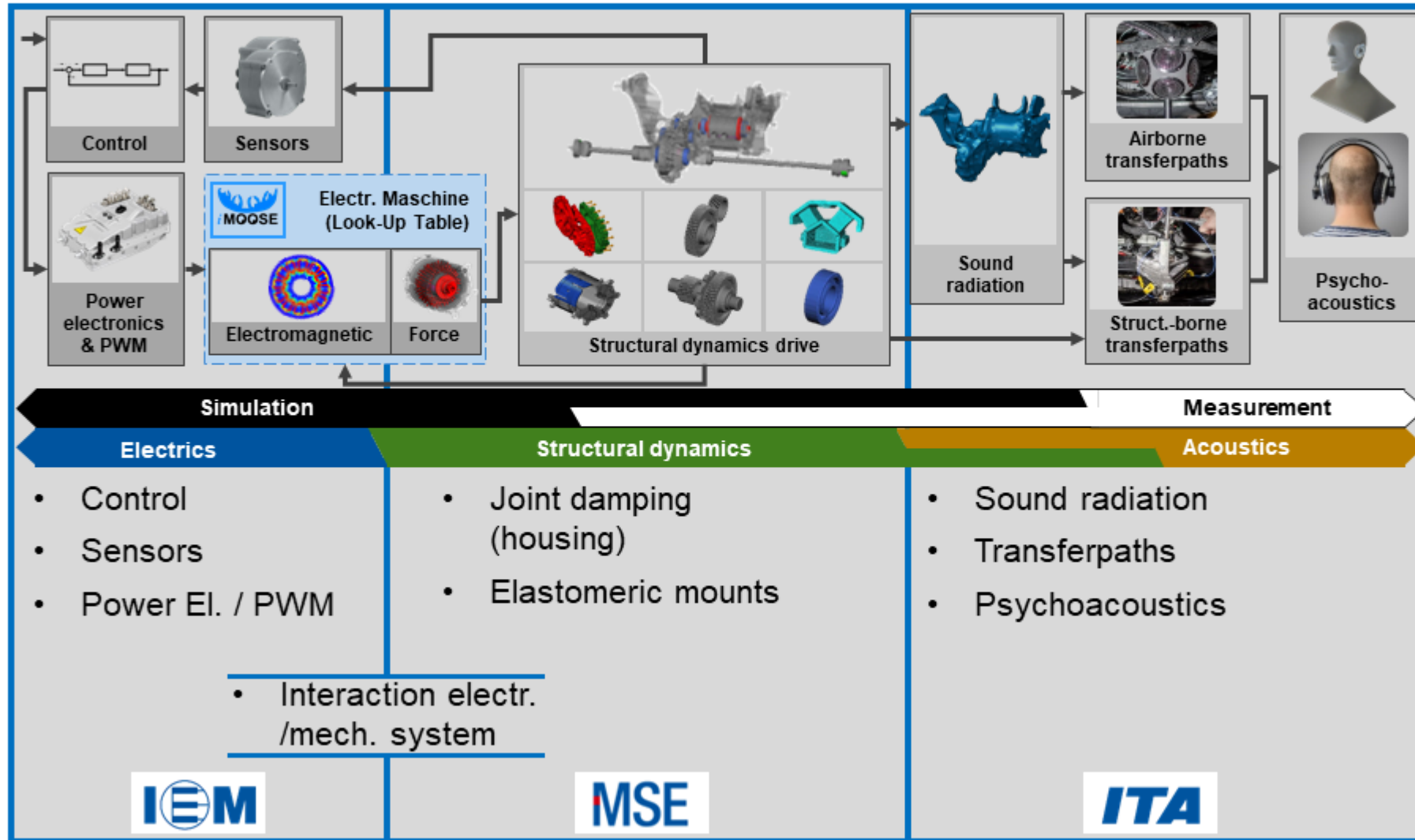


- Assessment of electrical drivetrains in the vehicle interior
- Development of a multi-domain, hybrid system model
- Development tool for hot spot analysis and optimization

- Increasing model fidelity in all domains

Drivetrain simulation for the assessment of the NVH-behavior of electric vehicles

Summary and outlook



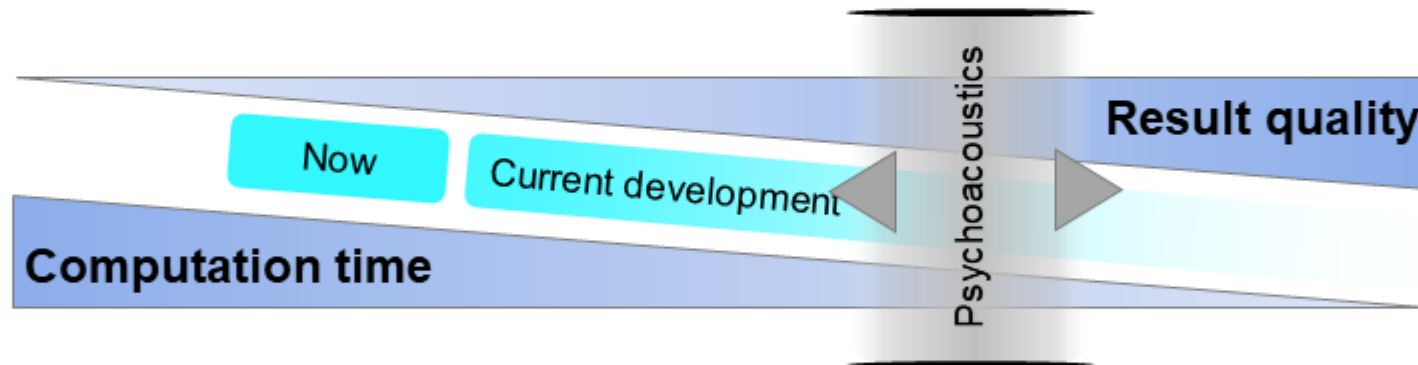
Drivetrain simulation for the assessment of the NVH-behavior of electric vehicles

Summary and outlook



- Assessment of electrical drivetrains in the vehicle interior
- Development of a multi-domain, hybrid system model
- Development tool for hot spot analysis and optimization

- Increasing model fidelity in all domains



- Balancing result quality and computation time with the analysis of different model fidelity levels using psychoacoustic metrics

**Thank you
for your attention.**

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