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Absicherung des thermischen Verhaltens im Fahrzeugbau

Jörg Meinlschmidt & Helge Tielbörger | 10:00-11:00 Uhr

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Conference Code: 861 802 1958#

Herzlich Willkommen

Jörg Meinlschmidt

Portfolio Development
Siemens PLM Software

- Studium Maschinenbau TU München
- 5 Jahre Forschung im Bereich „Einsatz von CAE-Methoden in der Produktentwicklung“
- Seit 2006 bei Siemens PLM Portfolio Development Engineering Services

Dr. Helge Tielbörger

Portfolio Development
Siemens PLM Software

- Studium der Luft- und Raumfahrt
- Promotion im Bereich Mehrphasenströmung
- Seit 2011 bei Siemens PLM Portfolio Development Systemsimulation

VEM / VTM Through the Vehicle Program
Contents

Introduction

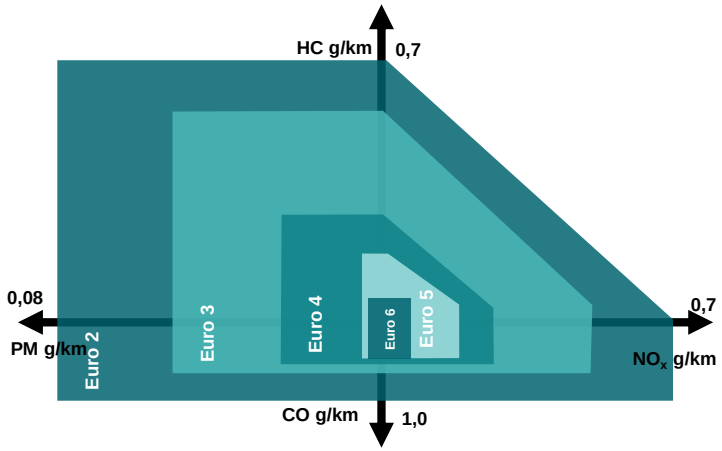
Vehicle Thermal Management Solution through the Development Cycle

- Testing solution
- 1D System level modelling
- 3D CFD approaches
- Combined 1D-3D strategies

Working in the boundaries of a stringent legal & financial environment

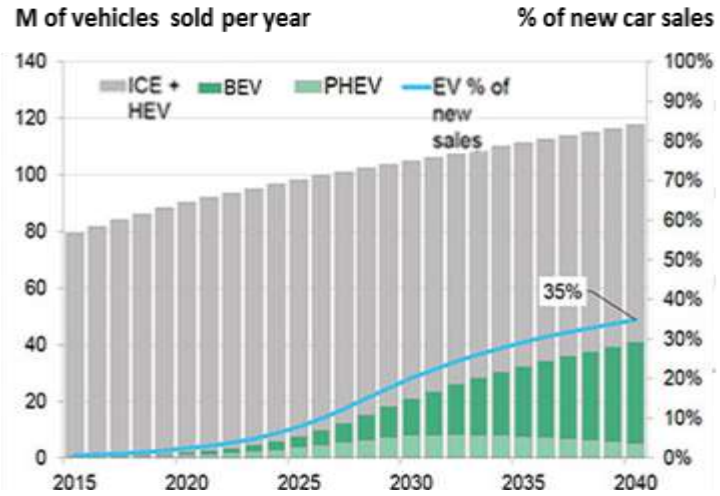
Stricter Regulations
Europe driving emissions control

Digital technology enabling reduced costs, and time to market.



Increased Complexity
Hybrids to full EV

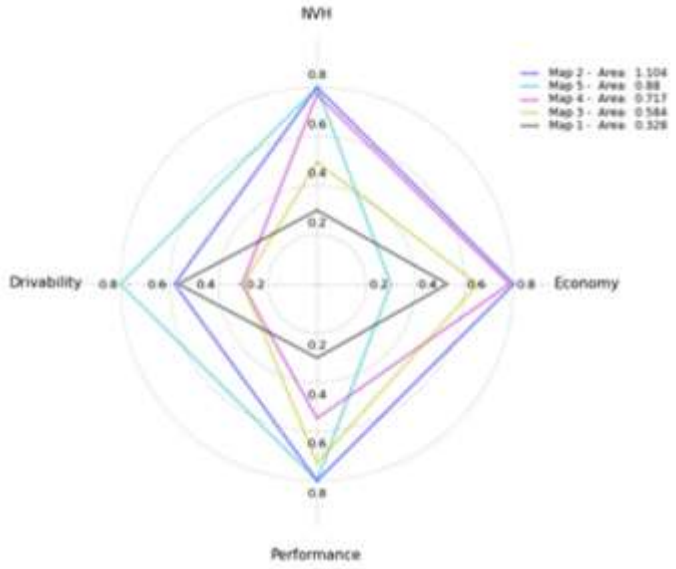
Electric vehicles (HEVs & EVs) share could range from 10-50% of new vehicle sold in 2030.



Source: Bloomberg New Energy Finance

Reduce Cost & Time
Maintain brand value

Adoption of right technology and finding the best balance differentiates those that thrive from those that fail



Thermal Management Challenges

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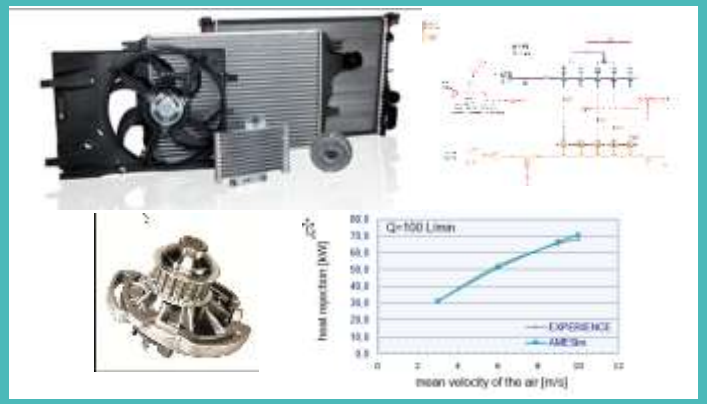
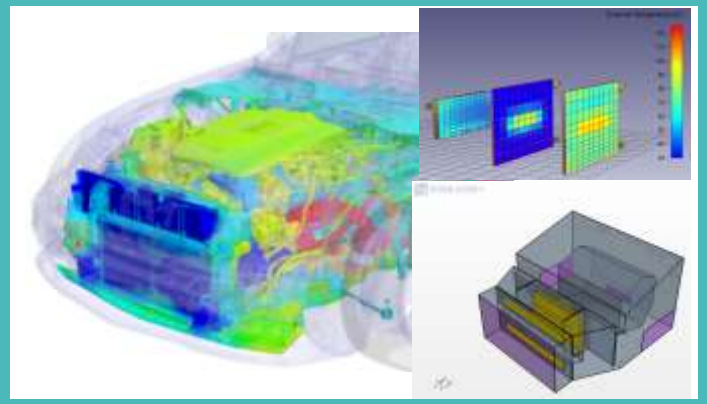
Define flow requirements and pre-sizing of heat exchanger and cooling pumps



Easily assess and validate heat exchangers packaging & design and controls strategies



Balance aerodynamic drag and efficient thermal management

Siemens Offering and Expertise

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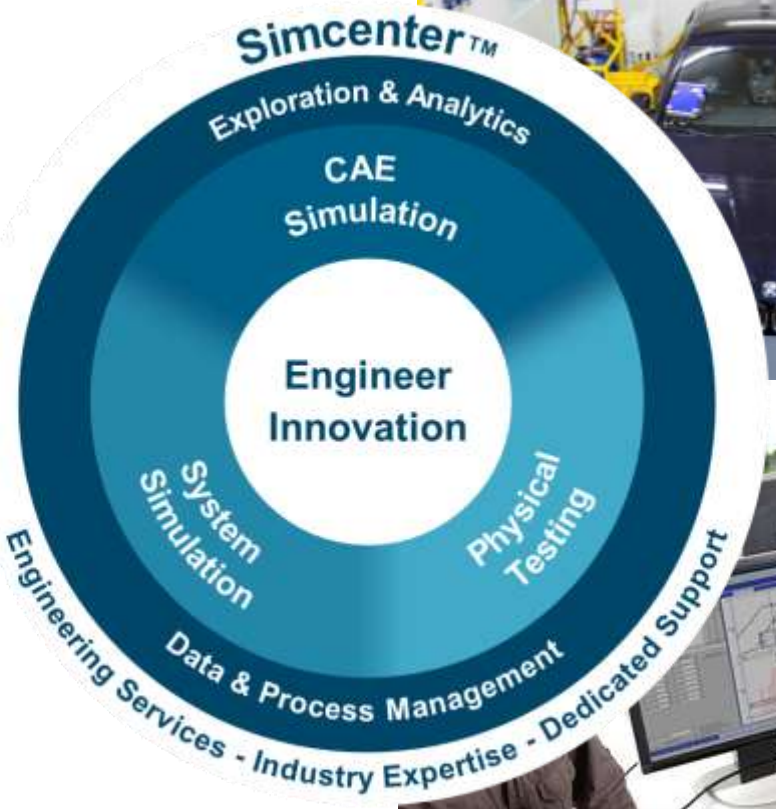
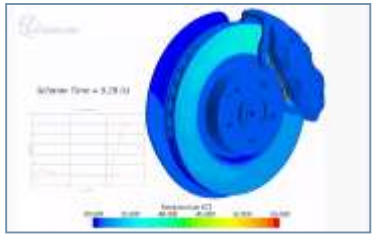
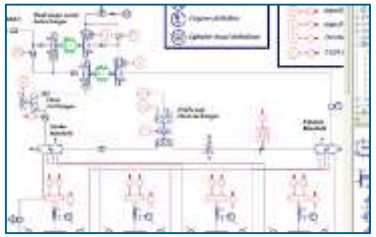
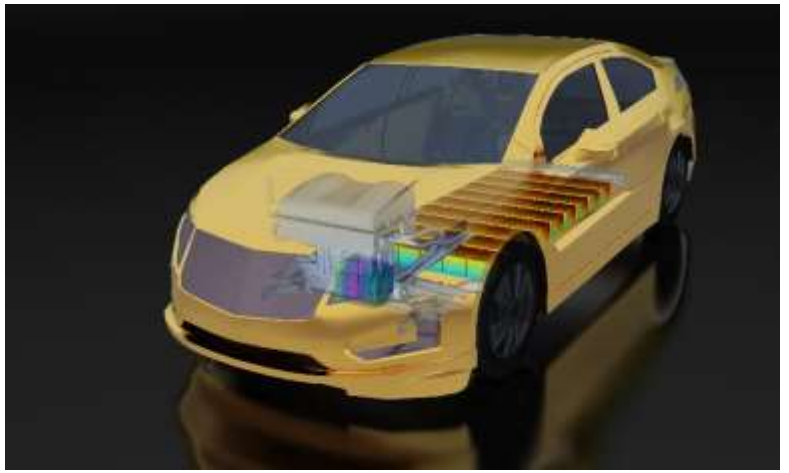
Engineering Services



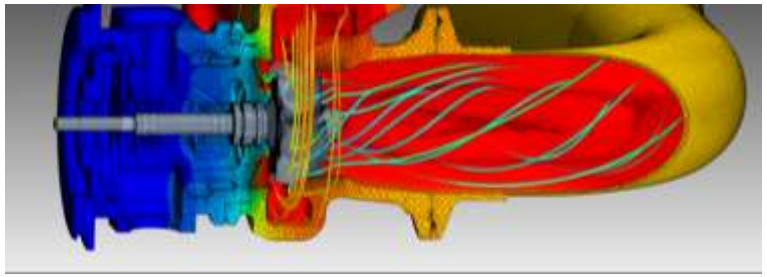
Testing Solutions







Scalable 1D-3D Simulation Solutions



VEM / VTM Through the Vehicle Program
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Introduction

Vehicle Energy Management Solution

- **Testing solution**
- **1D System level modelling**
- **3D CFD approaches**
- **Combined 1D-3D strategies**

Simcenter™ Portfolio for Predictive Engineering Analytics

Energy management and Performance Attributes Balancing – Digital Twin

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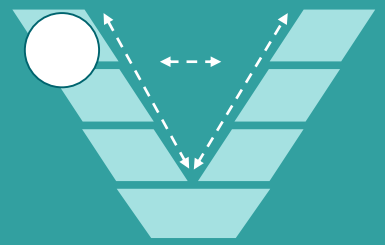
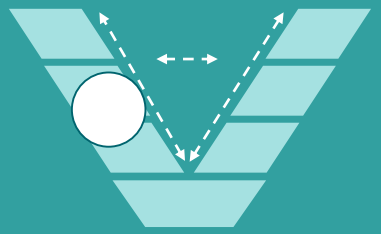
Requirements → Concept & Architecture → Virtual Design, Verification & Validation → Physical Design, Verification & Validation → Launch

