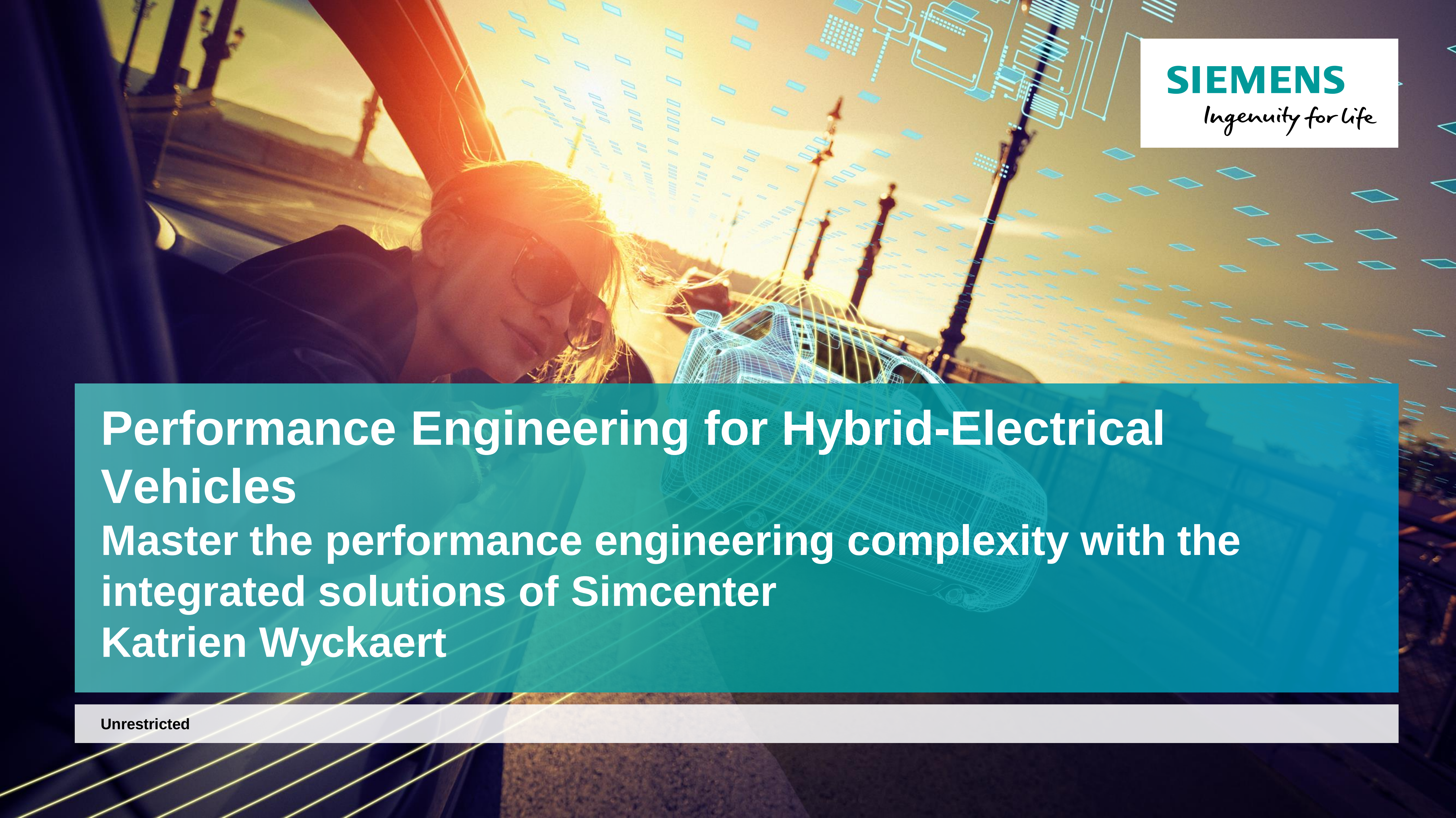

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Performance Engineering for Hybrid-Electrical Vehicles

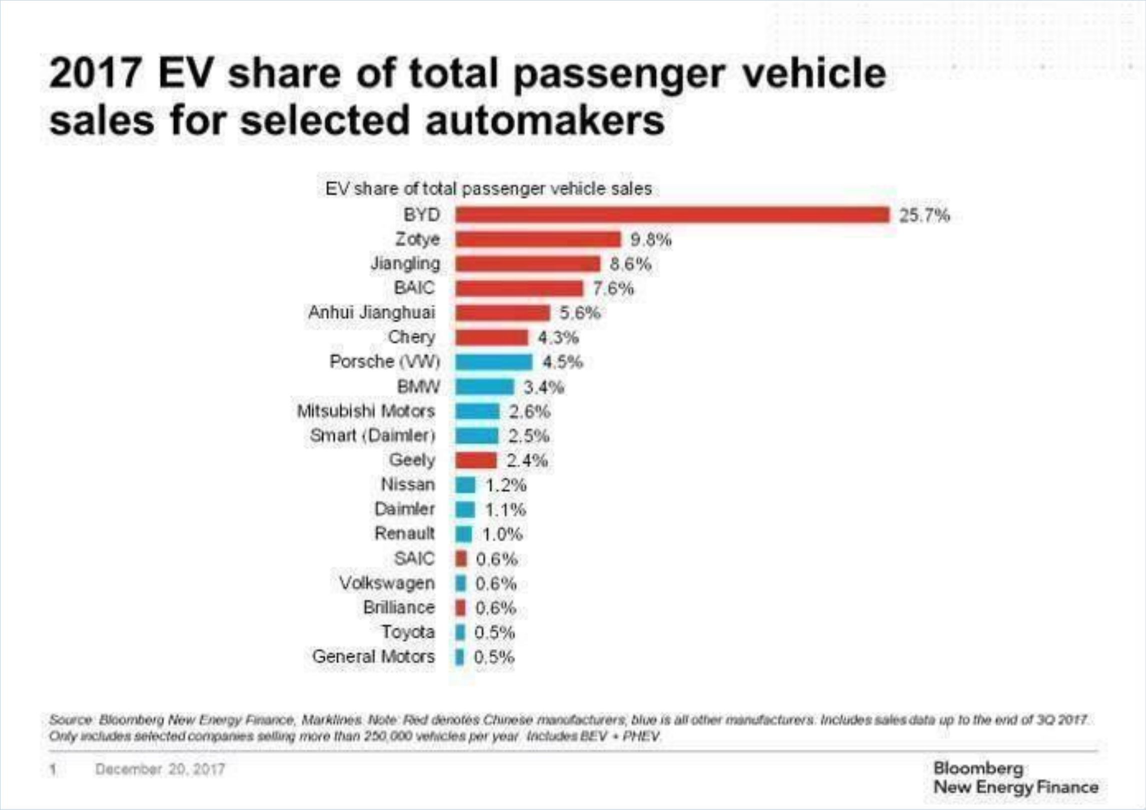
Master the performance engineering complexity with the integrated solutions of Simcenter

Katrien Wyckaert

Electrification
Trend is solidifying

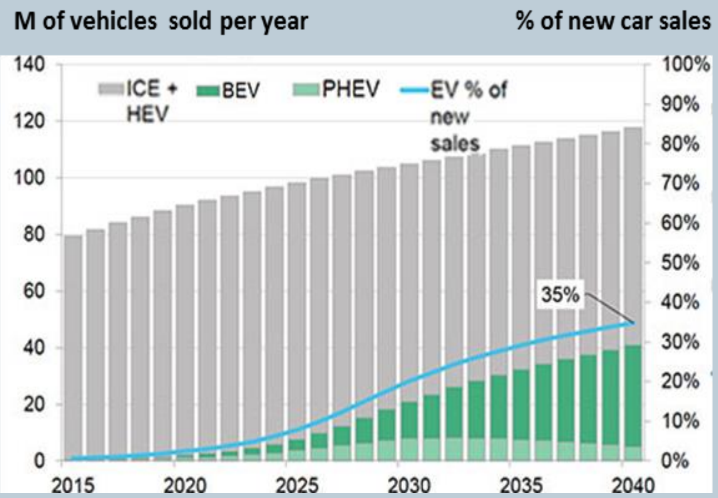
Ingenuity for life

Electrical Segment growing – China a dominant player



Worldwide sales EV grew 45% in 2016 (McKinsey)

Electric vehicles (HEVs & EVs) share could range from 10-50% of new vehicles sold in 2030



Source: Bloomberg New Energy Finance

Trends driving innovation in today's vehicle market

Challenging vehicle engineering teams

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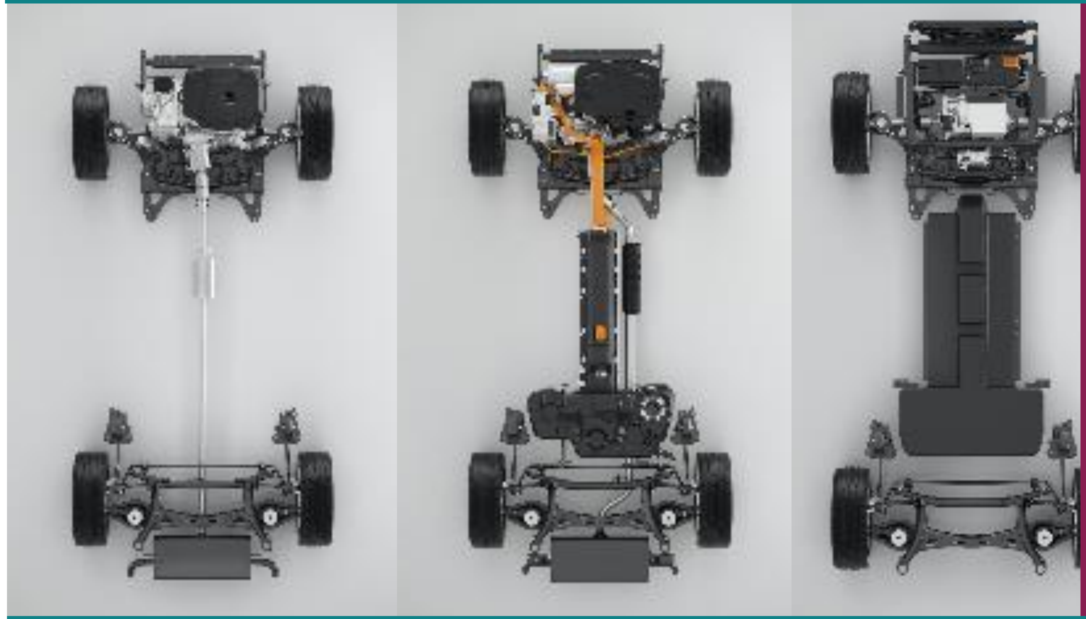
Delivering Lightweight, Emission-Friendly, Fuel Efficient Vehicles…

Systems Performance

…yet Managing Expected Vehicle Performance

Managing Complexity of Required Mechatronic System Innovations…



Mechatronic Complexity

…and Guarantee Quality of Integration

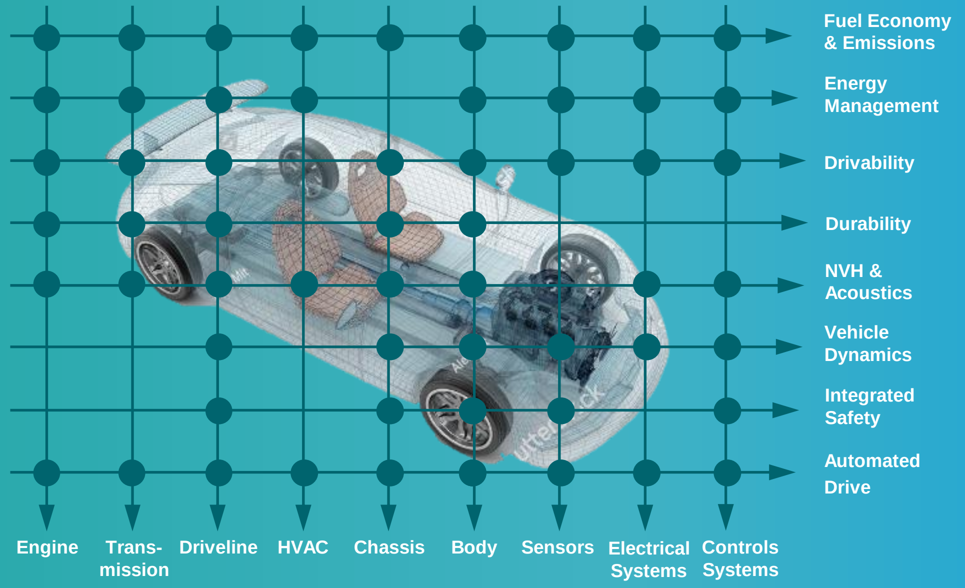
Engineering implications in vehicle development

A growing complexity in **systems** interactions

System Driven Product Development

Rethink the vehicle development processes to effectively deal with nowadays challenges

- Powertrain electrification & hybridization
- Towards automated driving
- A balanced driver experience in a global market
- Quality in software and hardware complexity



Addressing the challenge of innovations while managing the complexity of mechatronic system development

Deploying the digital twin for performance engineering

Simcenter in support of multi-attribute performance engineering

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Multi-attribute Performance Engineering

Fuel Economy & Energy Management

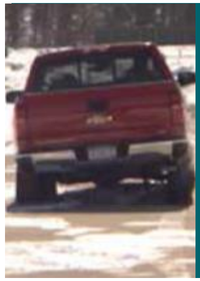
Drivability

Vehicle Dynamics

Integrated Safety

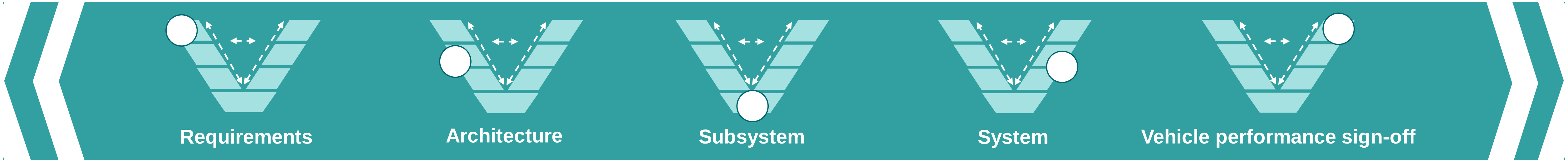
NVH & Acoustics

Aerodynamics & Water Management



Strength & Durability

Automated Driving



Model based System Solutions
Supporting (H)EV Vehicle Development

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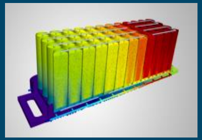
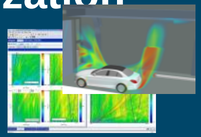
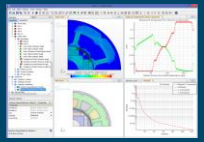
Battery Design
Chemistry | Package | Charging



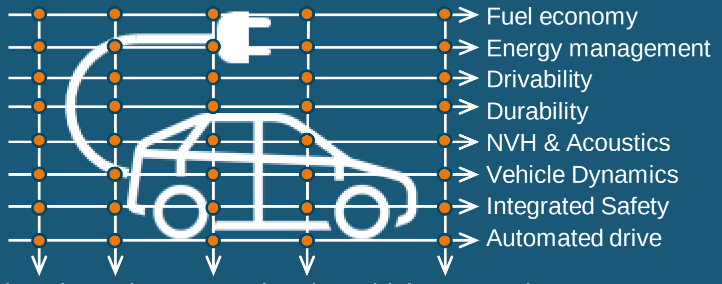
Performance Optimization
Energy & Thermal management
Acoustics & NVH



Electric Drive
Motors | Invertor | Convertor

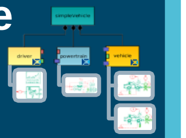


Continuous Verification & Validation Framework



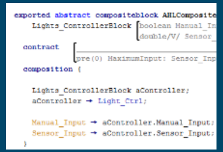
Systems Driven Product Development

Powertrain Architecture
Vehicle Platform



Electrical Distribution Systems
EMI/EMC

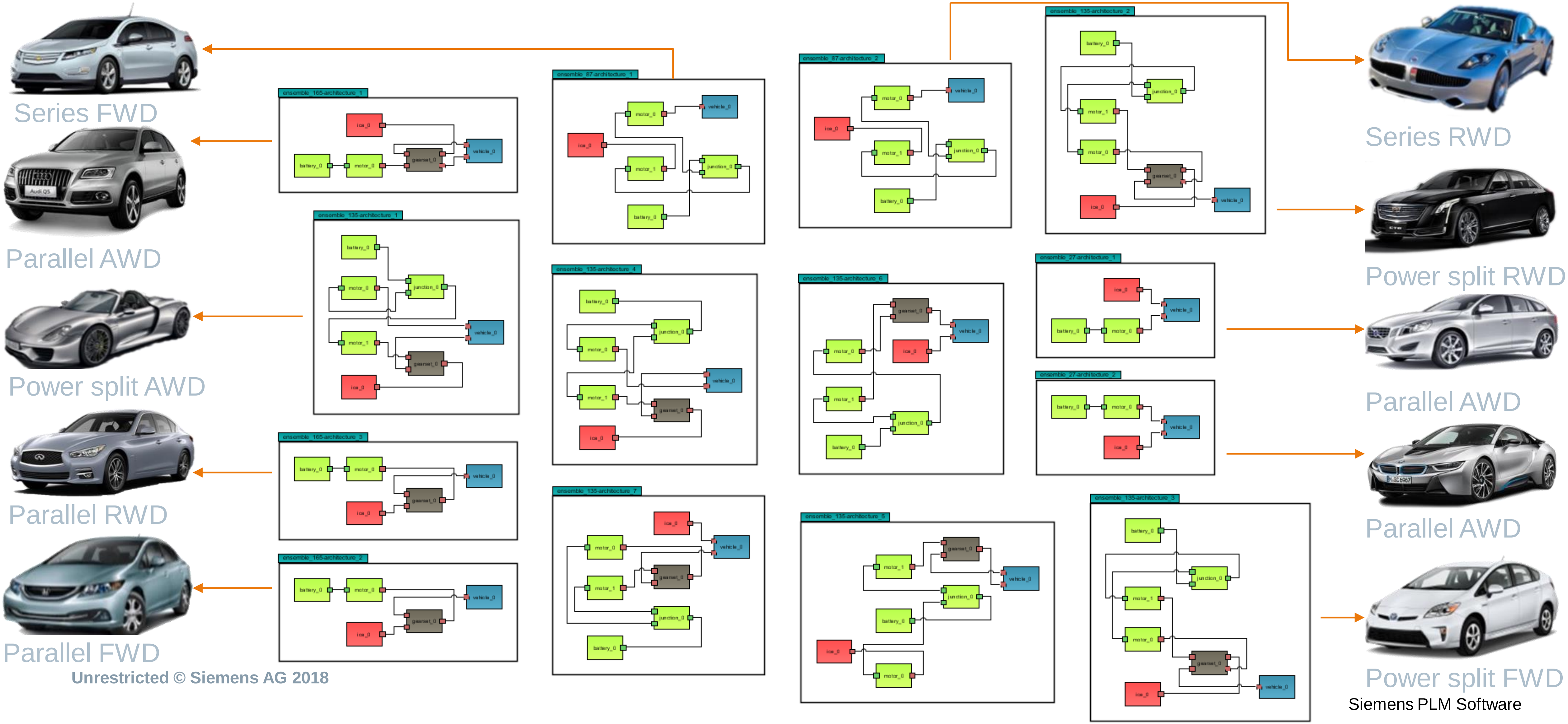
Software & Controls



Ensuring system continuity, multi-domain traceability and functional safety across domains

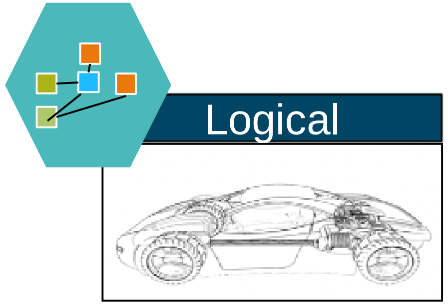
Exploiting architectural options to its maximum potential?