Program Planning

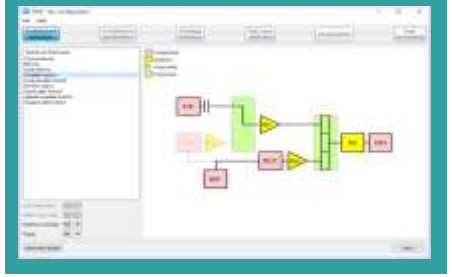


Requirements Capturing
Target setting

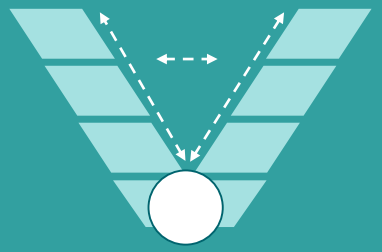
Initial Design



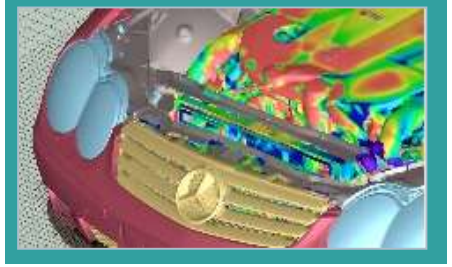
Architecture Selection
and Evaluation



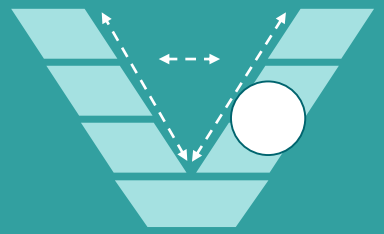
Detailed Design



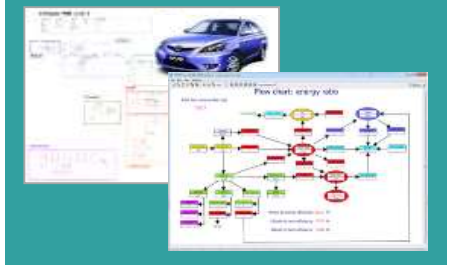
Subsystem Design
Validation & Testing



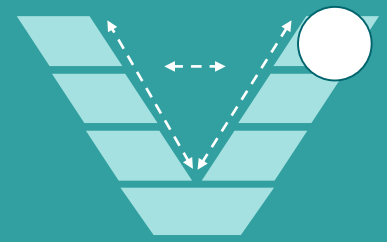
Perf. Attributes



Vehicle Integration Design
Validation & Testing



Program Verification



Prototype Validation
Certification

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Integrated test and simulation process

- ✓ Define the right test for the simulation needs
- ✓ Build and validate the rights models
- ✓ Merge test and simulation results for deep analysis
- ✓ Testing competing technology
- ✓ Benchmarking

Vehicle Energy / Thermal Management
Target Cascading and Performance

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- Model scalability and associated test requirements
- Specify required data and data acquisition methodology
- Interface contract between subsystems but also stakeholders
- Engineering performance evaluation (post processing and metrics)

Level 0
Vehicle

Performance Analysis (metrics)
- Fuel consumption
- Battery SOC
- Thermal passenger comfort

Level 1
Subsystems

What if study / Control Calibration
- Gear shifting calibration
- Gear ratio set optimization
- Benchmarked transmission integration
- …

Level 2
Components

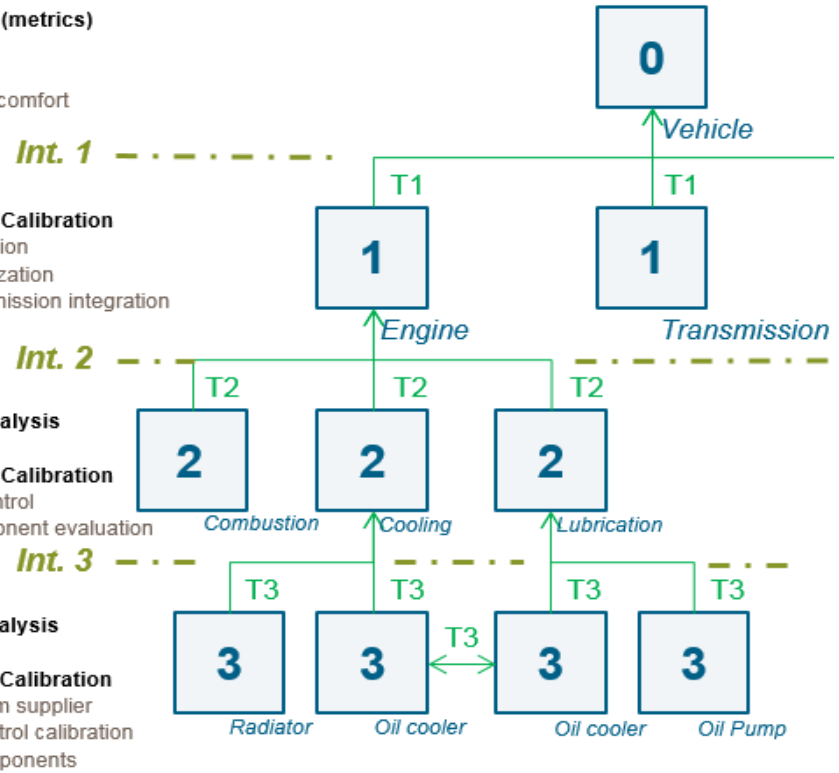
Energy Distribution Analysis
- Energy flow charts

What if study / Control Calibration
- Engine actuation control
- Benchmarked component evaluation
- …

Level 3
Components / Thermal

Energy Distribution Analysis
- Energy flow charts

What if study / Control Calibration
- New exchangers from supplier
- Fan / thermostat control calibration
- Electrification of components



Vehicle Energy / Thermal Management
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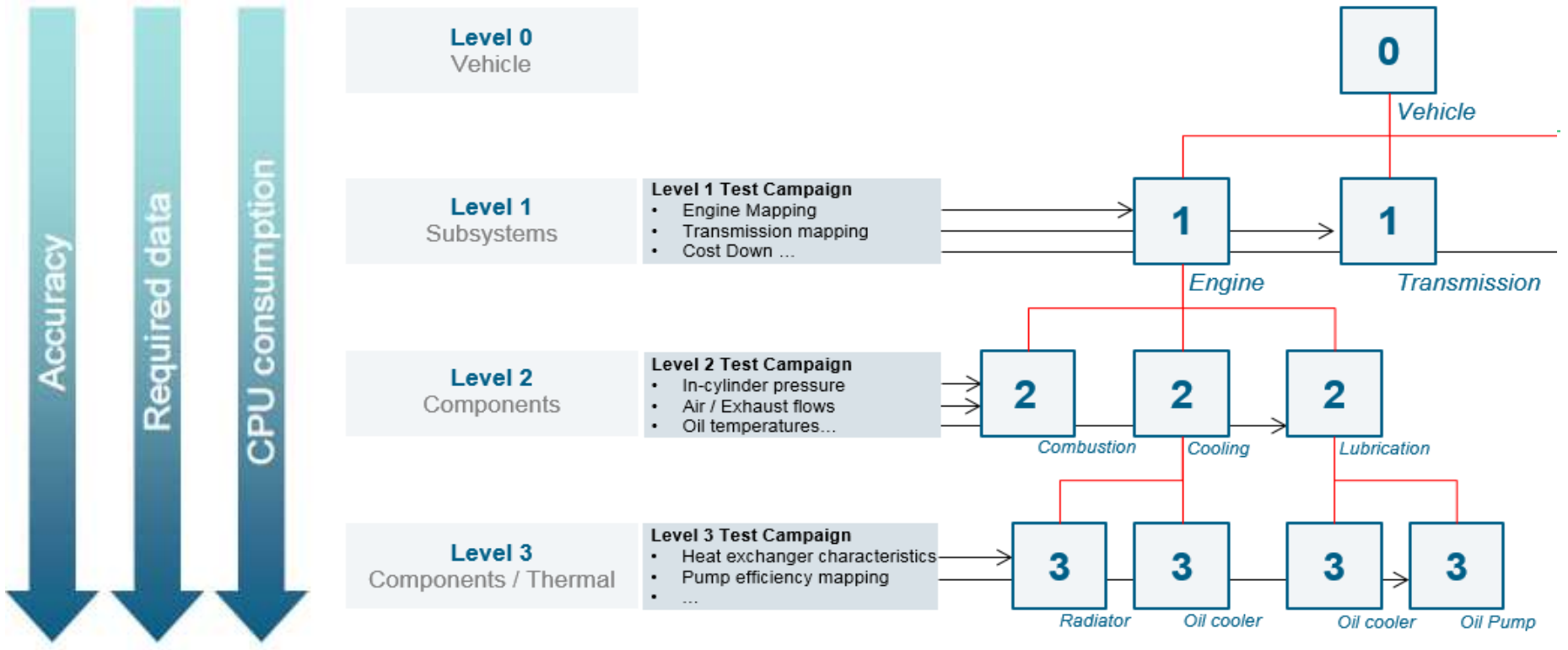

Customer Use Case:
Multi-attribute virtual trade-off investigation

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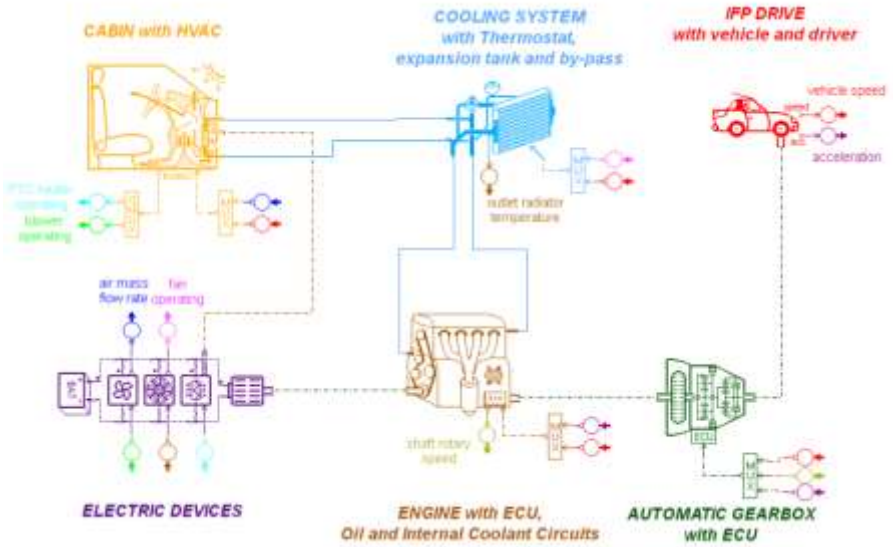
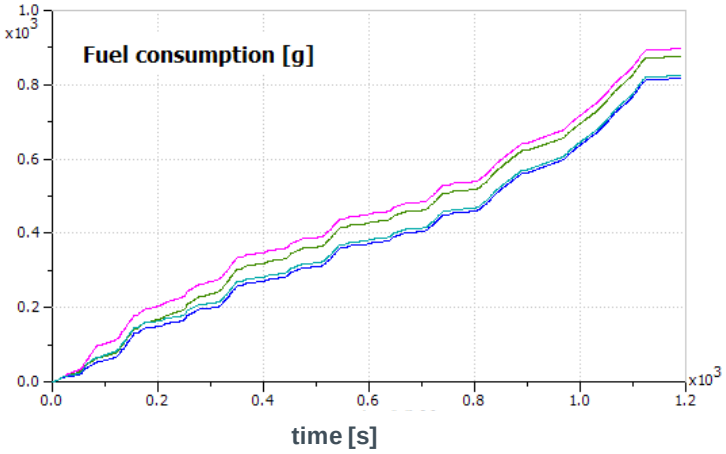
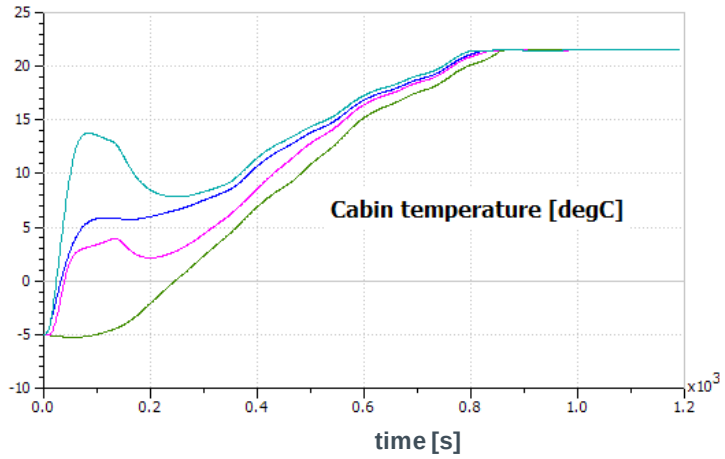
Passenger comfort vs Fuel economy

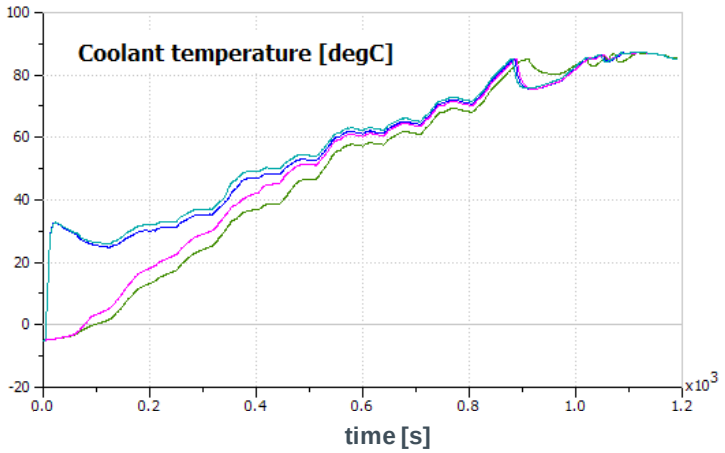
case 1: baseline, no PTC, no Heat Storage
case 2: baseline + Heat Storage, no PTC
case 3: baseline + PTC, no Heat Storage
case 4: baseline + PTC + Heat Storage