14 Hybrid Architectures on the Market



Architecture Generation

Basic Idea



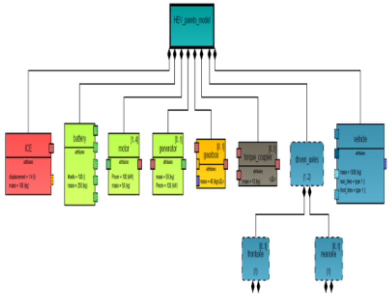
Computational Design Synthesis

Design knowledge and intent

Design/Architectures/Concepts

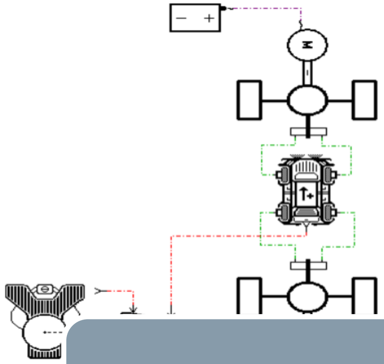
Generative Engineering - Architecture

The Process Illustrated

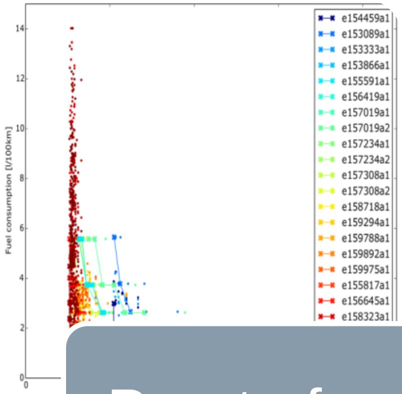


System definition

Architecture generation

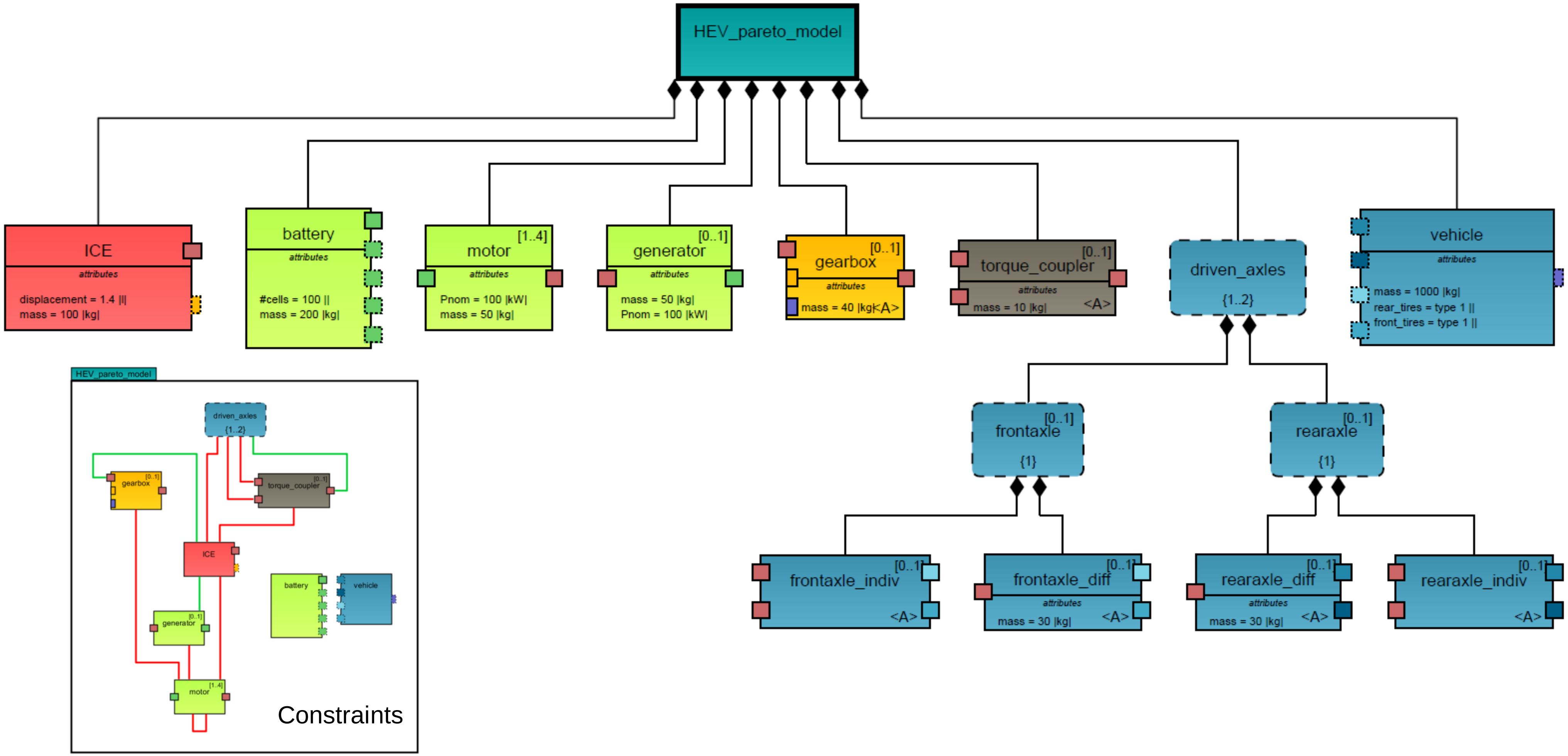


KPI evaluation



Pareto front visualization

System definition
System model



Architecture generation

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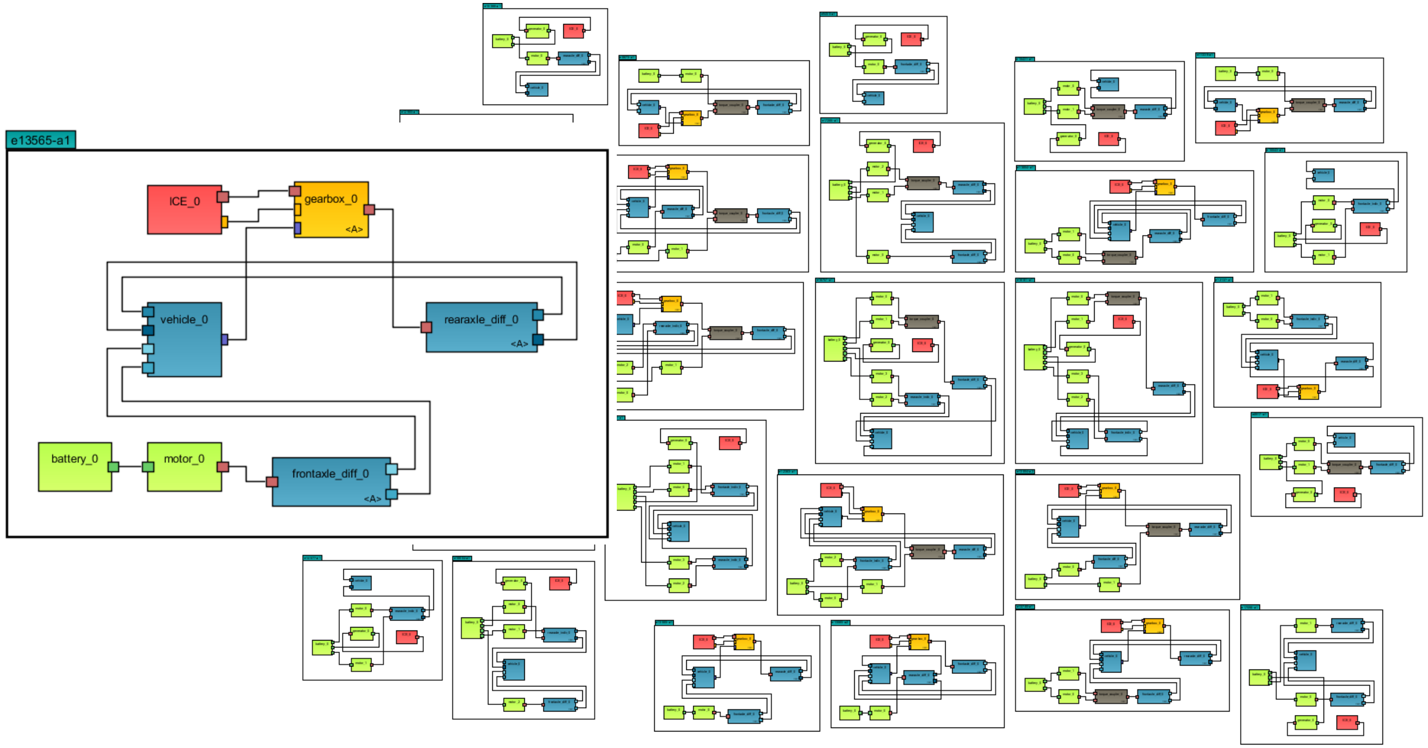
26 topologically different architectures



dimension of component variability

ICE	Electric motor	Battery	Shaft & wheels	Vehicle
3 variants	3 variants	1 variant	1 variant	1 variant
1.5 l 2.0 l 2.4 l	**96 kW, 250 Nm** 50 kW, 200 Nm 33 kW, 210 Nm	96 cells/bank 1 banks in series 1 banks in parallel	Final gear ratio: 3.68	1 560kg
		20.0 Ah	Front tires: 195/50R20	C_d: 0.26 S: 2.11 m²
		Li-Ion (NMC) 3.7 V (cell)	Rear tires: 215/45R20	

KPI definition

Acceleration

Time required for 0-100 km/h acceleration

No traction control
Simple tire models

Fuel consumption

Fuel consumption at cruise @100 km/h, SOC sustaining mode

Optimization on the torque inputs of the torque generating devices, large penalty for deviations on vehicle speed and SOC

System definition | **Architecture generation** | KPI evaluation | Pareto front visualization

Pareto front visualization
Other architectures

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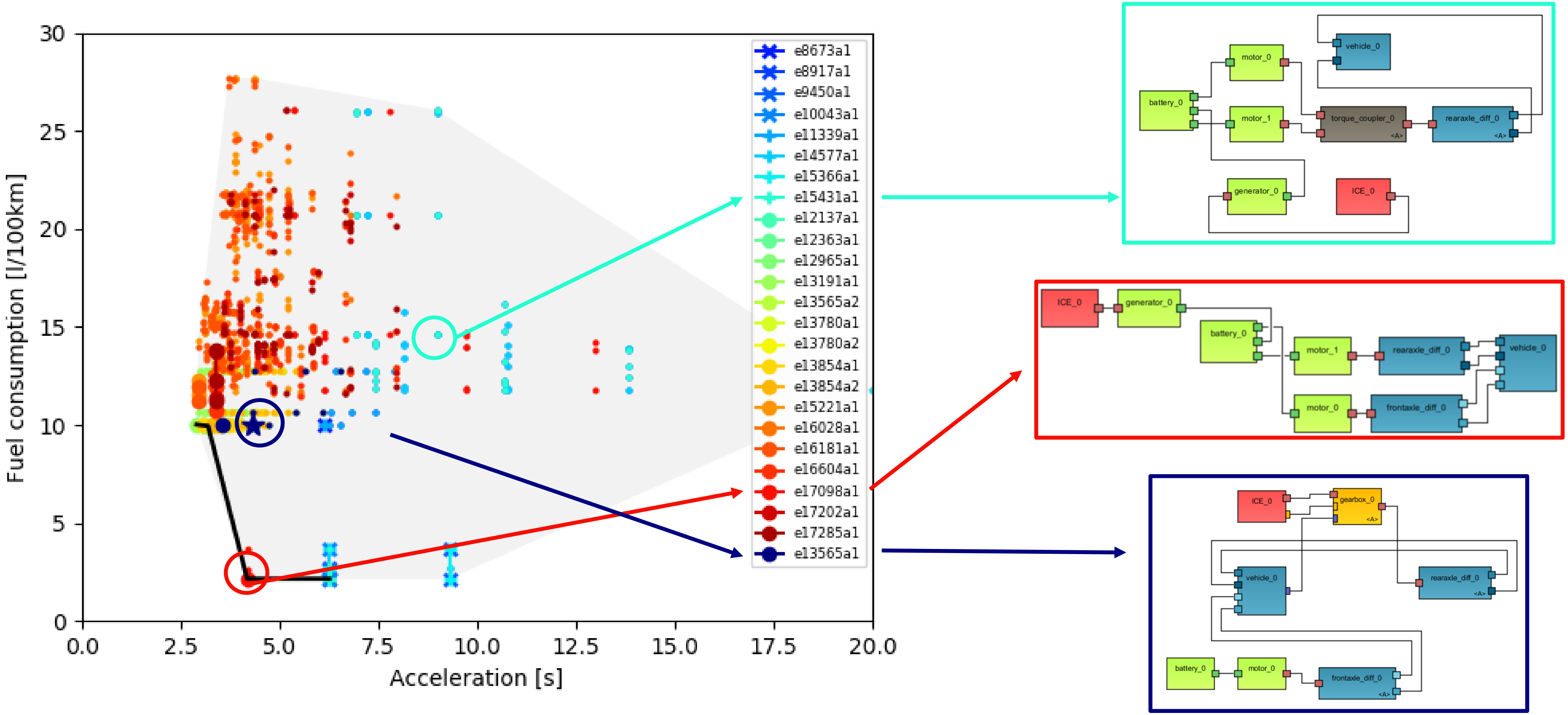

Conclusions

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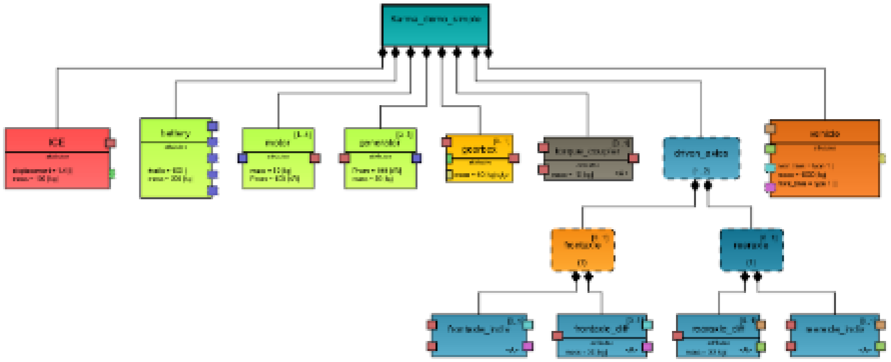
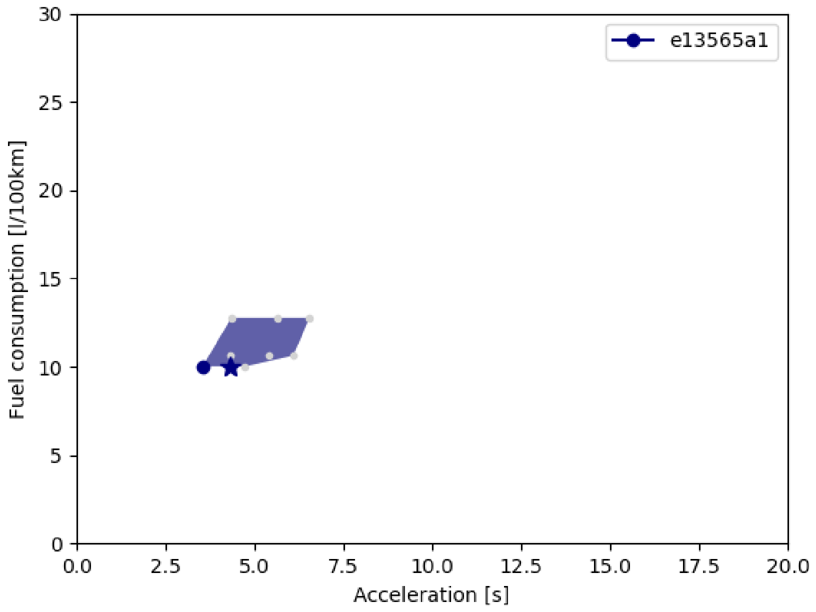
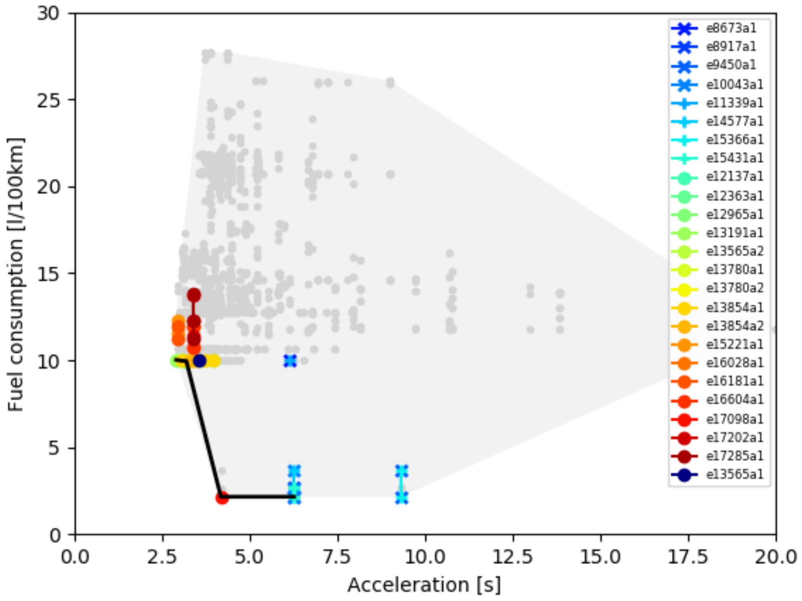
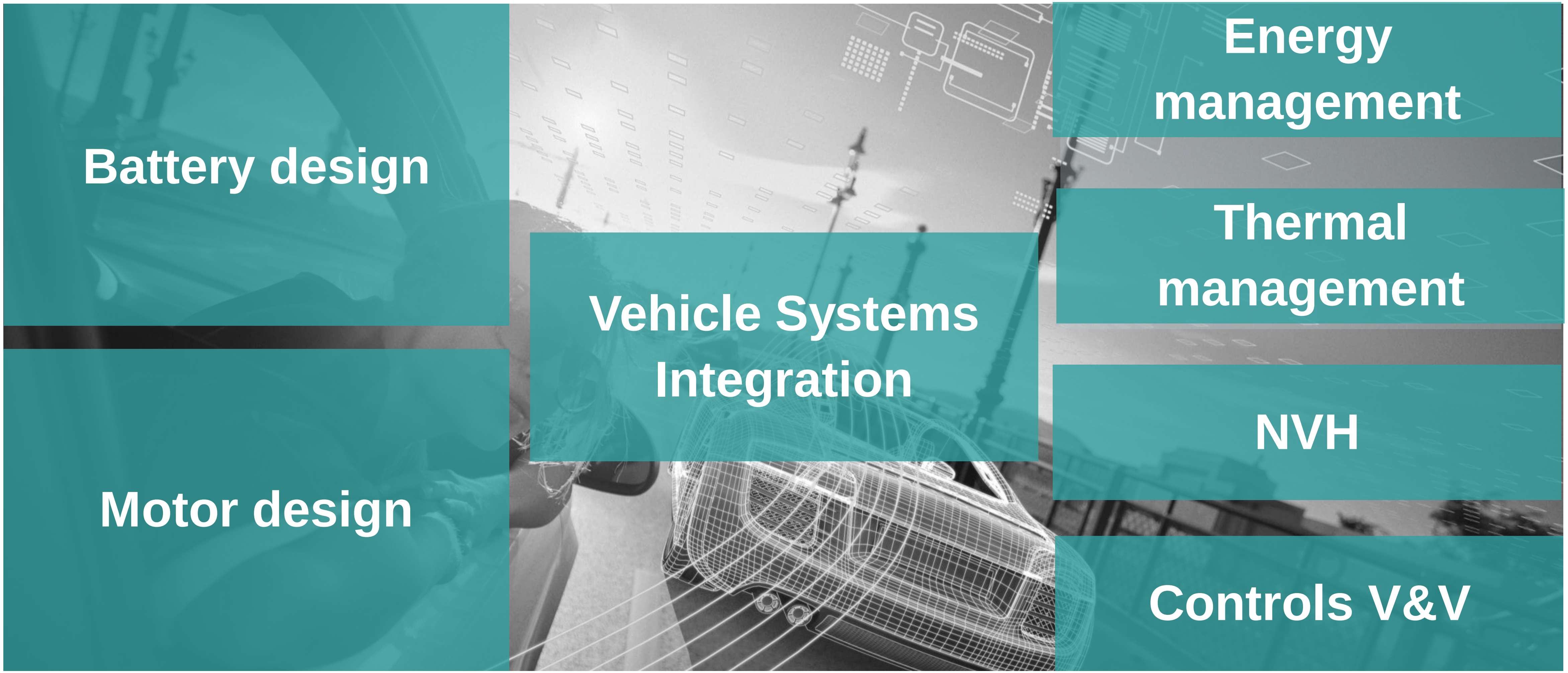
- Generation of architectures from a variant model
- Automatic generation and evaluation of simulation models
- Evaluation of KPI’s allows for a more elaborated decision







Electrified Powertrains
Solution areas with Simcenter



Implications for Powertrain Performance Engineering

Finding the optimal balance between powertrain performances

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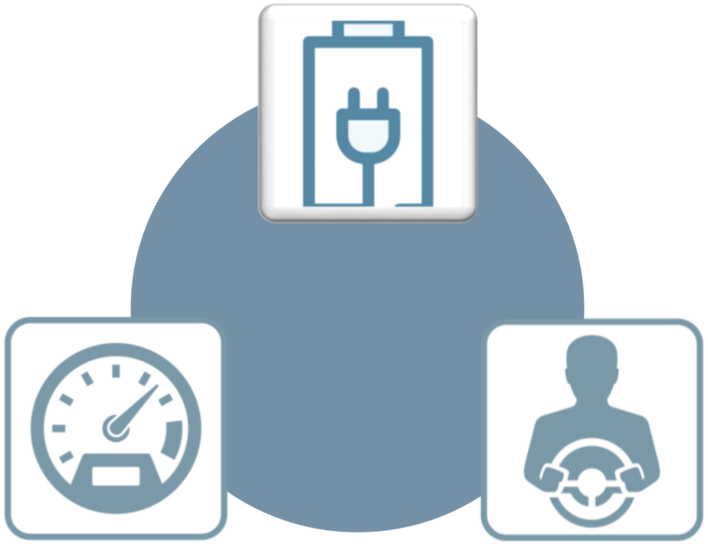
Balance attributes to reach targeted performance levels during integration



Assess the impact of technology implementation on key attributes

Electrification	Engine control	Performance	Reliability
Cylinder deactivation	Gear shifting map	NVH	Drivability
Split cooling	Emission optimization	Thermal comfort	Real driving emissions

Finding the optimal balance between powertrain performances

Delivering solutions with Simcenter

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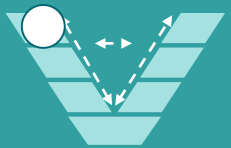
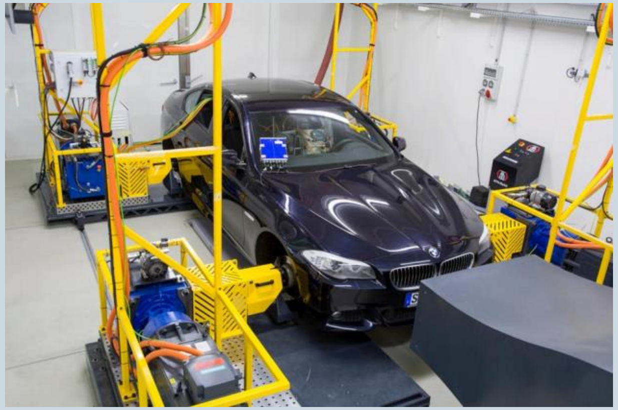


Refining energy management requirements

Objectivize target requirements for next driveline design

In-vehicle testing

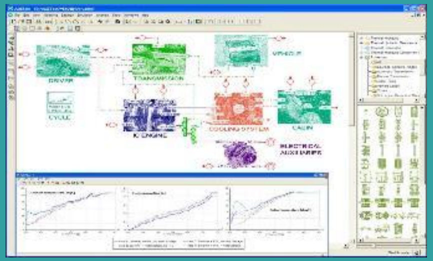


Climatic vehicle cell robot driver, dedicated instrumentation

Integrating test and simulation

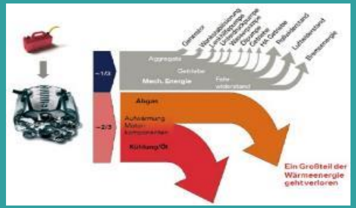
Simulation

- Plant model
- Control
- Multi level
- Multi physics

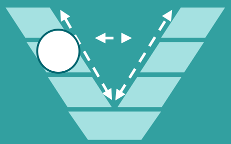


In-depth analysis

- Energy losses & flow
- Benchmarking
- Fuel eco optimization
- Study alternate systems



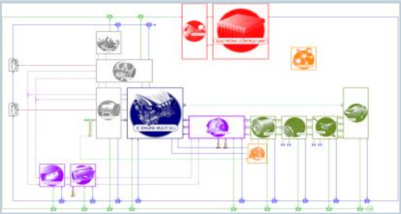
Finding the optimal balance between powertrain performances
Delivering solutions with Simcenter



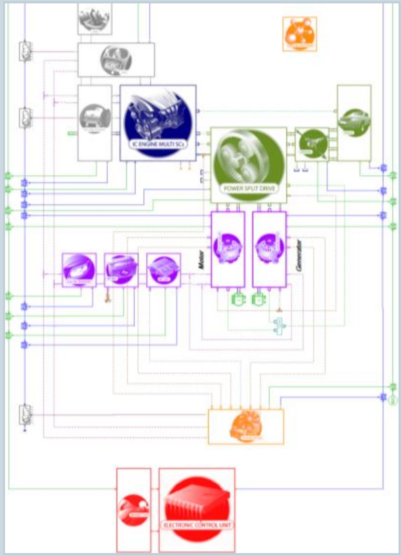
Early trade-off for powertrain configurations

Architectural trade-off for fuel economy, emissions, drivability and low frequency NVH