	Cabin comfort		Fuel consumption [g]	
	Time to reach 15°C [s]	diff vs baseline	NEDC / -5°C	diff vs baseline
case 1	595	-	877	-
case 2	548	-7.9%	818	-6.7%
case 3	563	-5.4%	898	2.4%
case 4	530	-10.9%	825	-5.9%









Vehicle Energy / Thermal Management
1D-3D Simulation Scalability through the V-cycle

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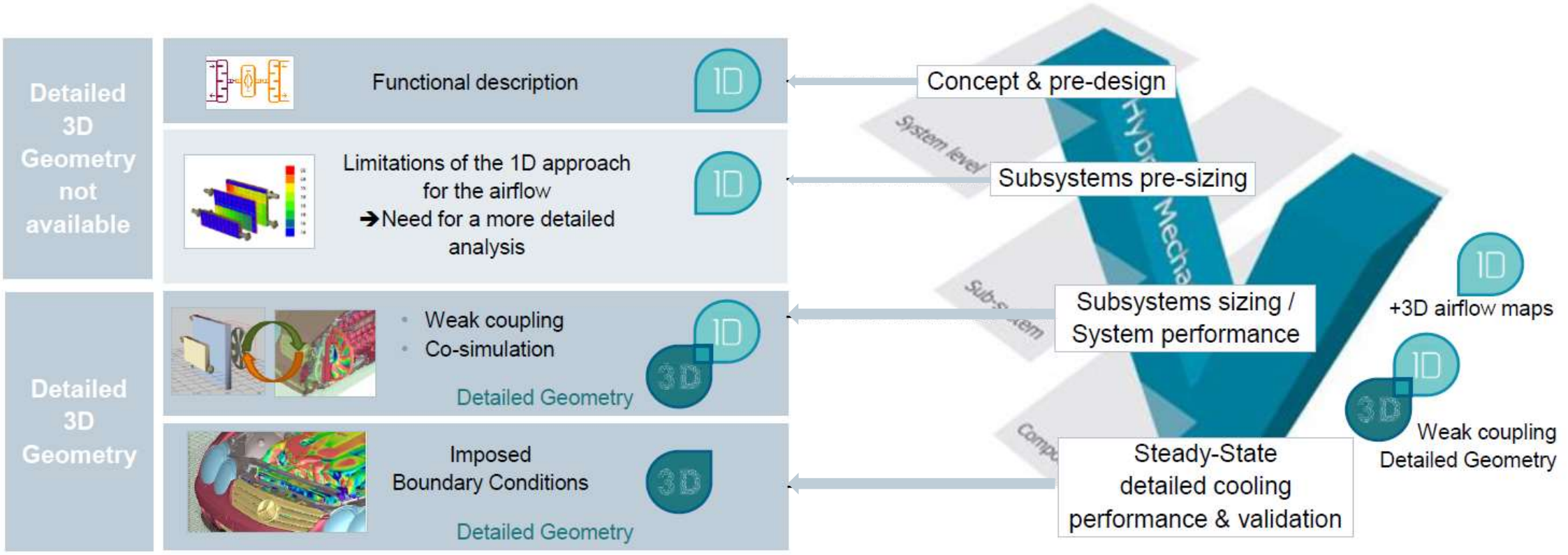

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1D-3D Simulation Scalability through the V-cycle

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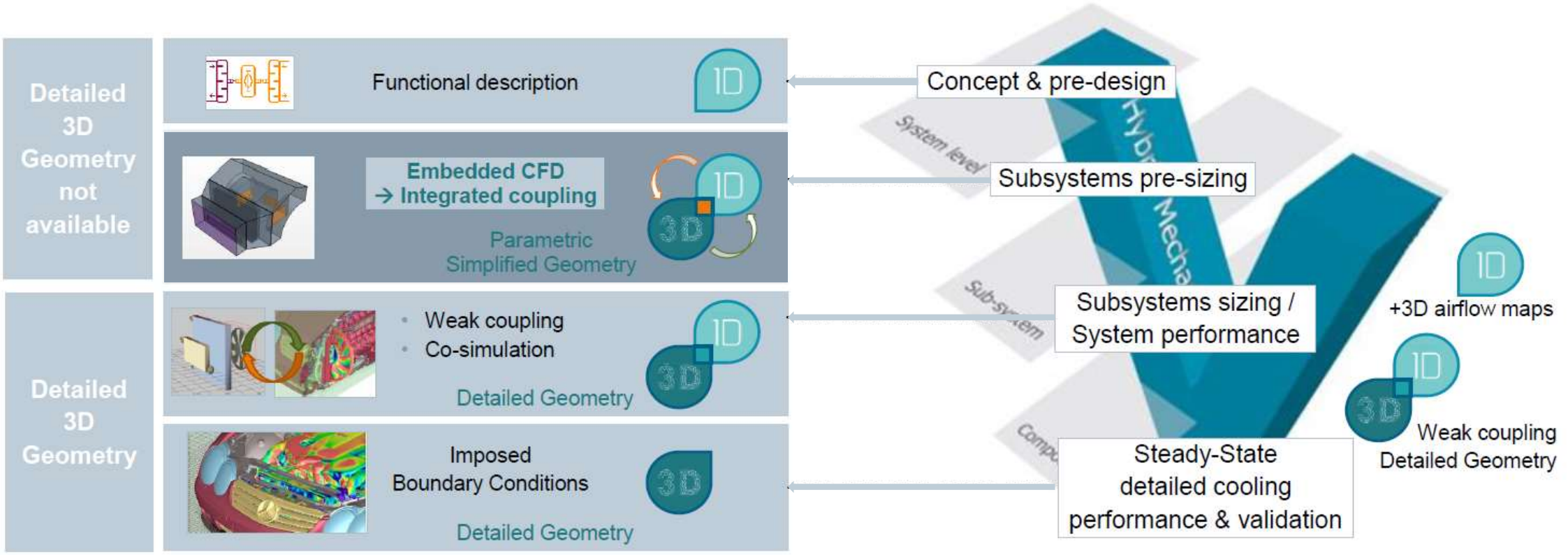

➔ 1D internal flows added value: transient analysis, system simulation & when no CAD available
➔ 3D external flow added value: detailed steady-state analysis

Vehicle Energy / Thermal Management
Bridging the 1D / 3D Divide

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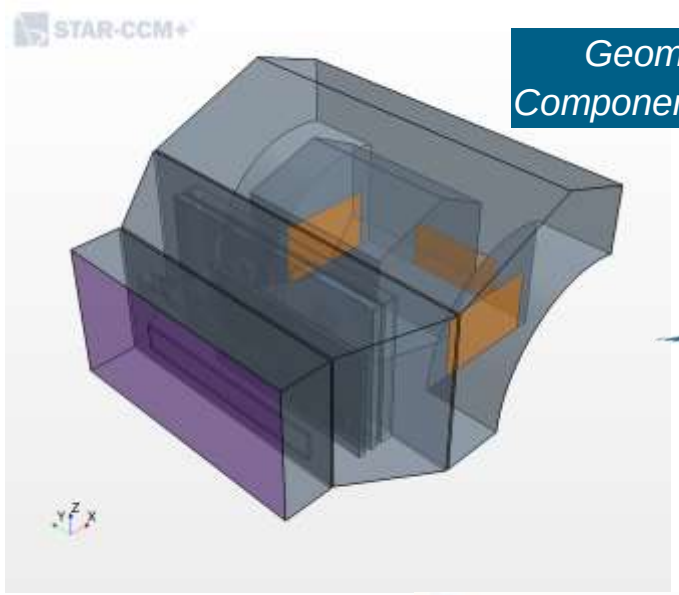
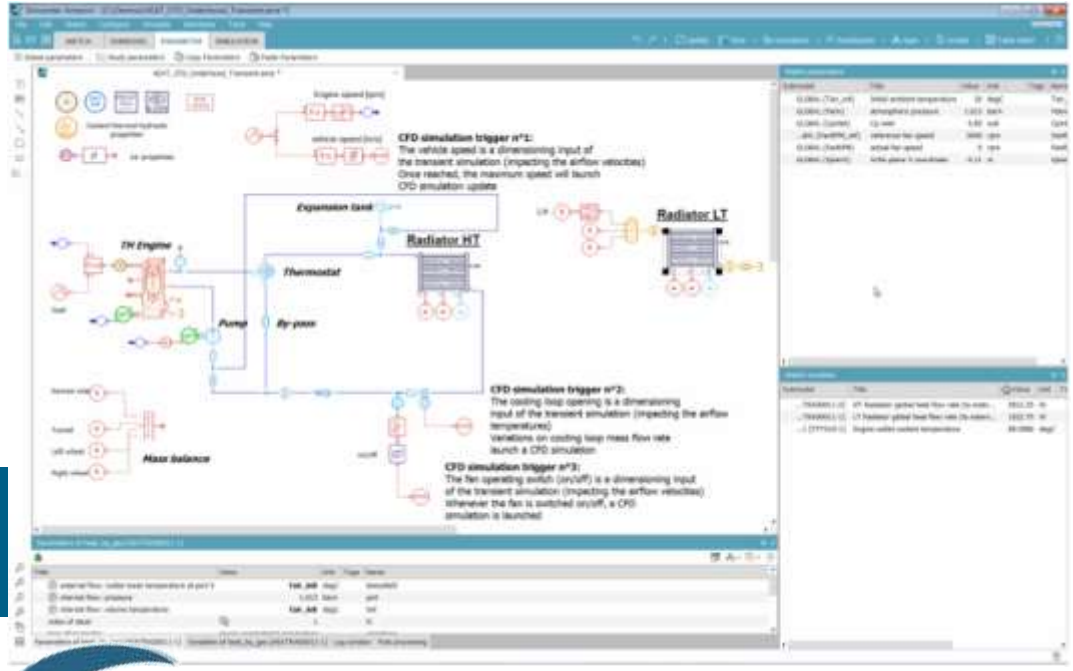
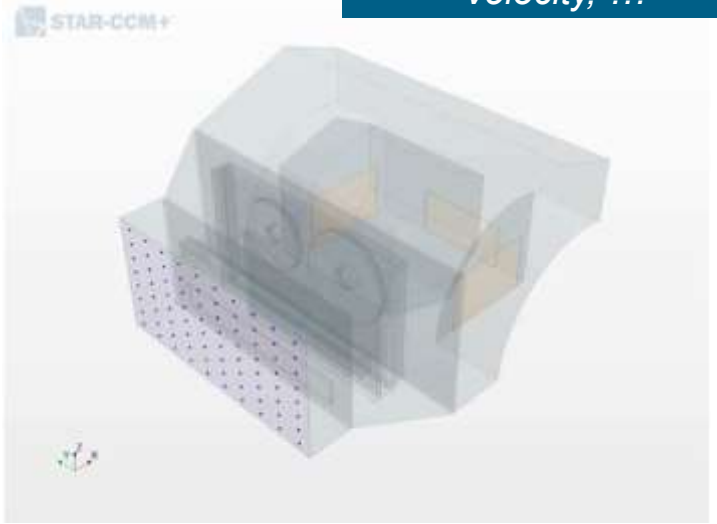


Geometry Parameters Components Performance data



Heat release from each Heat exchanger, car velocity, …



Air velocity and temperature maps for each Heat exchanger

Vehicle Energy / Thermal Management
Architecture selection and design refinement

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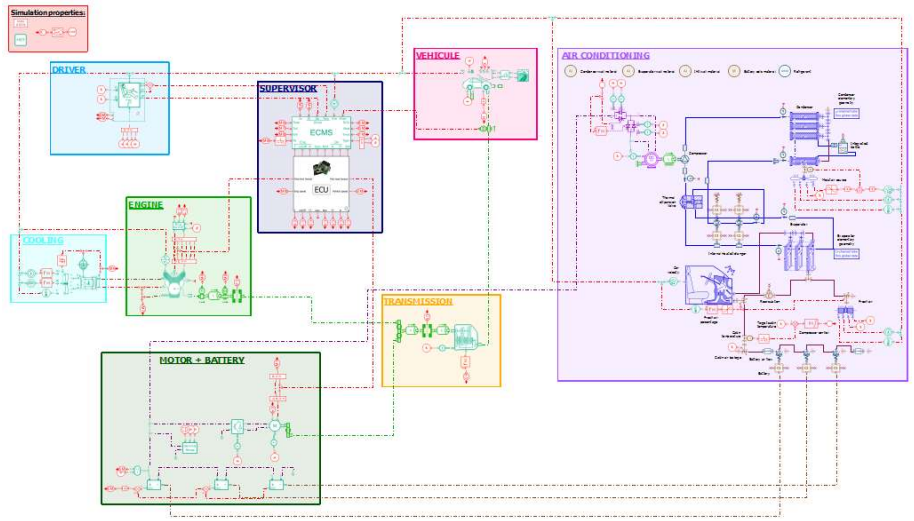
Thermal management modelling – The Digital Twin development

When necessary, integrate impact of thermal management on subsystem performance and so define thermal management targets

- Subsystem cooling systems (ICE / Battery / EM / Fuel Cell)
- Heat exchanger stacking
- HVAC system with cabin volume