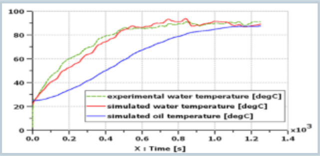
Series hybrid architecture



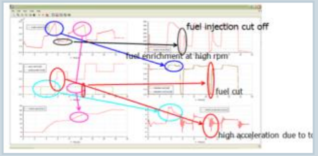
Power Split architecture



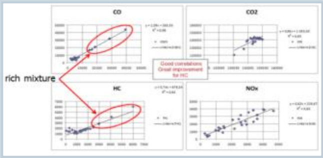
Fuel economy



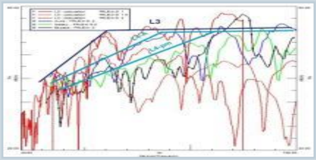
Drivability & comfort

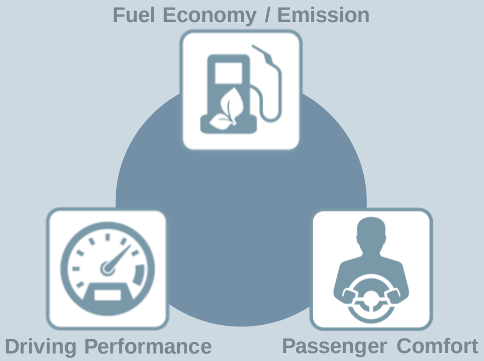


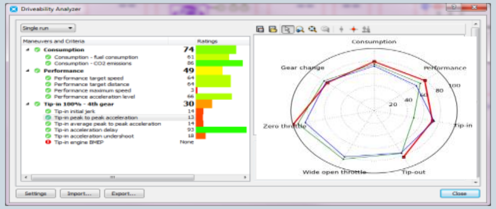
Emissions



Low frequency NVH







Renault

Reaching high energy savings in hybrid vehicles using LMS Imagine.Lab Amesim

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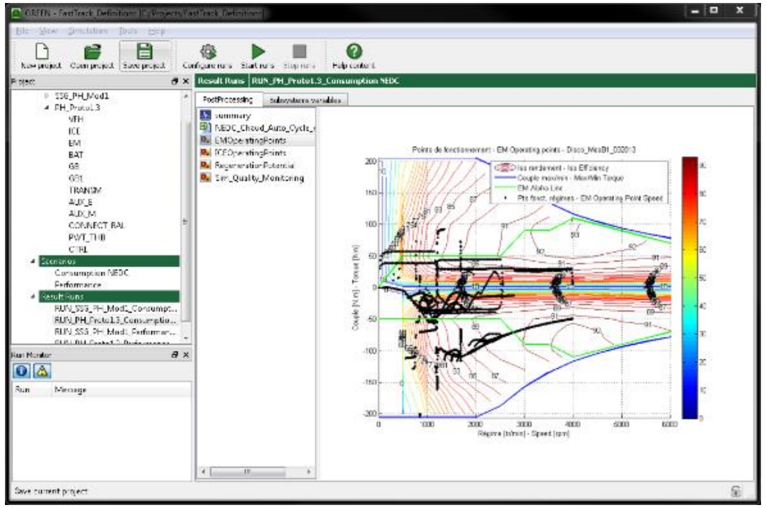
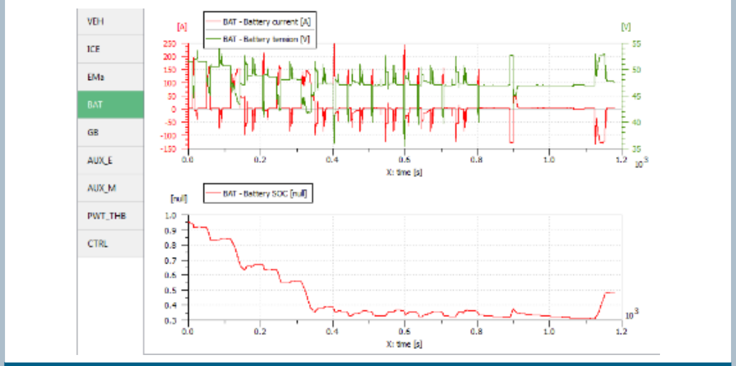
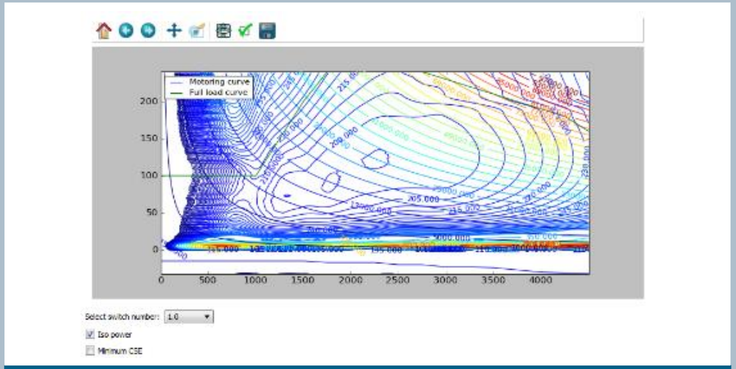


- **Delivered high-quality product on-time and with reasonable costs**
- **Created flexible development platform to support future projects**
- **Shortened time-to-market**

Operating complex multi-domain analyses



Battery behavior simulation



Internal combustion engine analysis

- Facilitate communication and decision-making thanks to a common platform
- Implement co-simulations to assess the energy synthesis of any hybrid configuration

"LMS Imagine.Lab Amesim enables us to get a deep insight on energy performance of hybrid architectures and helps us select optimal architectures that fit our requirements early in the design process."

Eric Chauvelier, Method and Simulation Manager

Optimize Energy Management of Low Emission Vehicles
Simcenter for vehicle performance engineering

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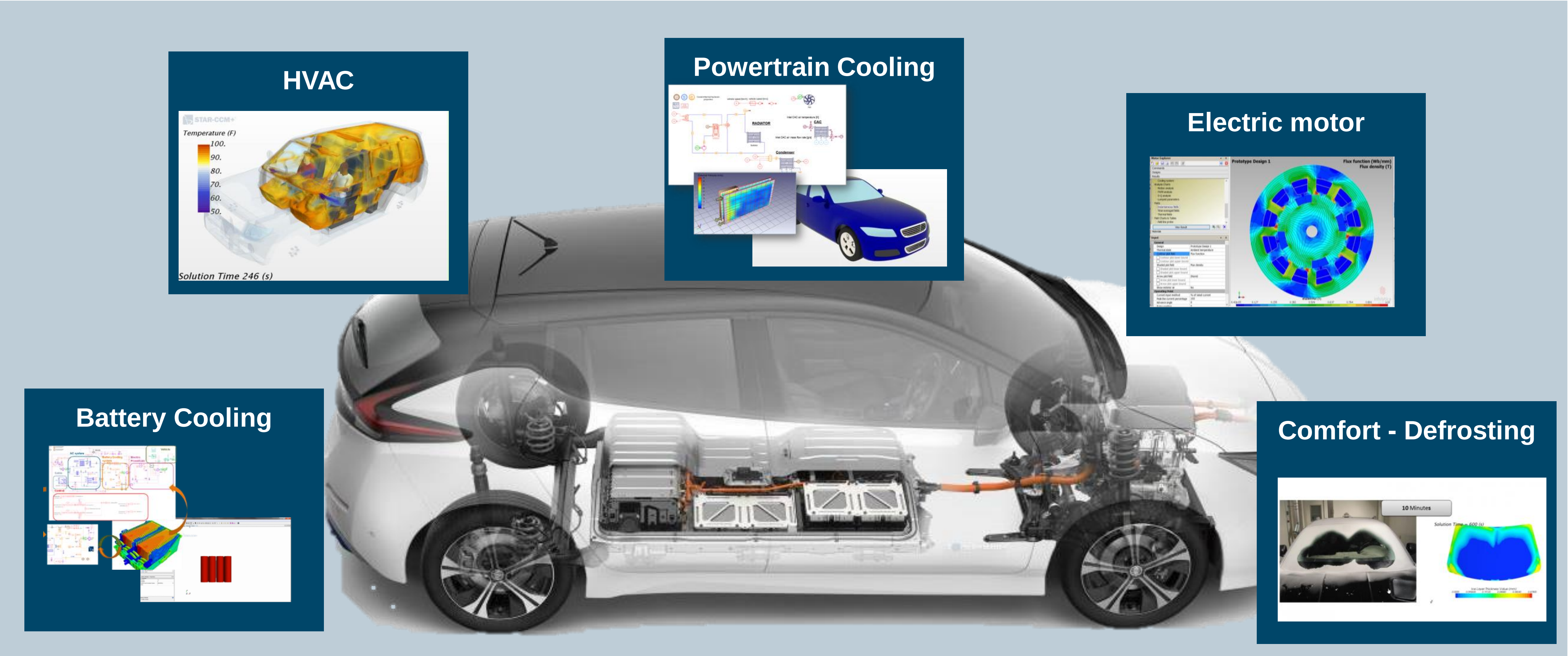

Frontloading Mechatronic System Performance

Scalable use of 1D & 3D system simulation

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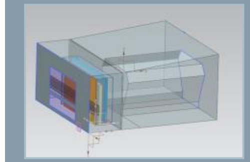
Detailed 3D Geometry not available

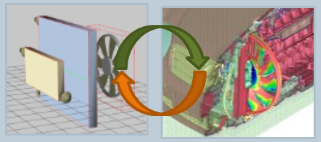
1D **Functional description**



1D + 3D CFD
Parametric Simplified Geometry

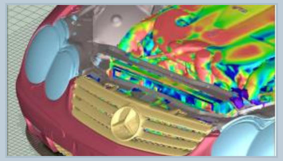
Embedded CFD = Integrated Coupling

Detailed 3D Geometry



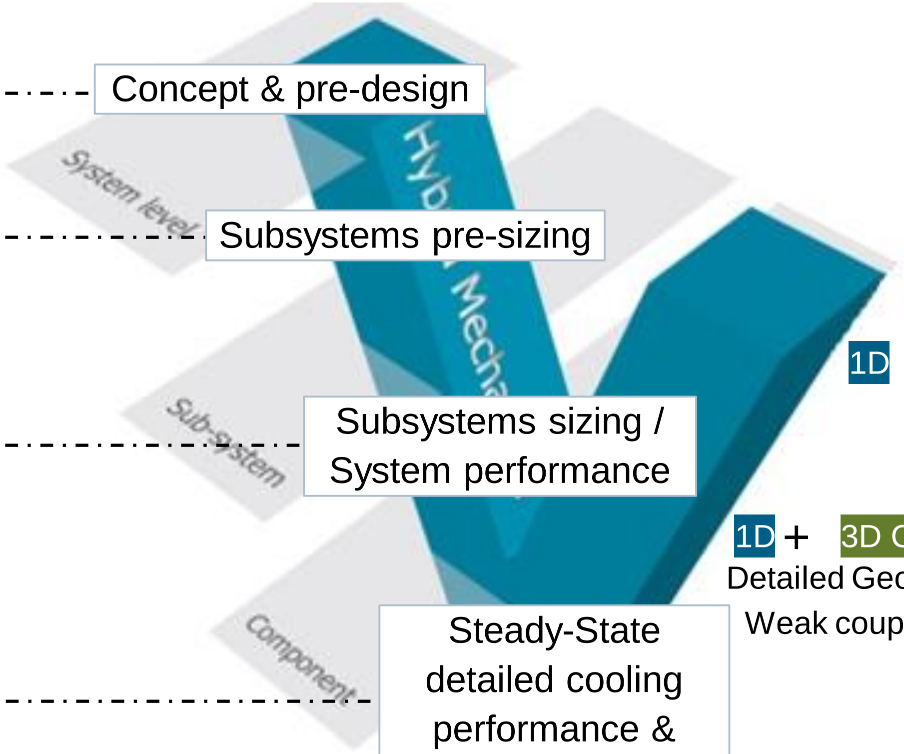
1D + 3D CFD
Detailed Geometry

- **Weak coupling**
- **Co-simulation**



Full 3D CFD
Detailed Geometry

Imposed Boundary Conditions



Concept & pre-design

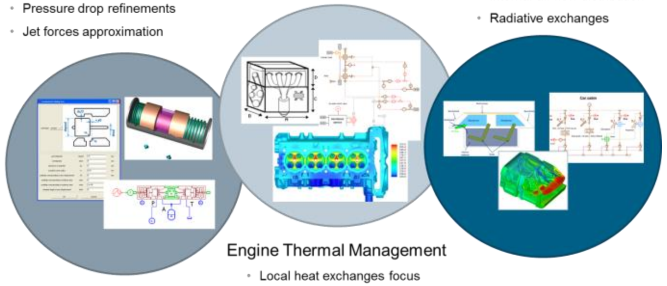
Subsystems pre-sizing

Subsystems sizing / System performance

Steady-State detailed cooling performance & validation

1D + 3D airflow maps

1D + 3D CFD
Detailed Geometry
Weak coupling



Finding the optimal balance between powertrain performances
Delivering solutions with Simcenter

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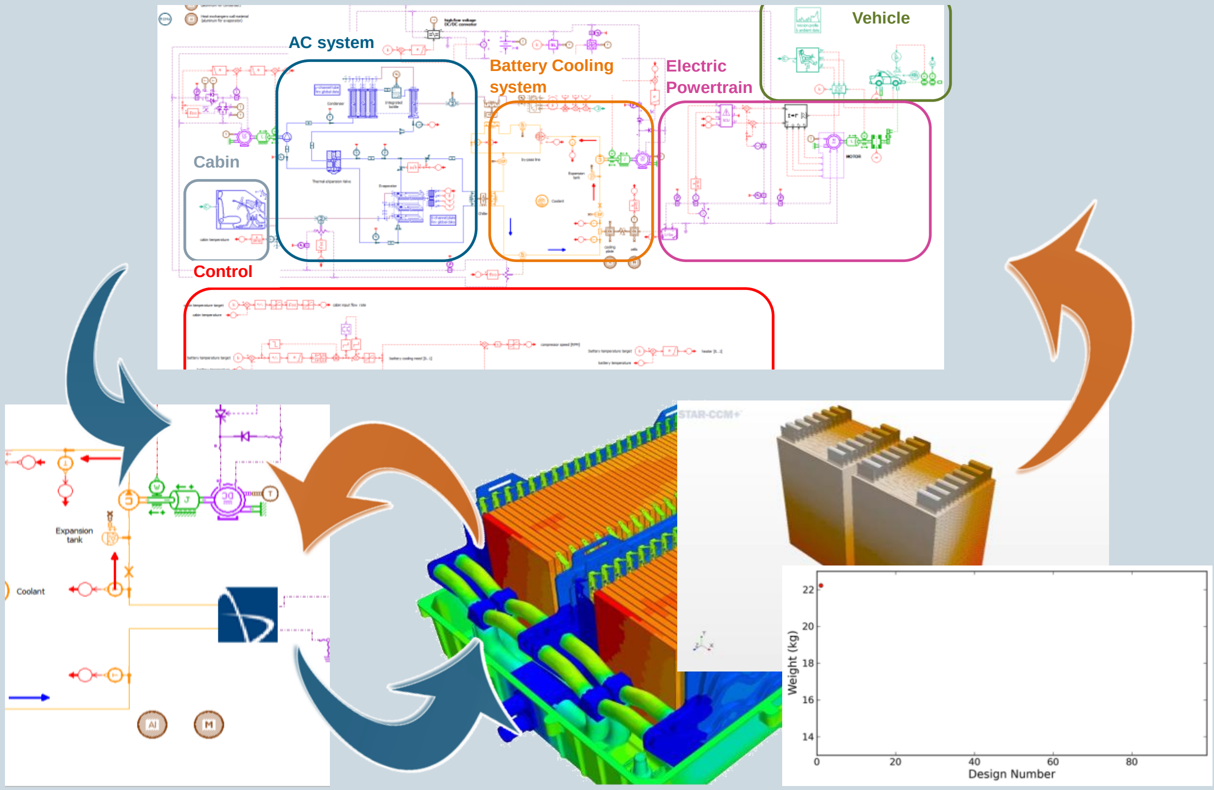
Detailed trade-off

Trade-off battery cooling requirements and vehicle energy management requirements

Balance battery performance to HVAC and control systems

Predict cell temperature variation, and optimize battery pack using full system simulation including battery, electric systems, thermal systems, coupled with detailed 3D cell model



Finding the optimal balance between powertrain performances
Delivering solutions with Simcenter

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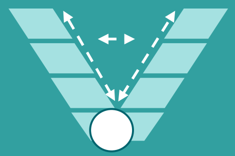
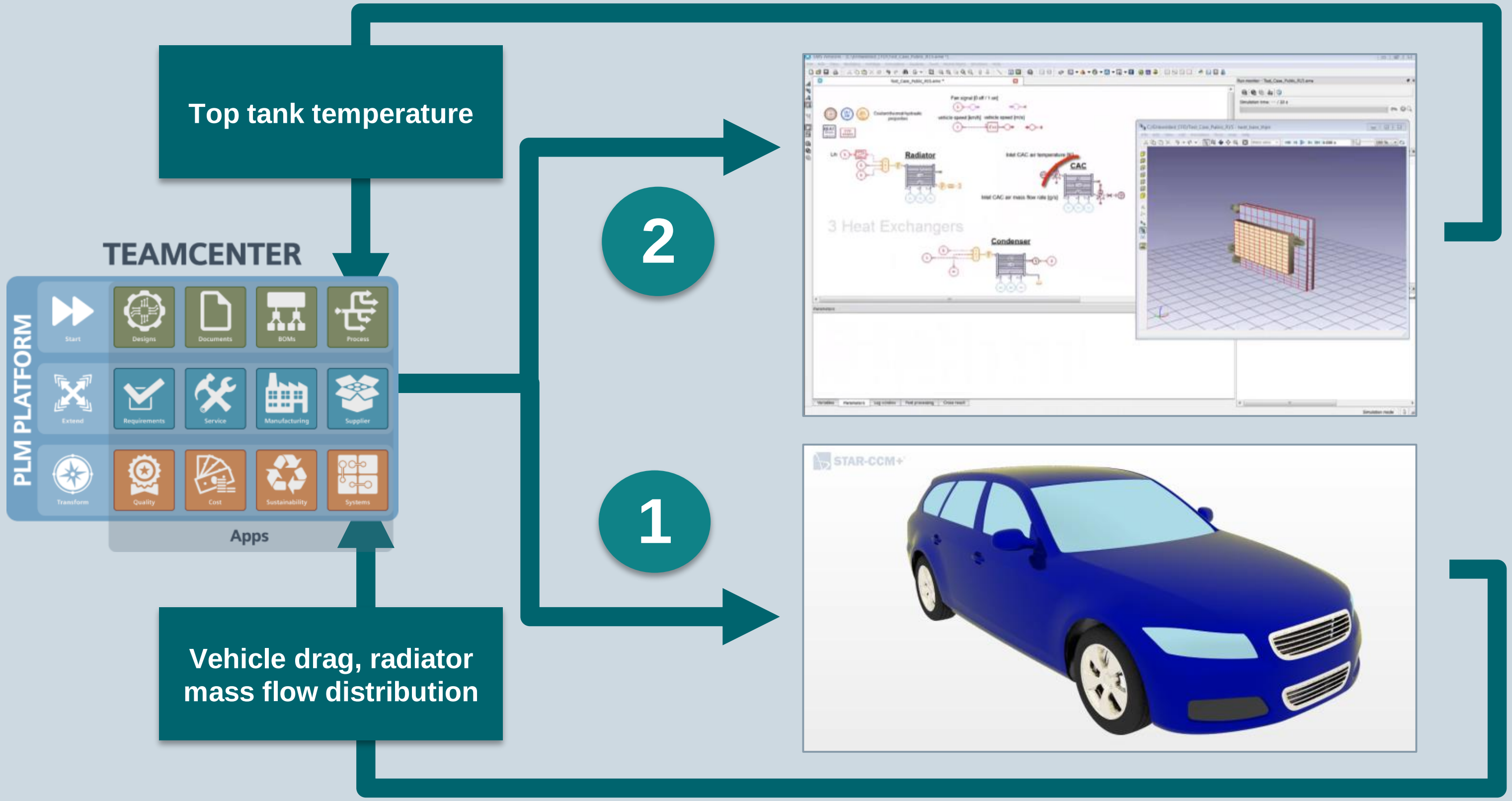


Subsystem versus system trade-off for energy management

Achieve engine cooling performance targets and meet system energy consumption / fuel economy requirements

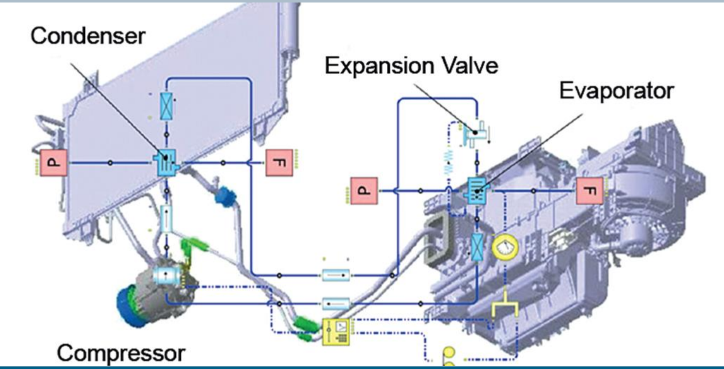


Mitsubishi

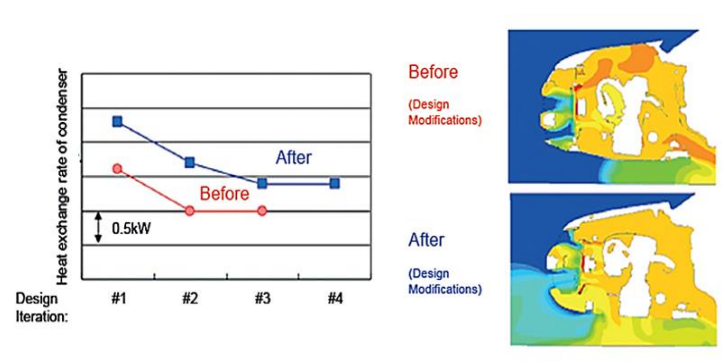
Simcenter enables thermal management for PHEV SUV

- **Ensured SUV has extended range while balancing thermal challenges in the design.**
- **Enabled cutting edge innovation for Plug-in Hybrid Electric Vehicles**
- **Conducted loosely coupled 1D/3D simulation to enable different drive conditions.**

Vehicle thermal management study using 1D & 3D CFD



HVAC System with Simplified 1D Network



Using 1D Simulation Coupled to 3D for Improved Idle Performance

- Used 1D and 3D CFD to define all internal thermal ventilation for optimal performance.
- 3D CFD applications include cabin comfort, windshield defrosting, air ventilation duct design, radiator and underhood thermal design.

“Currently, our 1D and 3D co-operative analysis approach is leading our accuracy improvements. We use it to evaluate equipment parts and it is ideal to have the performance of each single, required AC part, simulated to satisfy the targeted cooling system performance level. “

Optimize NVH of Low Emission Vehicles

Simcenter for vehicle performance engineering

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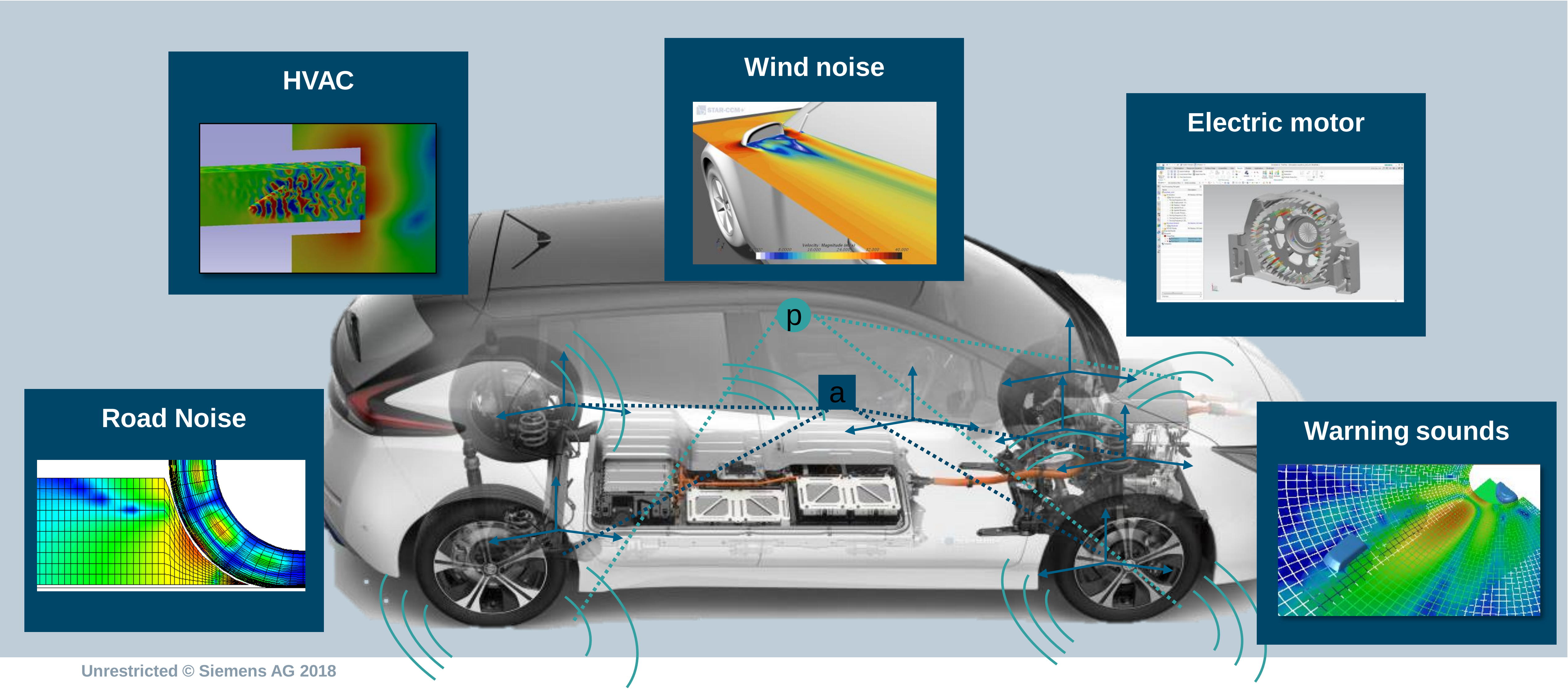
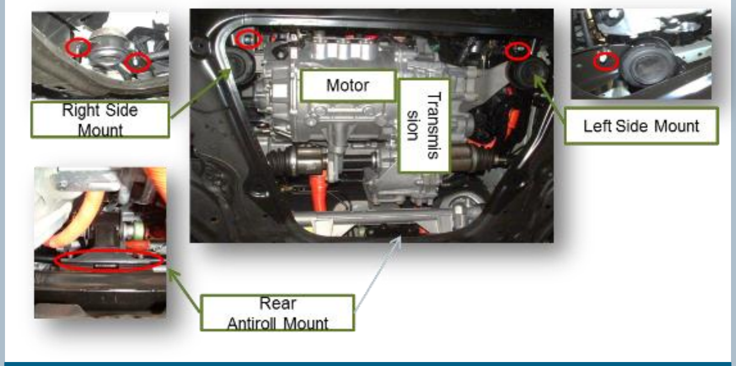