Vehicle Energy / Thermal Management

Architecture selection and design refinement

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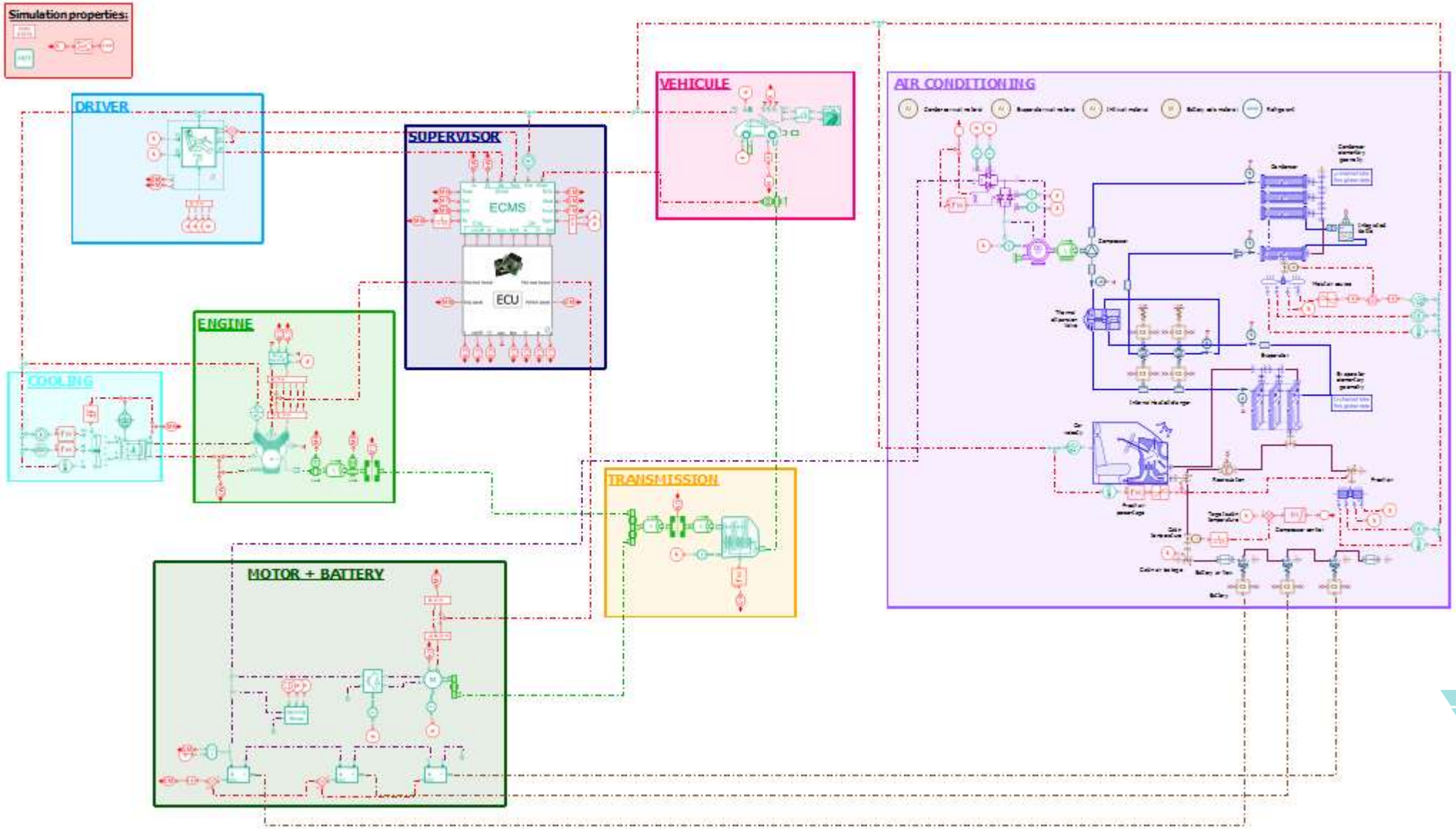


Vehicle Energy / Thermal Management
Architecture selection and design refinement

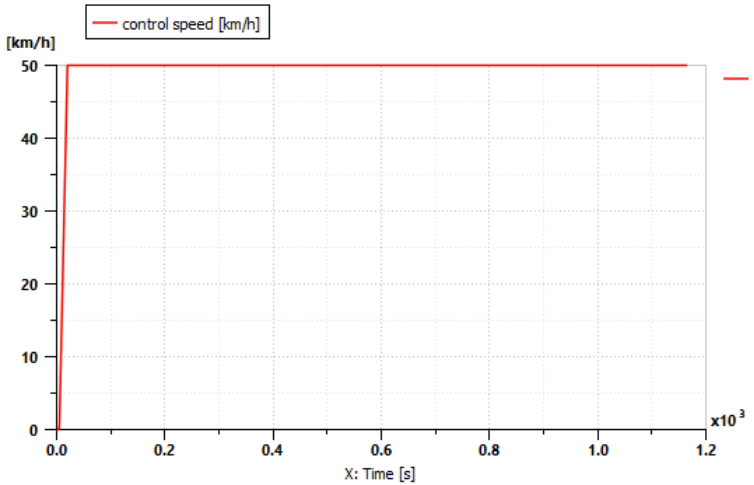
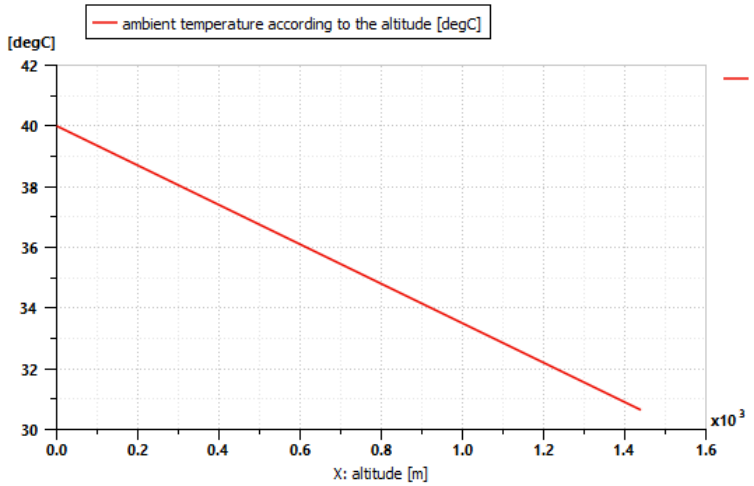
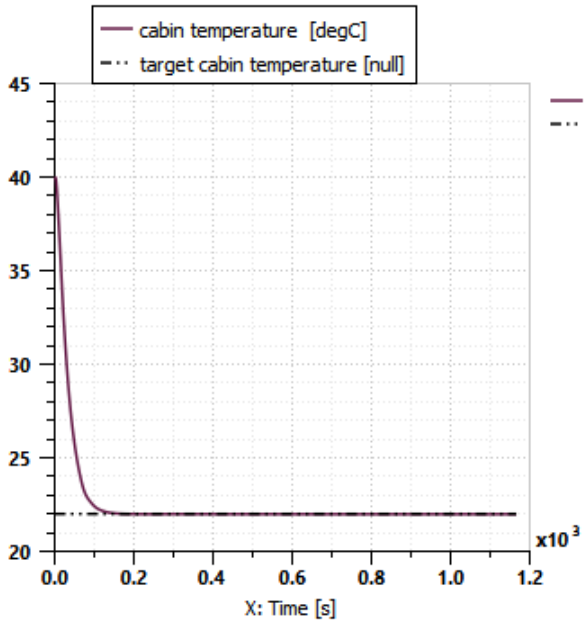
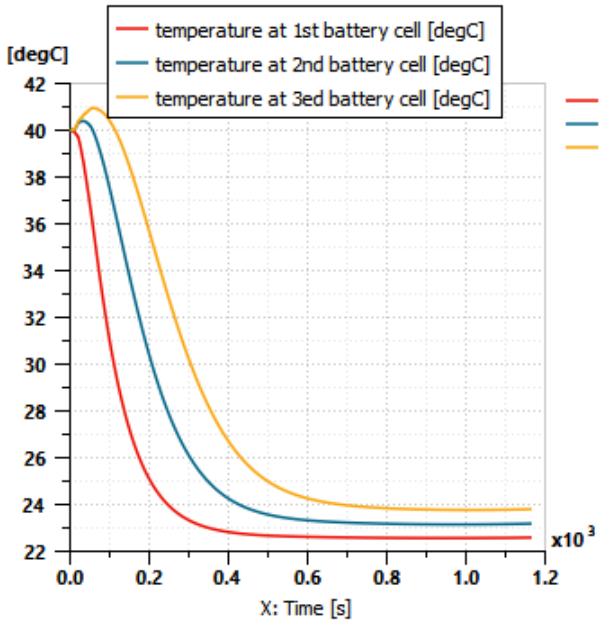


Figure 2: driving cycle







Vehicle Energy / Thermal Management
Architecture selection and design refinement

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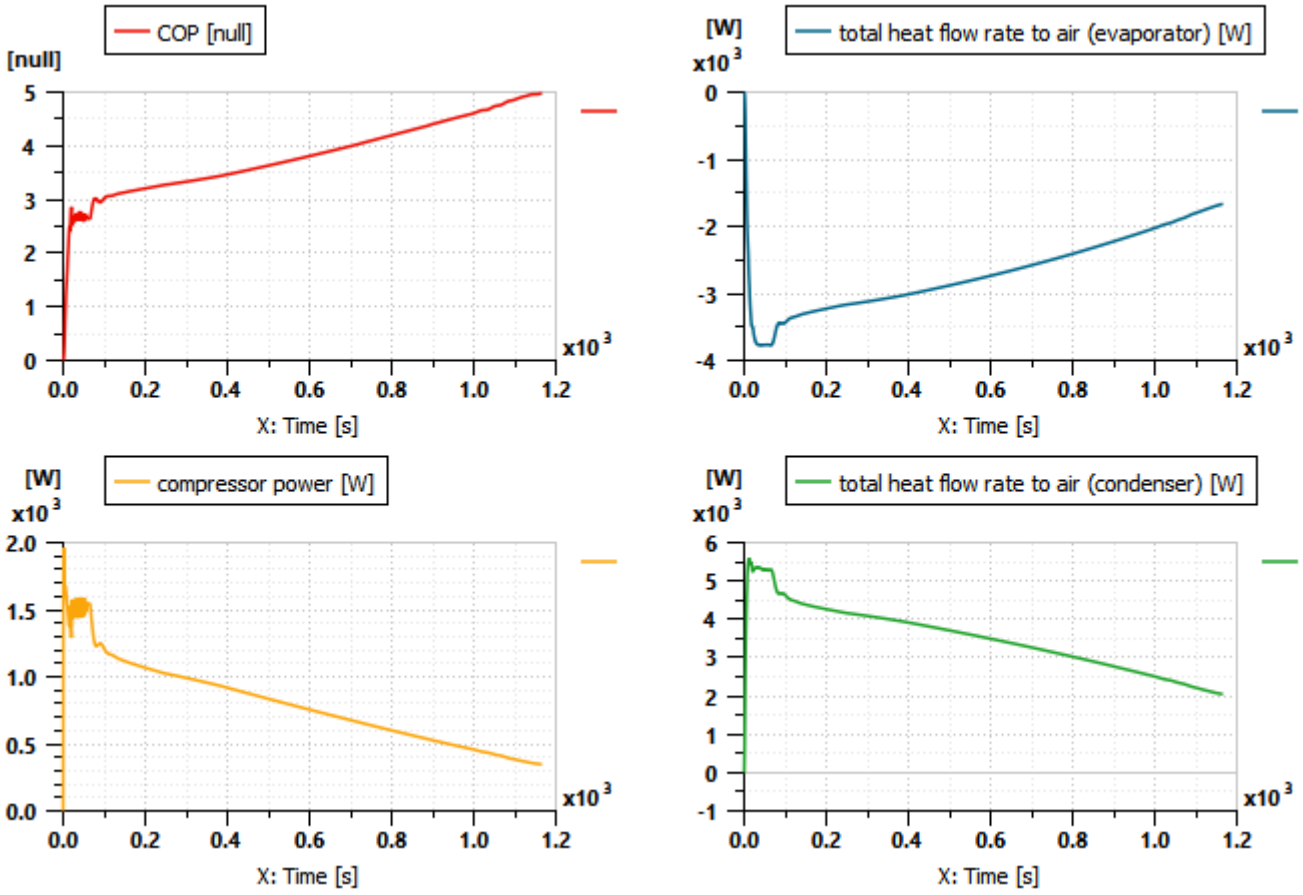
Coefficient Of Performance (COP)



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Architecture selection and design refinement

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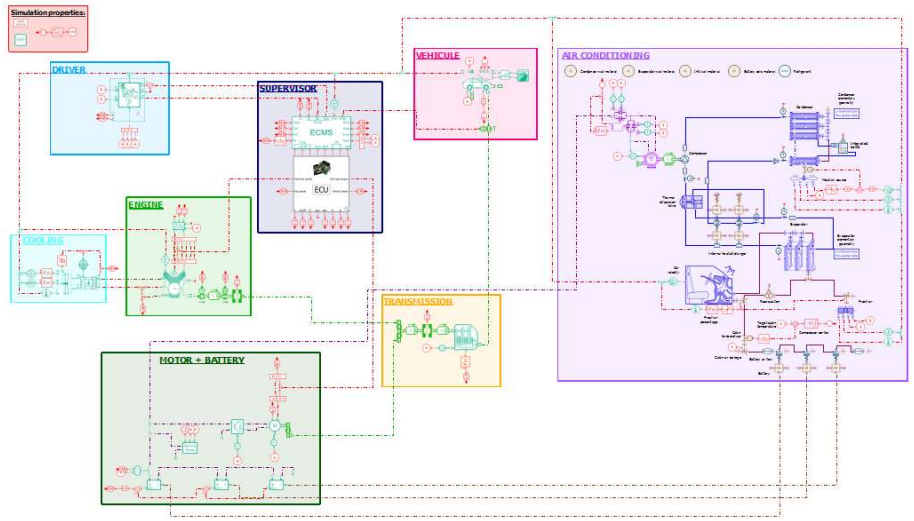

Outcome:

- Compute Thermal Management component heat exchanges / load requirements to complete target
- Analyze impact of such Thermal Management on system global performances

Vehicle Energy / Thermal Management
Architecture selection and design refinement

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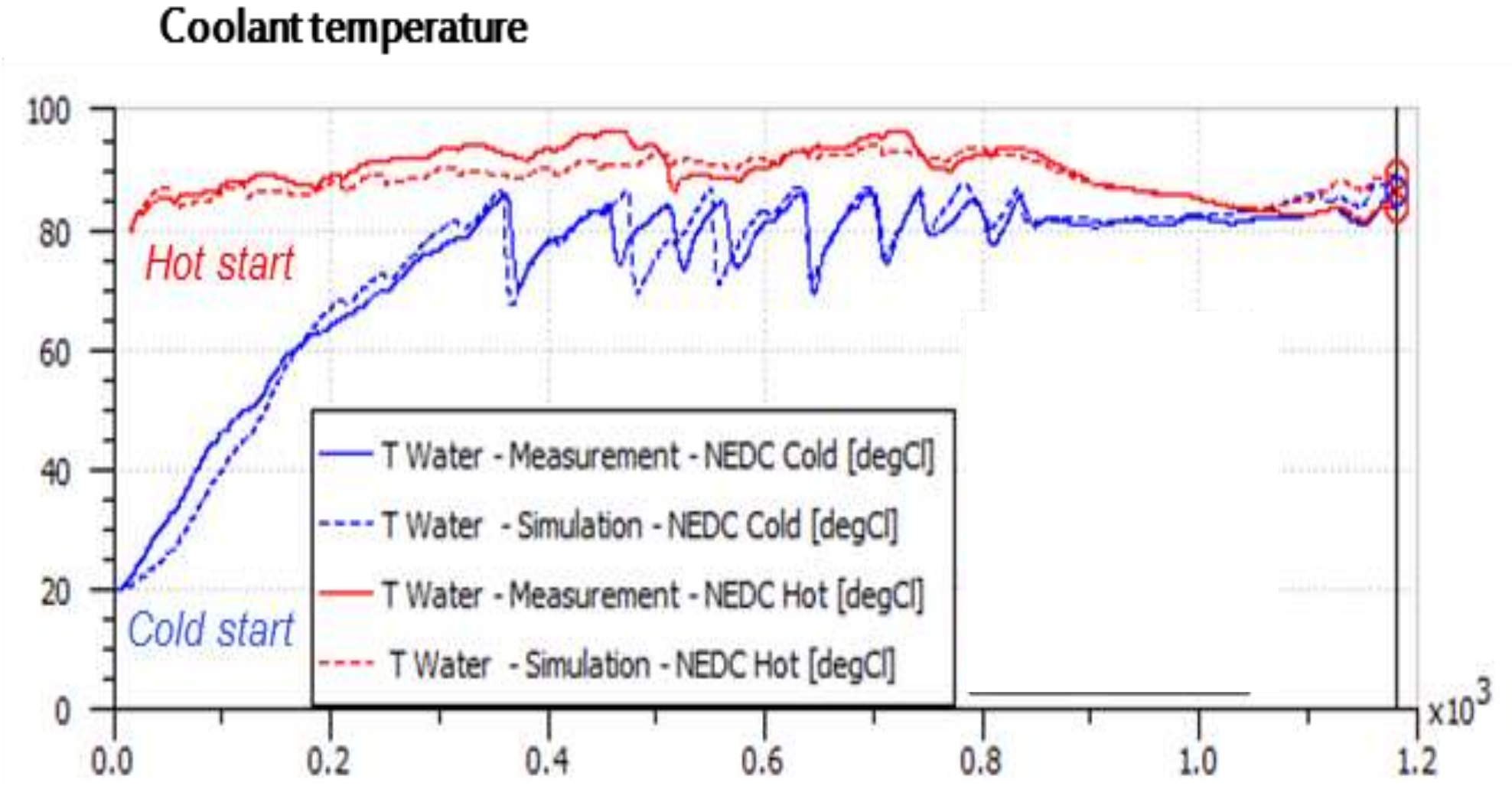

Vehicle Energy / Thermal Management
Architecture selection and design refinement

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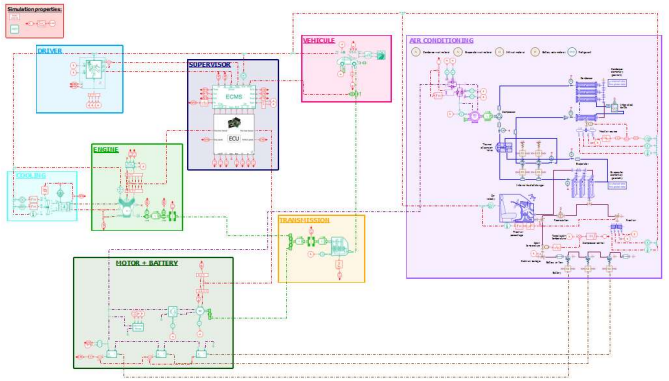
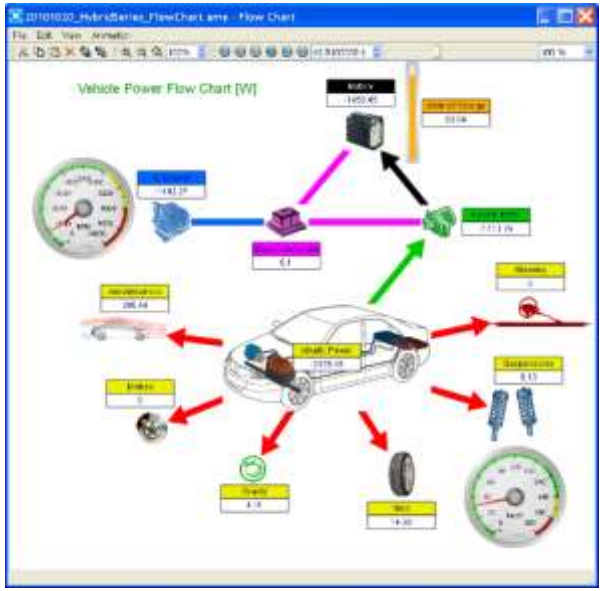
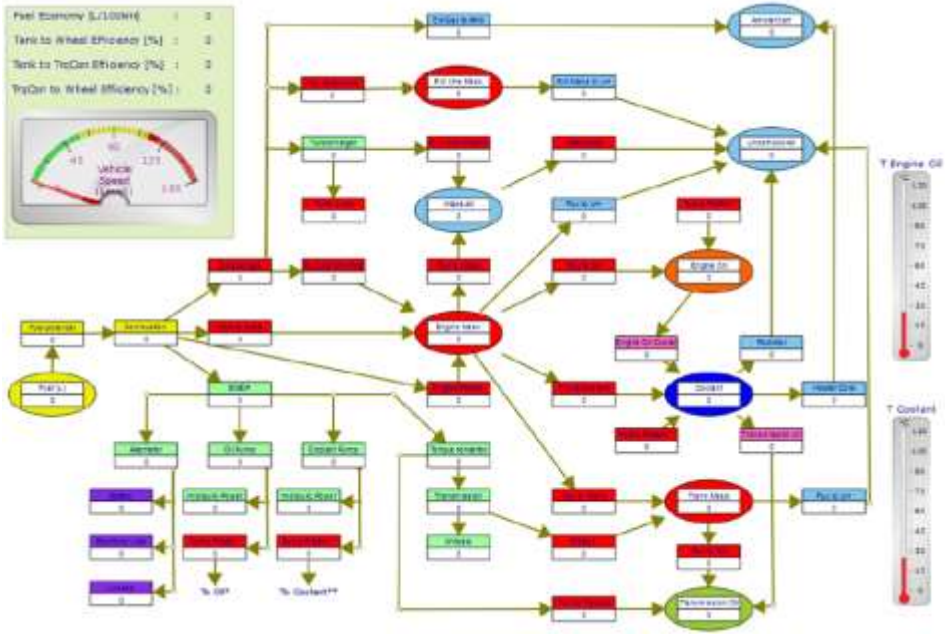
Digital Twin outcome - Energy distribution flow chart

- Energy decomposition available thanks to model and test results
- Track the different energies: transferred, stored, losses
- In different physical domain: electrical, mechanical, thermal
- Battery status, energy recovery, …







Vehicle Energy / Thermal Management
Architecture selection and design refinement

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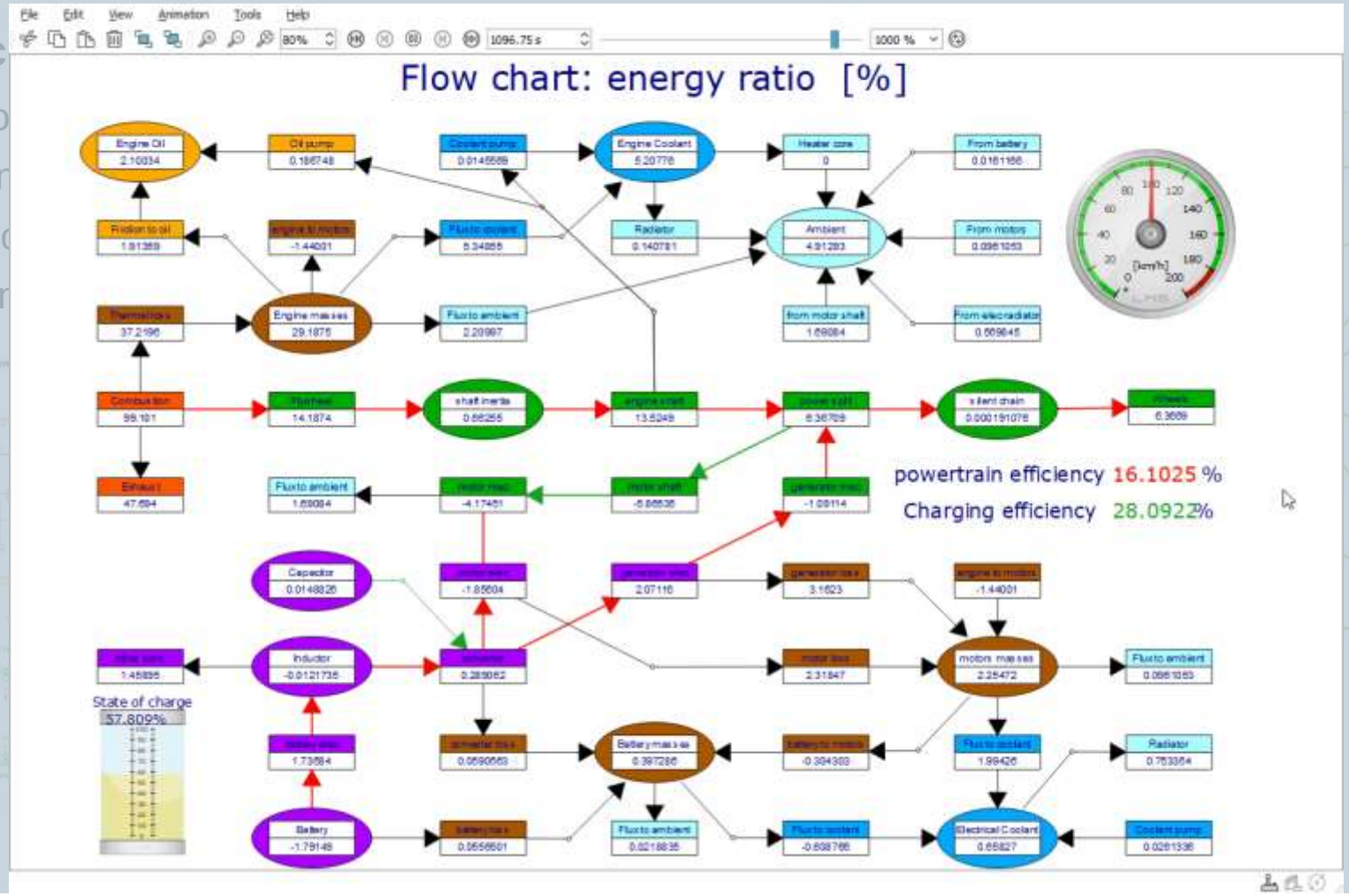
Digital Twin outc