Target Setting – Requirements – EV - Specific Noise performance

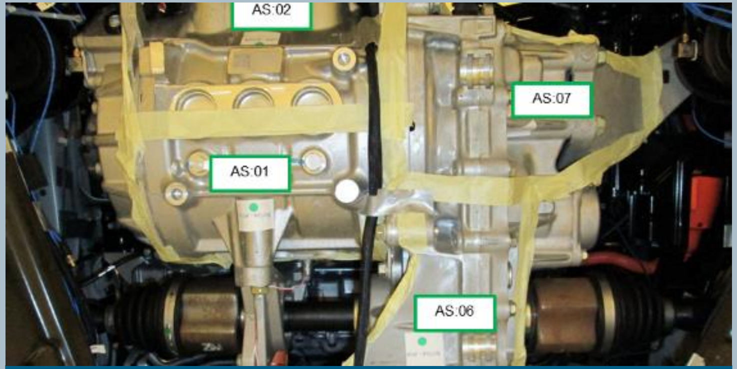
Source-Transfer-Receiver methodology

- **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.

BYD Auto Company Limited

Boosting NVH performance of plug-in hybrid and electrical vehicle fleet

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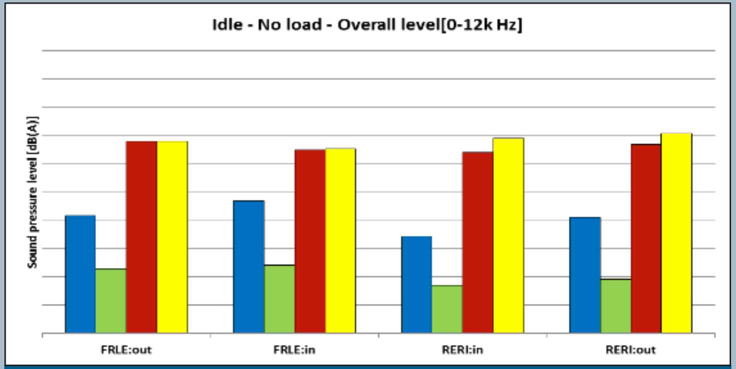
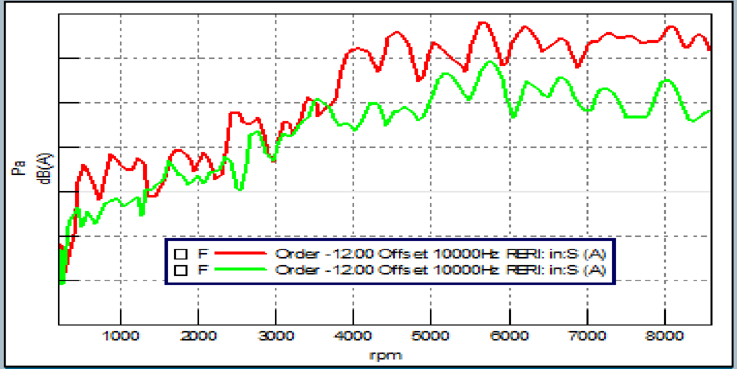
- **Reduced noise and vibration levels in hybrid vehicles and other NVH-related problems, such as wind and cooling pump noise**
- **Optimized overall hybrid vehicle structure for NVH performance without compromising other quality parameters, such as drivability and handling**

Improving the NVH development and control process



Target setting and benchmarking



NVH optimization

- Dedicated and comprehensive troubleshooting methodology
- Integrated simulation and testing to determine and resolve the root causes of problems

"15 versions of the Qin were praised for NVH performance by our customers. Working together with Siemens Simcenter Engineering for NVH optimization has helped us position ourselves as the top seller in plug-in new energy vehicles"

Zhang Rongrong, Manager NVH performance research division

Balancing performances for low emission vehicles
Simcenter for vehicle performance engineering

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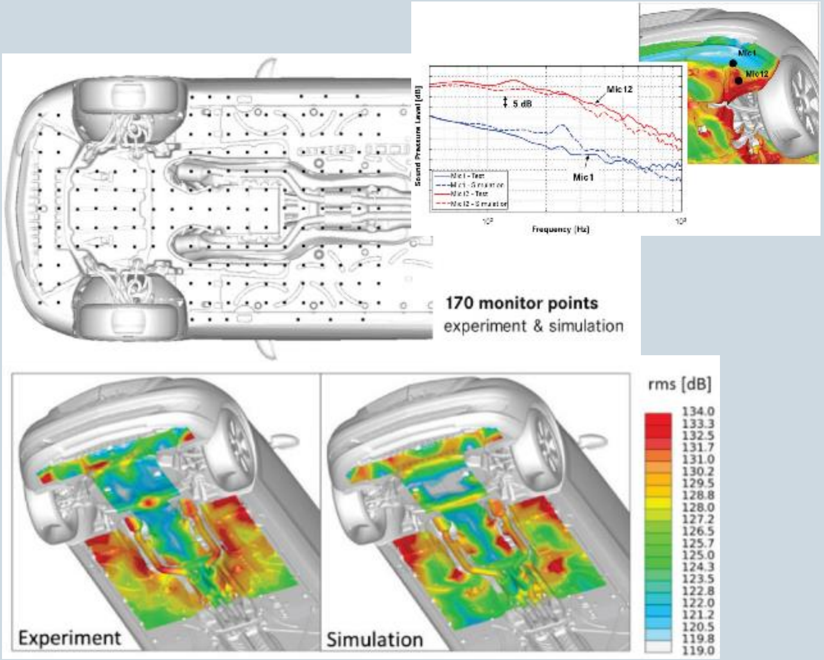
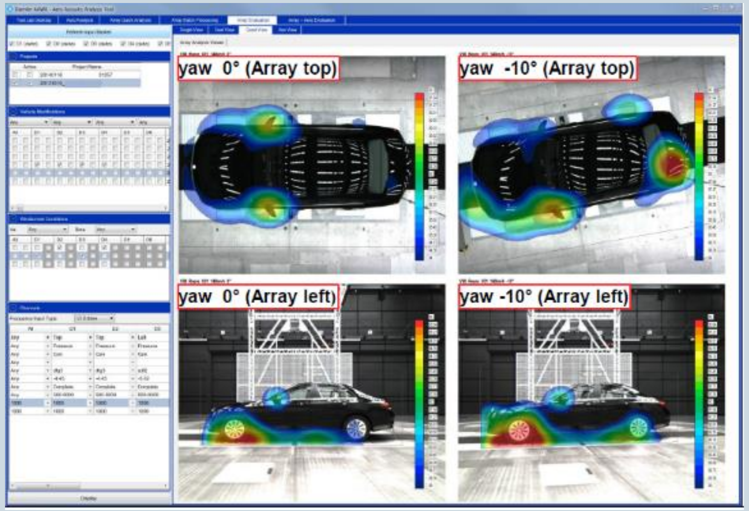
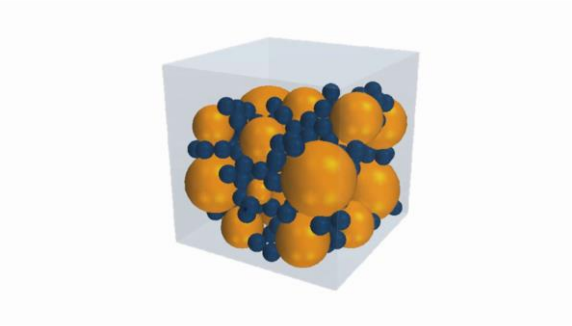
Electrification impacts NVH balance
Developing the digital twin for aerodynamic and wind noise

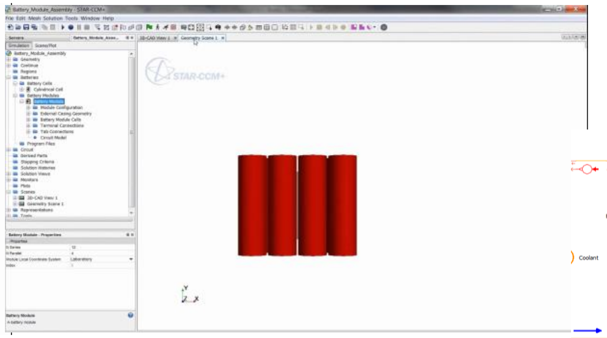


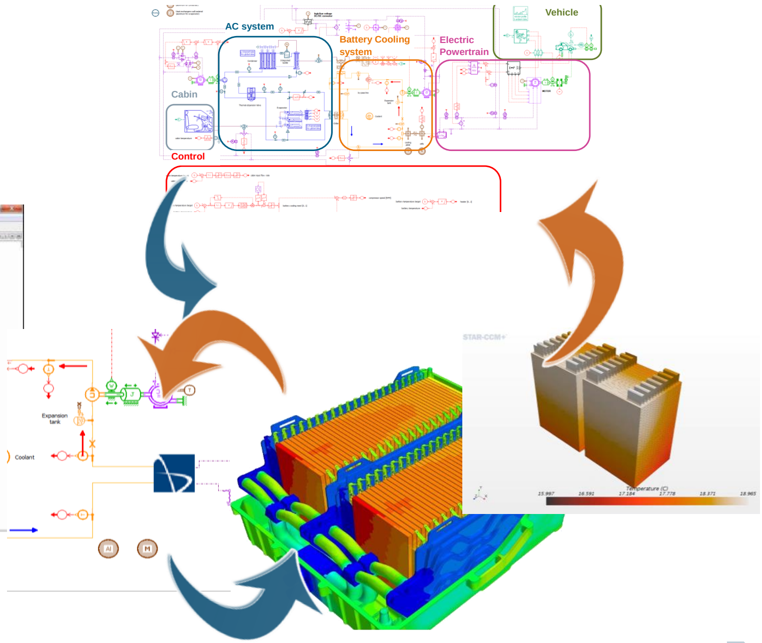
Ref. "The New Daimler Automotive Wind Tunnel Acoustic Properties and Measurement System", Published at 10th FKFS Conference 2016



Siemens Battery Modelling Expertise







Micro-structure Electrochemistry

Virtually test SEM produced electrode geometry

Conduct design studies on new concepts

Virtual Cell Design and Test

Detailed geometrical representation coupled to performance model to build cell digital twin

Battery pack design

Flow, thermal & Electrochemistry analysis of complex power systems

Study detailed spatial effects at cell, module & pack level

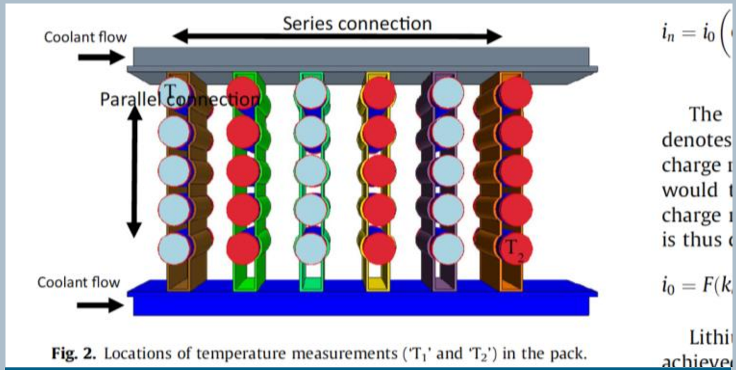
Overall System Design

Interface Module & Pack 3D analyses with complex power train 1D functional system models