- Energy decompo
- Track the differen
- In different physic
- Battery status, er



Vehicle Energy / Thermal Management
Detailed Design

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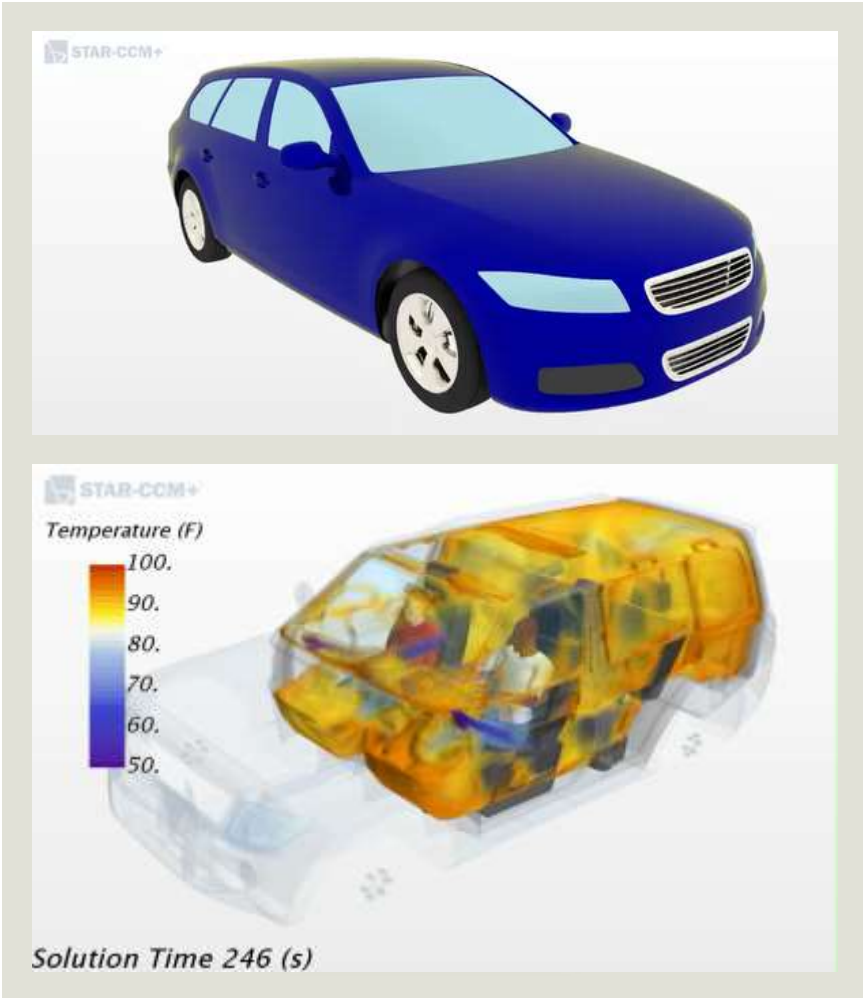
Capturing 3D physics to explore performance improvements

Performance evaluation
- For each subsystem
- Prepare integration
- Provide transparent link between 1D and 3D simulation

Optimize component performance
- Retrieves CAD and non-geometric data
- Automate workflow
- Run Design Exploration
- Optimize component design for critical operating points



Vehicle Energy / Thermal Management
Detailed Design

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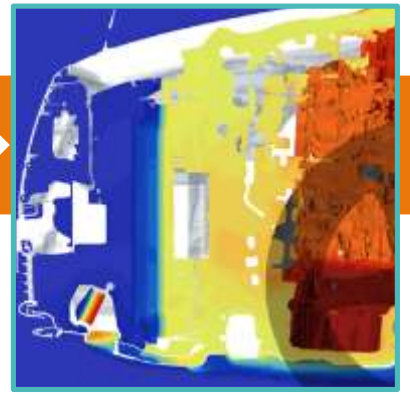
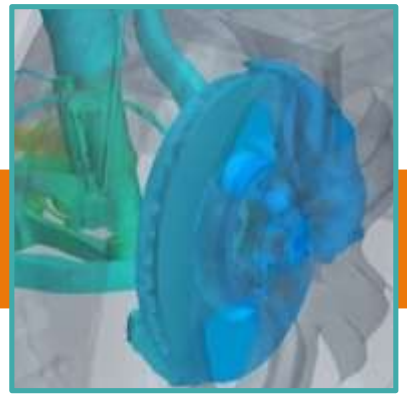
Working Towards the Virtual Prototype

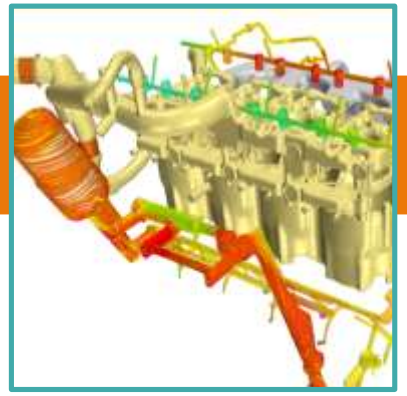
Front End / External Air Flow





Detailed Sub-Models

Complex Sub-system Modeling



VTM Modelling – Over 5k+ Parts

Greater Model Complexity

Vehicle Energy / Thermal Management
Optimizing the Aerodynamics

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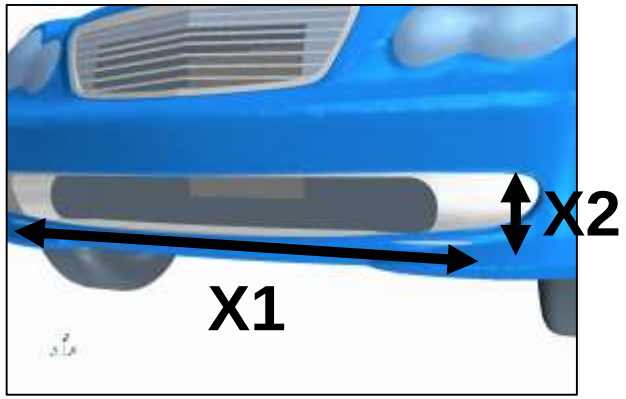
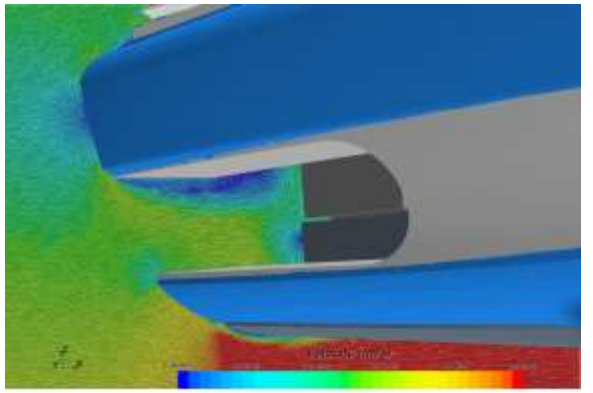
Challenge:
- Increased legislation / demand to drive up efficiency and fuel economy
- Decrease emissions
- Increased importance of noise with EVs

Steady State:
- Efficient method to study design changes and narrow down selection

Transient:
- Used to provide accurate drag and lift coefficients on selected designs

Design Space Exploration:
- Multiple objective optimization: Reduce drag, heat shield temperature, weight, cost…. But maximize cooling, efficiency,…
- Find Sensitivities in your design space: Random sampling technology lets you see “what happens if”





Mercedes-Benz
Using design exploration to achieve record drag value

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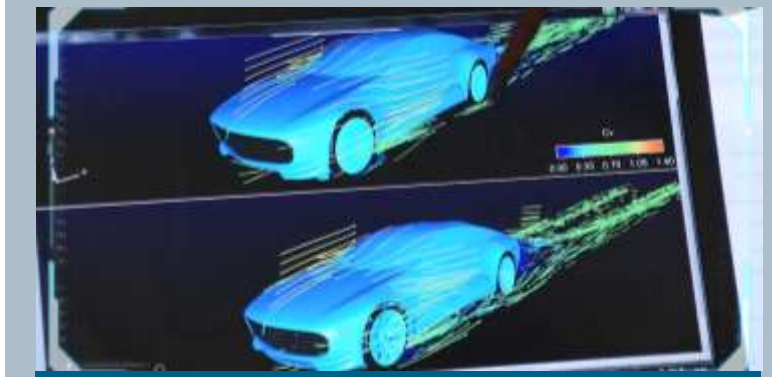
- **Reduced time for generation new concept by nearly 50%**
- **Over 300 design variations were compared**
- **Digitalizing entire value chain – from development, through production to marketing & sales**

Concept IAA (Intelligent Aerodynamic Automobile)



Aerodynamics was developed with numerical flow simulation

Vehicle changes shape over 80 km/h to reduce drag at highway speeds

- Over one million CPU hours was used to simulate air flow of the new prototype
- Drag coefficient reduced to 0.19 through design exploration

“What previously took up to one and a half years, we managed in less than 10 months thanks to digitalization”

Dr. Dieter Zetsche, Head of Mercedes-Benz Cars

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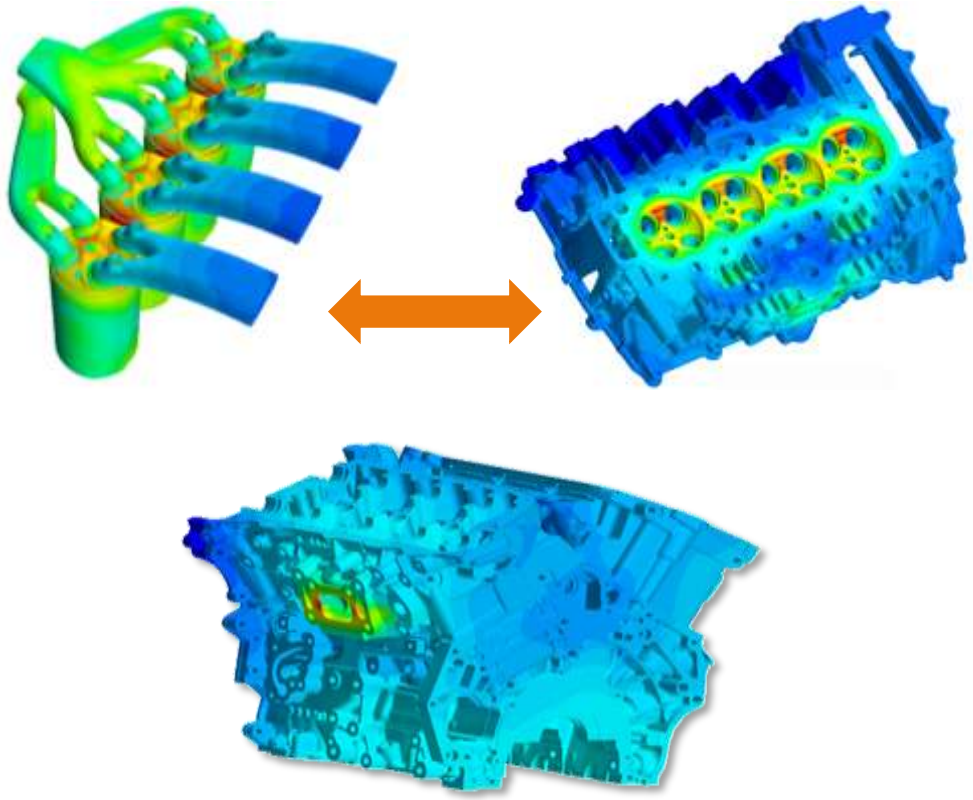
Case Study: Thermal Cracking

Challenge:

- Assess temperature distribution in block and associated potential cracking

Services Solution:

- Close collaboration with Engineering Services team helped develop validated CHT methodology
- Analysis shifted from reactive to predictive
- Provides ability and confidence to run the analysis months ahead of the tests, highlighting any concerns



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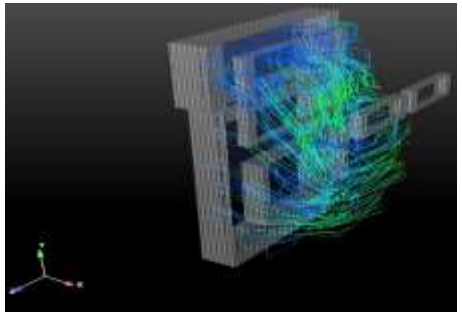
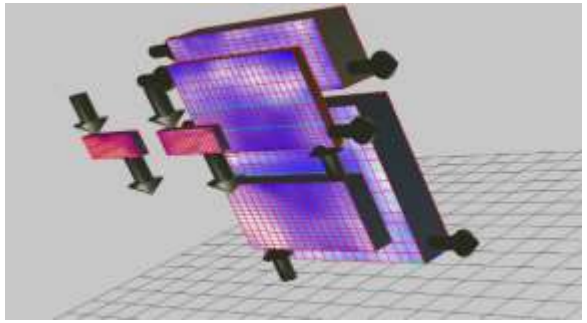
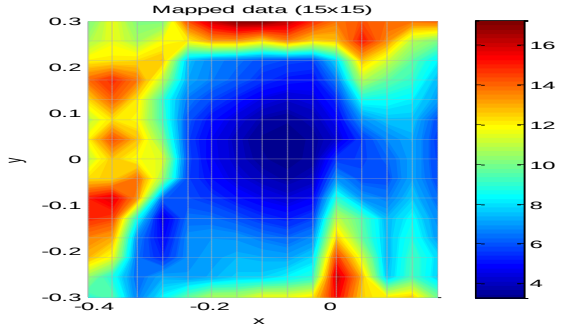
Detailed Subsystem Modelling: Heat Release Through Cooling Circuit

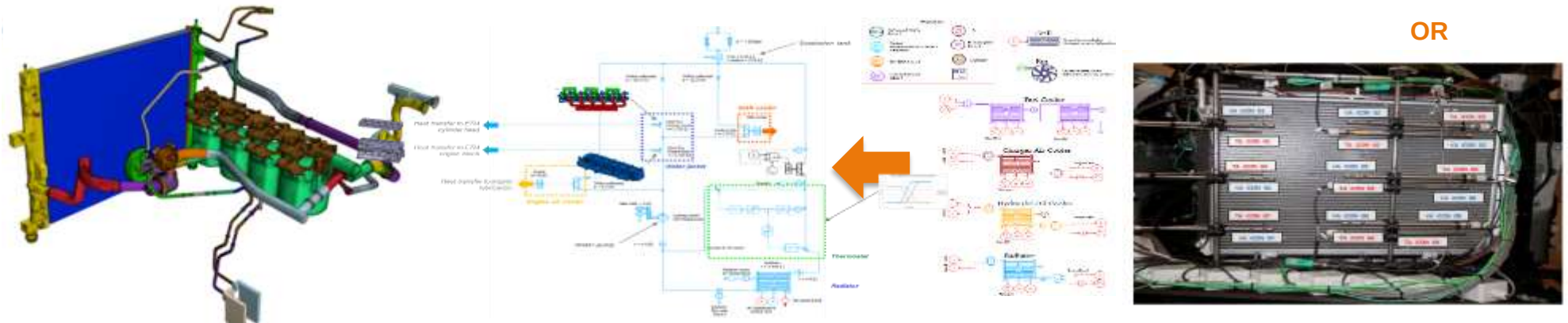


3D velocity maps extracted from CFD





Amesim stack model with HEAT library



Amesim System Model

OR

Vehicle Energy / Thermal Management
Detailed Design

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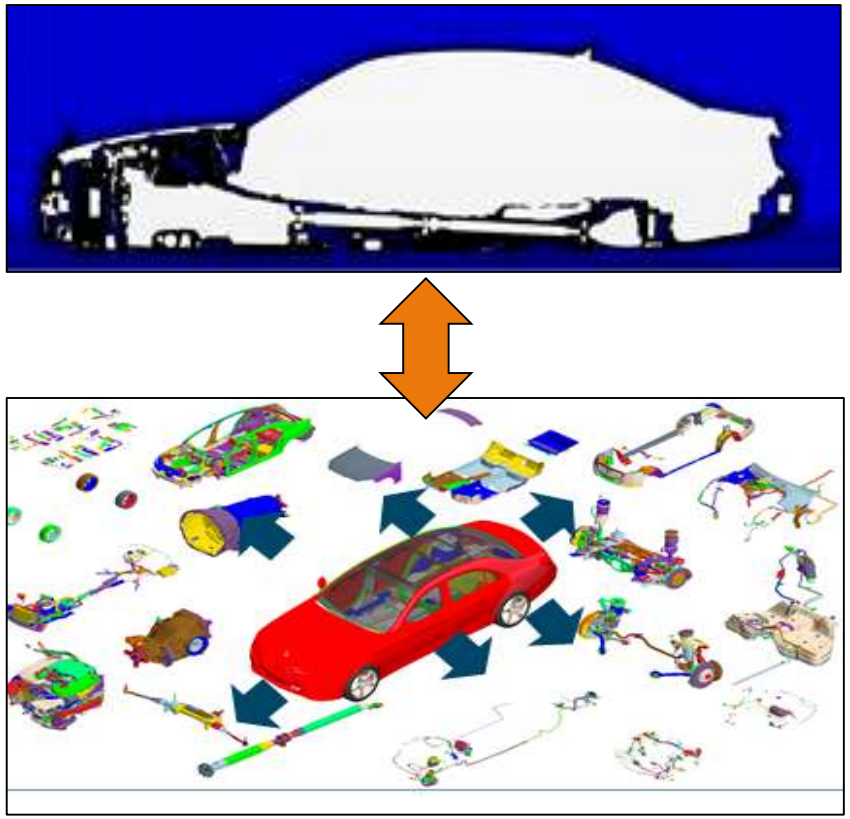
Case Study: Full Vehicle Heat Protection

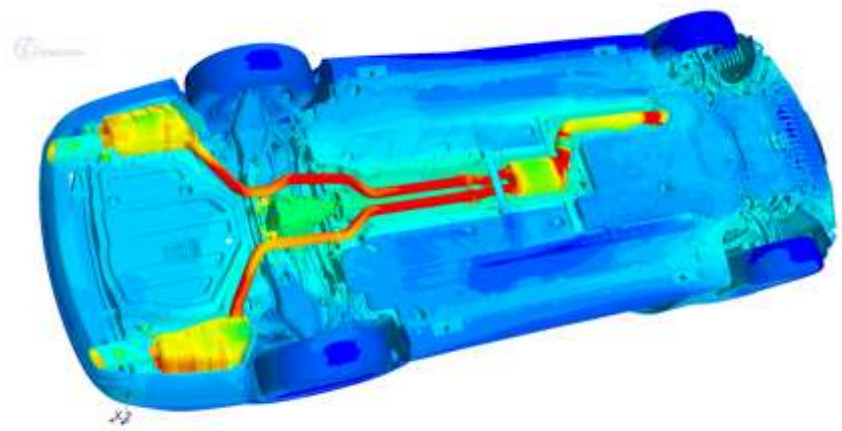
Challenge:

- Predict temperature and HTC distribution

Services Solution:

- Developed Co-simulation methodology (Fluid and Solid)
- Steady or Transient solution





Vehicle Energy / Thermal Management
Drive Cycle Analysis

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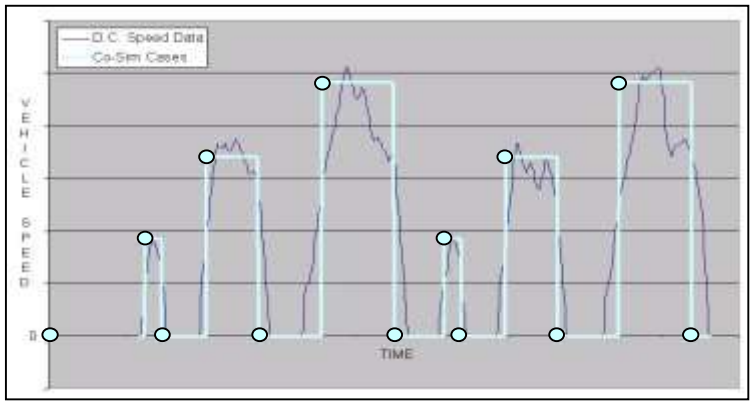
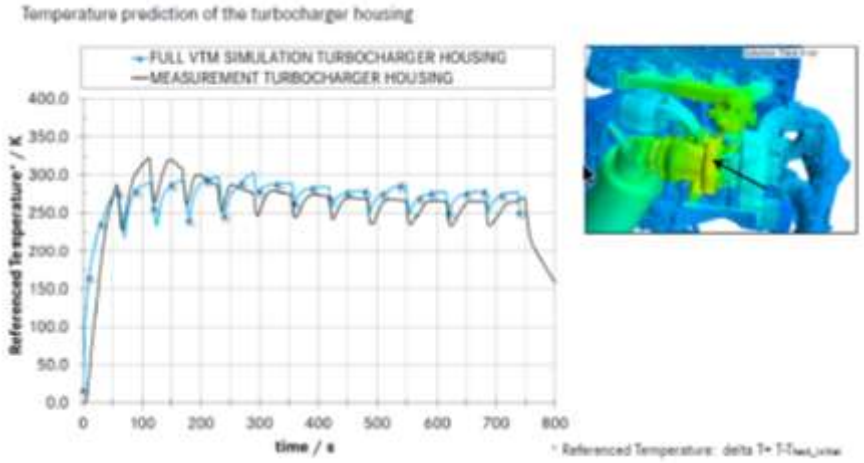
Challenge:

- Complete fluid / solid model (5000+ parts)
- Flexible de-coupled solution to allow easy set-up of different cycles
- Accurate prediction of component temperatures
- Using the full vehicle model enables prediction of transient component temperatures under different driving scenarios:
  - Vmax, Idle (Hot countries), Thermal Soak, Drive Cycles





Vehicle Energy / Thermal Management
Vehicle Integration, balancing attributes

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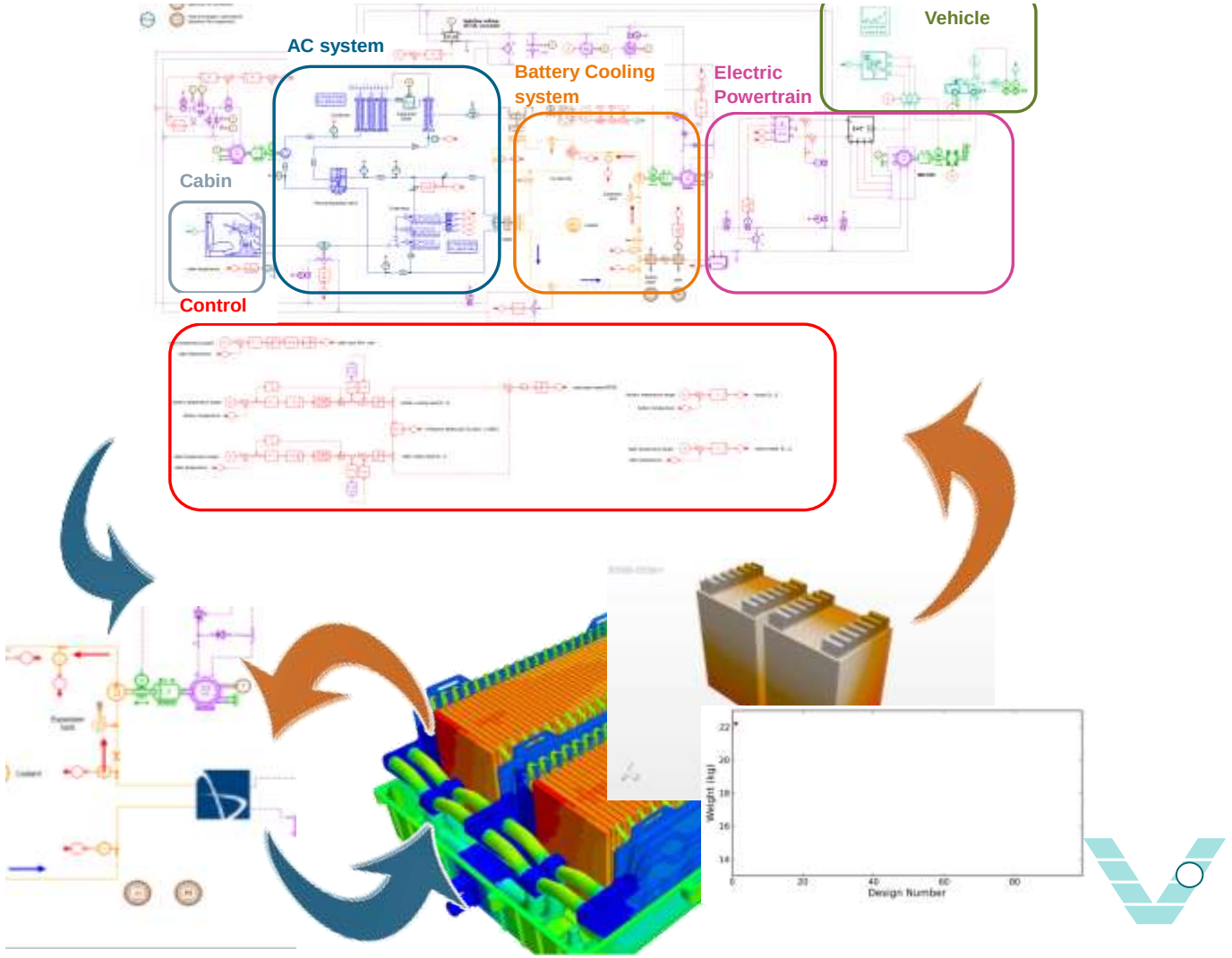
- Feeding back the knowledge gained from the detailed 3D analyses into the system model to further increase the accuracy
- Predict cell temperature variation, and optimize battery pack using full system simulation including battery, electric systems, thermal systems, coupled with detailed 3D cell model
- Use the model to balance battery performance to HVAC, defining the control systems



Vehicle Energy / Thermal Management
Vehicle Validation for Digital Sign Off

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Controls

- Final validation and calibration of control software (SiL / HiL)
- Simulate millions of miles and perform up to 80% controls software validation
- Pre-calibrate controls software parameters
- Model-based testing
- Prototype testing and verification

Final digital and product sign-off

Vehicle Energy / Thermal Management
Vehicle Validation for Digital Sign Off

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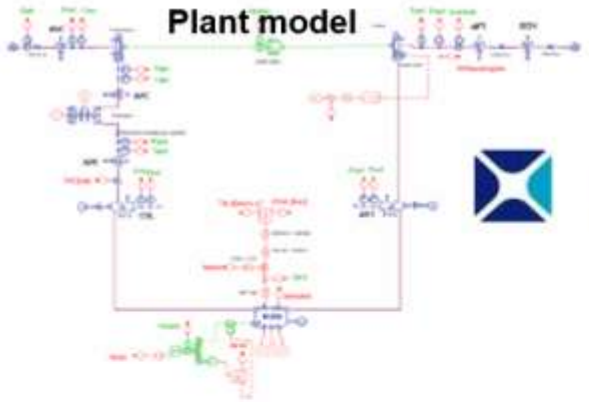
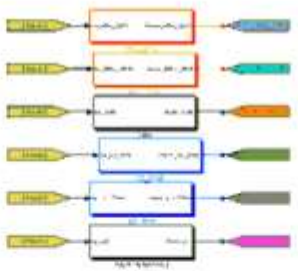