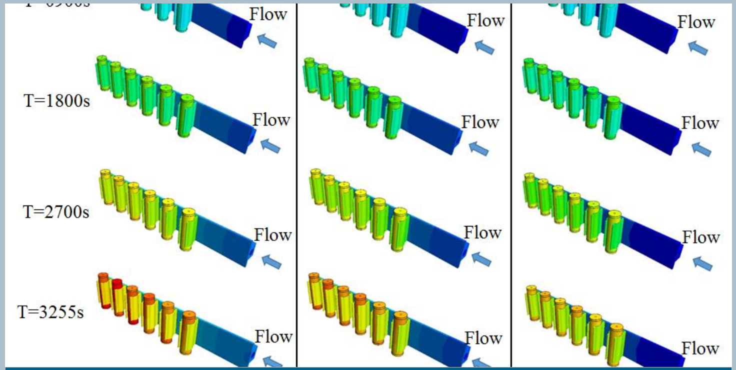
Samsung India
Improves battery pack cooling using STAR-CCM+

- **Designed novel liquid coolant based thermal system**
- **Predicted sensitivity of thermal performance to contact resistance**
- **Reduced thermal variation inside batter pack**

Improving the cooling system for jelly roll batteries



Examining tradeoff between pressure loss on coolant system to temperature uniformity



Exploring the effect of coolant flow rate on jelly roll temperature

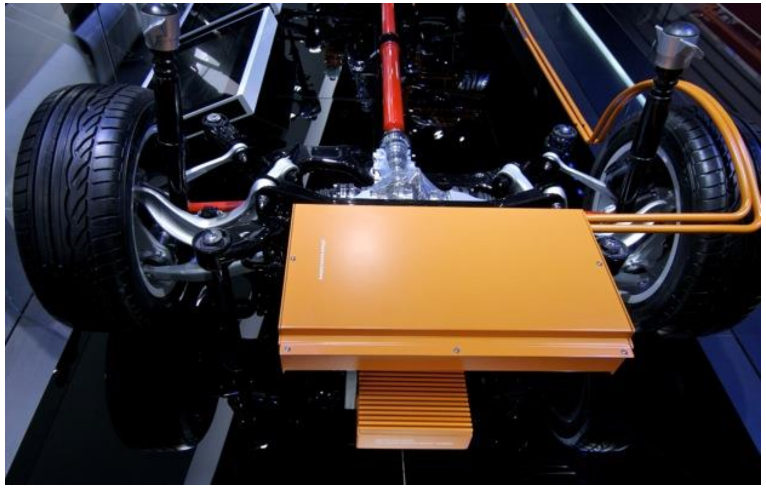
- Thermal systems is critical for high performance and long battery back life
- Simulation helps maintain batteries in narrow temperature range

"Using the CFD-based TMS functional model created with STAR-CCM+ and Battery Design Studio, a close agreement between simulations and experimental measurements was achieved, validating the model against experiment with greater than 90 percent accuracy"

Dr Suman Basu – Senior Chief Engineer

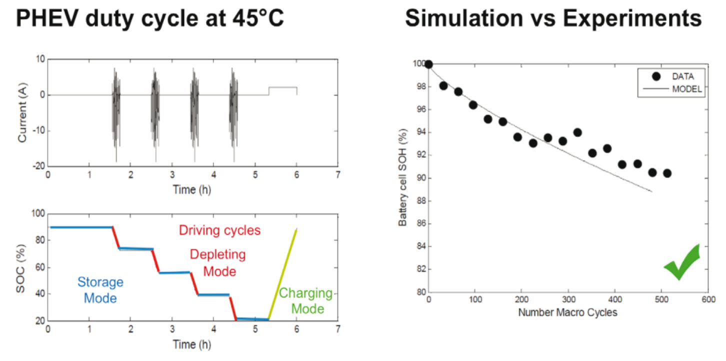
IFP Energies nouvelles

Enhancing battery lifetime modeling using LMS Imagine.Lab Amesim

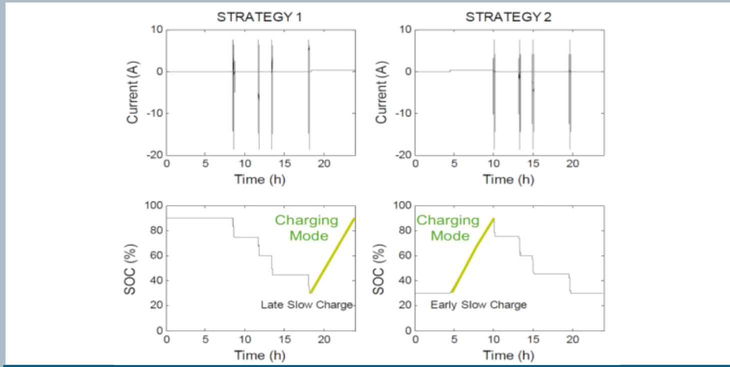


- **Built easy-to-use, high-fidelity aging models**
- **Obtained reliable aging simulation results**
- **Analyzed 10 years of battery behavior in a few hours**

Towards a robust battery aging behavior model



Validated PHEV battery model



Charging strategy influence on battery life

- Encapsulate fundamental physical phenomena
- Analyze electrochemical energy storage system behavior

“I strongly believe that LMS Imagine.Lab Amesim will become a best-in-class battery modeling and simulation platform (…)”

Eric Prada, Electrochemical R&D Engineer

Electric Machine design…
A true multi-physics problem

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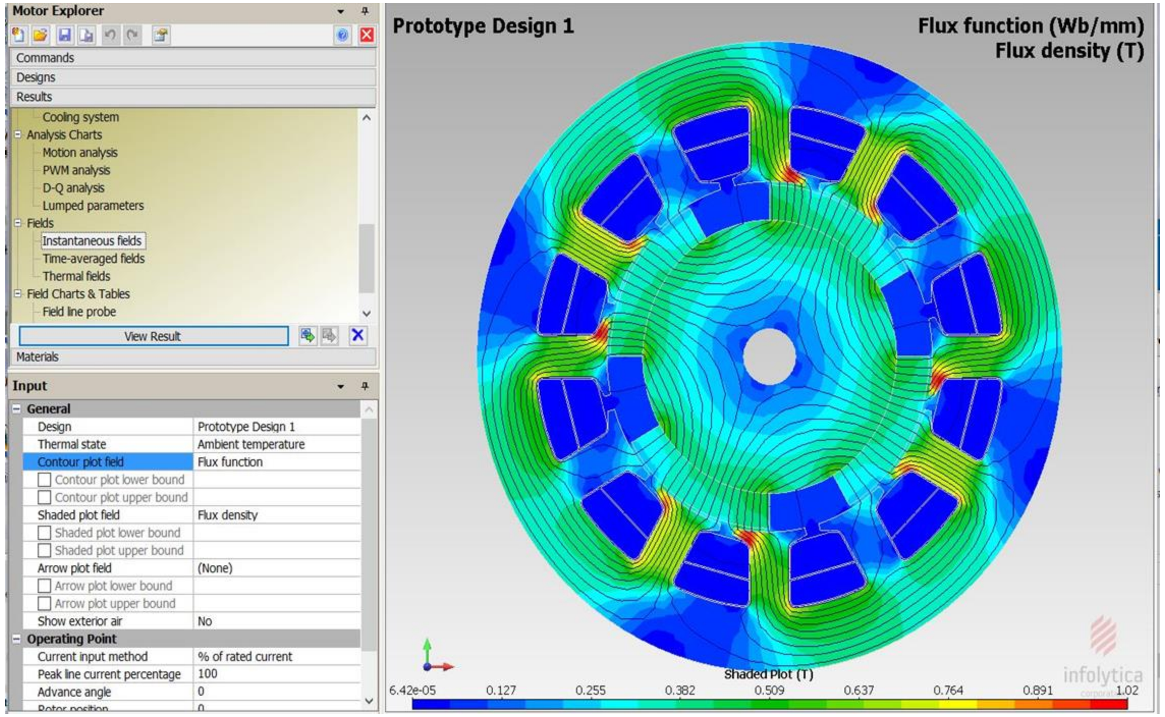
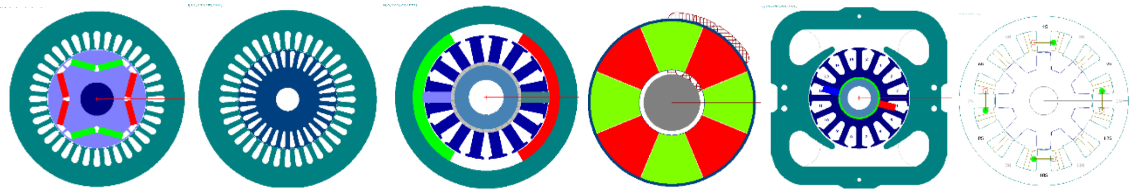
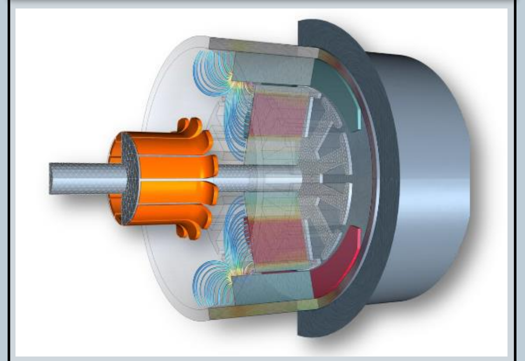


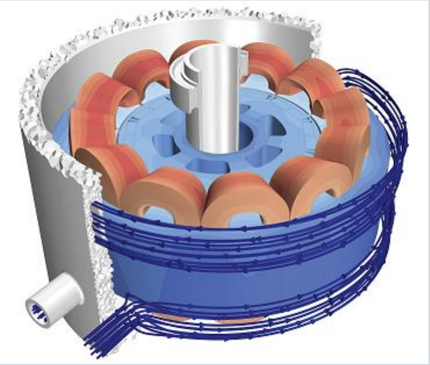
Discover Better Designs, Faster!



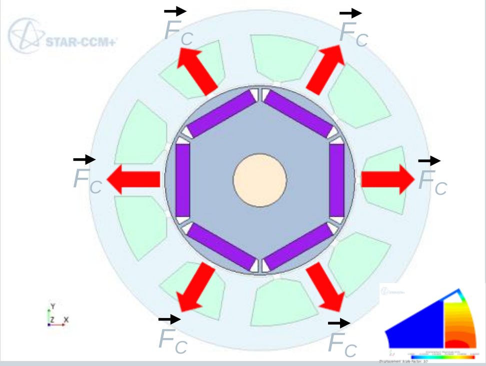
1. Electromagnetics



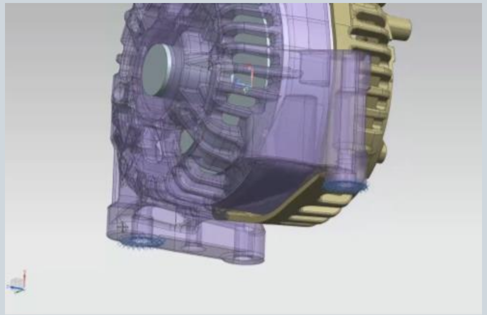
2. Thermal / CFD



3. Stress Analysis



4. Vibro-acoustic



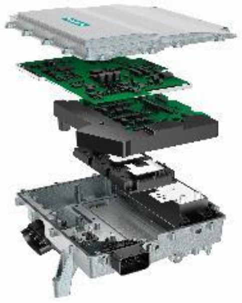
Siemens eCar Powertrain Systems

Designing advanced components for e-mobility with LMS Imagine.Lab

- **Streamlined design and customization process for all e-mobility devices**
- **Fulfilled market demands based on standardization and scalability**
- **Shorter development cycles and lower costs**

Forward through model-based systems engineering

Component behavior analysis for pre-sizing



Full vehicle assessment for performance and efficiency optimization

- Predict the efficiency of required powertrain electric components
- Re-use knowledge capitalized from past work and experience

“The implementation of model-based systems engineering is driving our innovation platform, and enables us to combine architecture definition with simulation capabilities to validate technical choices early in the design cycle”

Wolfgang Nebe, Director System Technology, eCar Powertrain Systems business unit

Electrified Powertrain

Solution areas with Simcenter

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