Export



HIL

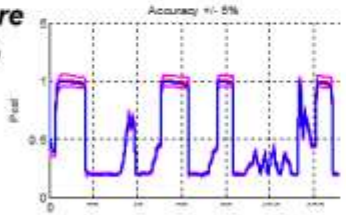
RT integration

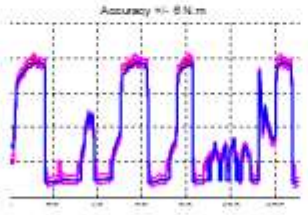
HIL Test bench

Remote access to HIL systems

Test automation

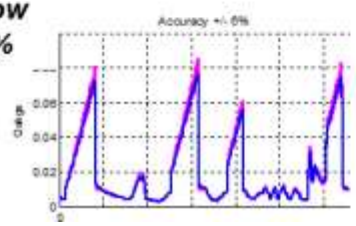
Intake Pressure +/-5%

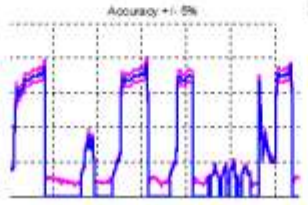




Torque +/-6%

AirFlow +/-6%





Injected fuel +/-6%

Vehicle Energy / Thermal Management
Vehicle Validation for Digital Sign Off

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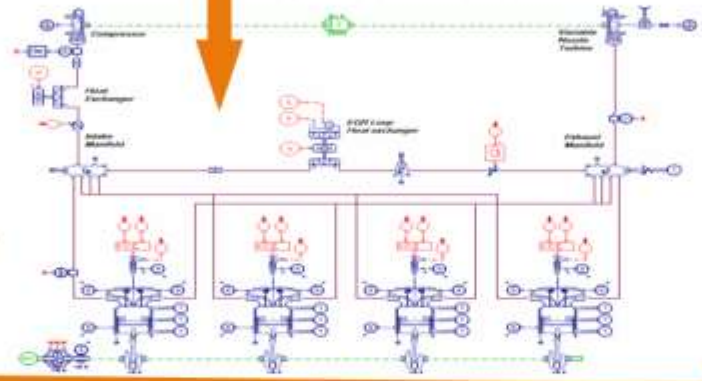
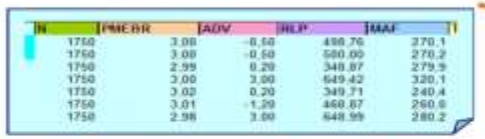
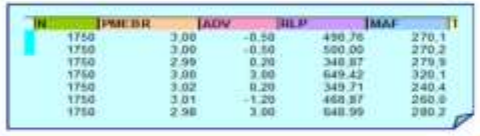
Test bench data (classical approach)

Model identification



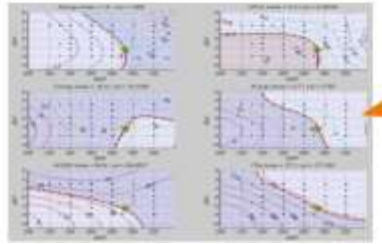
Inputs for additional DOE



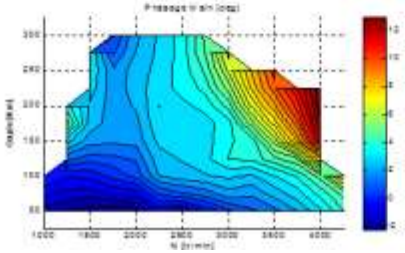


Run DOE on virtual engine

Concatenation of real and virtual data sets



Usual optimization process



Tuning quality ↗

Complexity handling ↗

R&D cost ↘

Customer Usecase – Continental

Optimizing electric vehicles driving range with Simcenter Amesim

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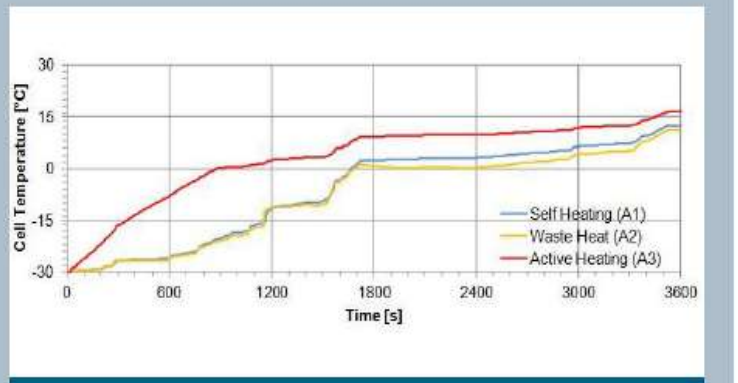
- Shortened early stages of design
- Optimized electric vehicle and increased driving range
- Enhanced reputation for expertise and knowledge in the marketplace

Accelerating strategic decisions and prototype development

Optimize electrical vehicle drivetrain



Battery-heating test in winter conditions

- Evaluate the impact of thermal management strategies on vehicle performance
- Compare different battery heating and cooling methods

"We were able to rapidly select the right architecture with the best performance and focus on the next steps of the project."

Sebastian Brixner, System Engineer

Samsung SDI
STAR-CCM+ improves battery pack cooling

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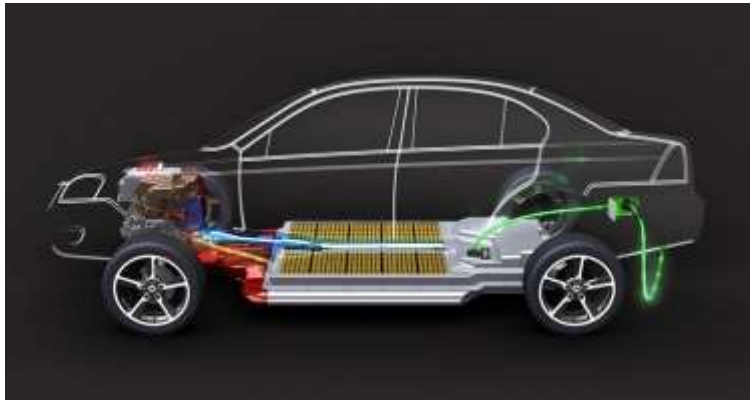
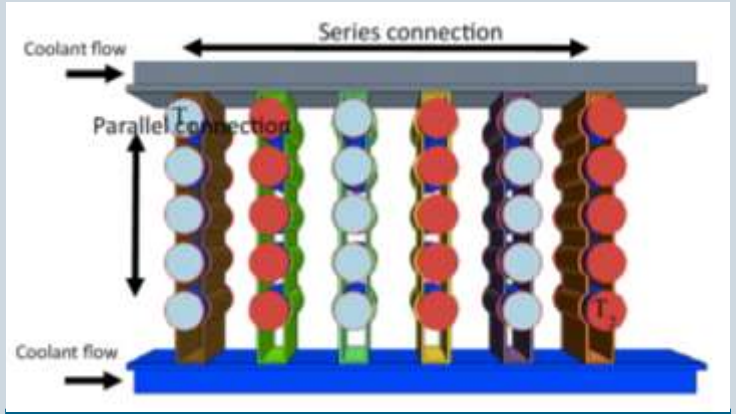
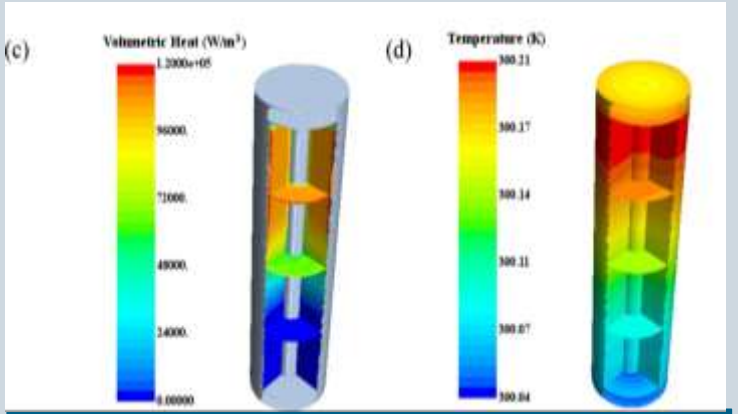


- **Designed novel liquid coolant based thermal system**
- **Predicted sensitivity of thermal performance to contact resistance**
- **Reduced thermal variation inside battery pack**



Examining tradeoff between pressure loss on coolant system to temperature uniformity



Volumetric Heat Rejection and Jelly Roll Temperatures are generated inside the pack.

- 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 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% accuracy"

Dr. Suman Basu – Senior Chief Engineer at SAIT

Mitsubishi
STAR-CCM+ enables thermal management for PHEV SUV

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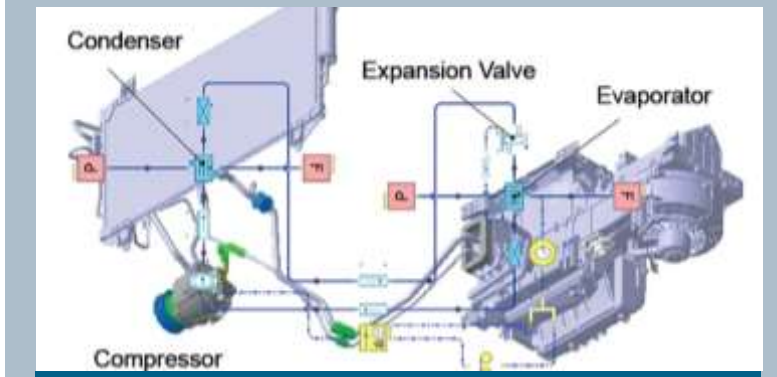
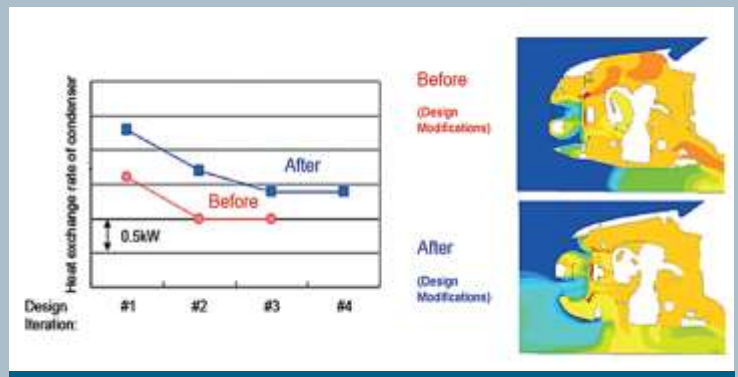
- **Ensured SUV has extended range while balancing thermal challenges in the design.**
- **Enabled cutting edge innovation for Plug-in Hybrid Electric Vehicles**
- **Conducted loosely coupled 1D/3D simulation to enable different drive conditions.**

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. "

Conclusions

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Simcenter provides a single source of products and consulting that encompasses complete vehicle testing, measurement and simulation for Vehicle Thermal Management applications.

Capabilities include:

- Appropriate use of Testing, 1D and 3D simulations that can help addressing the Full Vehicle Thermal Management challenges throughout the entire vehicle design program
- Thermal Analysis from component to system level
- Dedicated Testing facilities and Engineering Services expertise for Vehicle Thermal applications

Vehicle Energy / Thermal Management
Where to go next…

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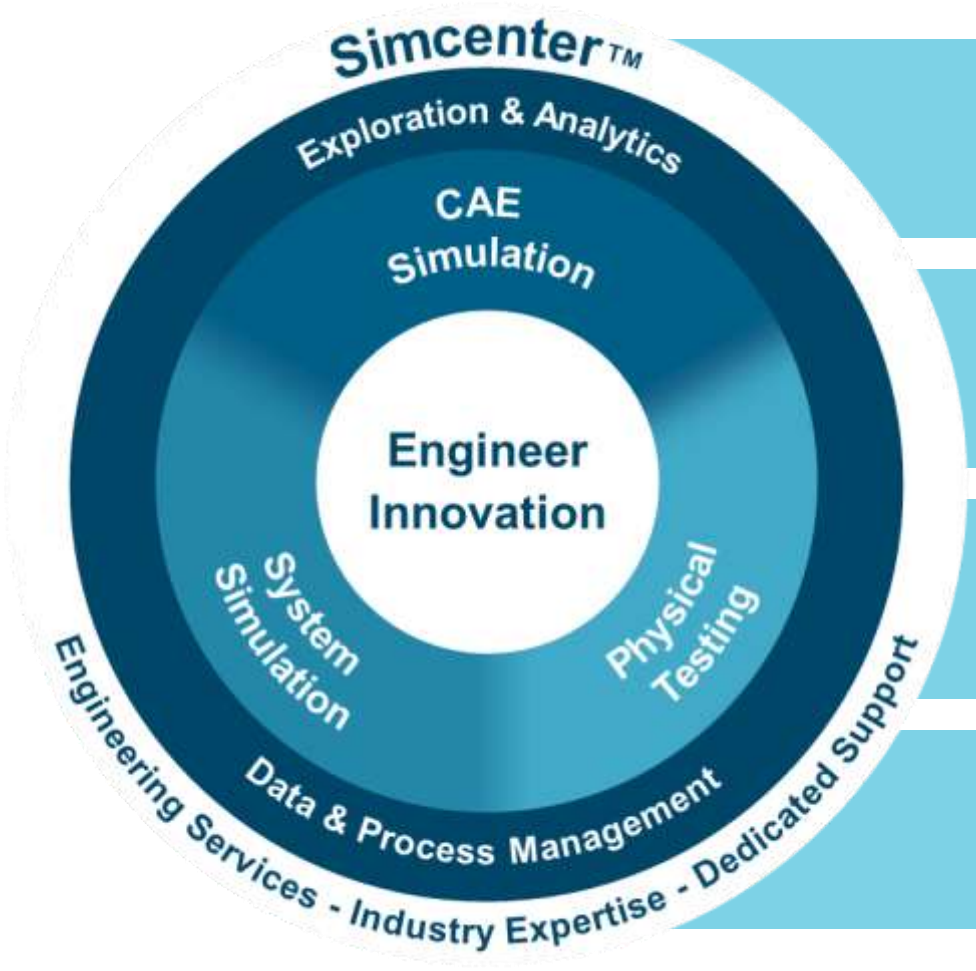

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