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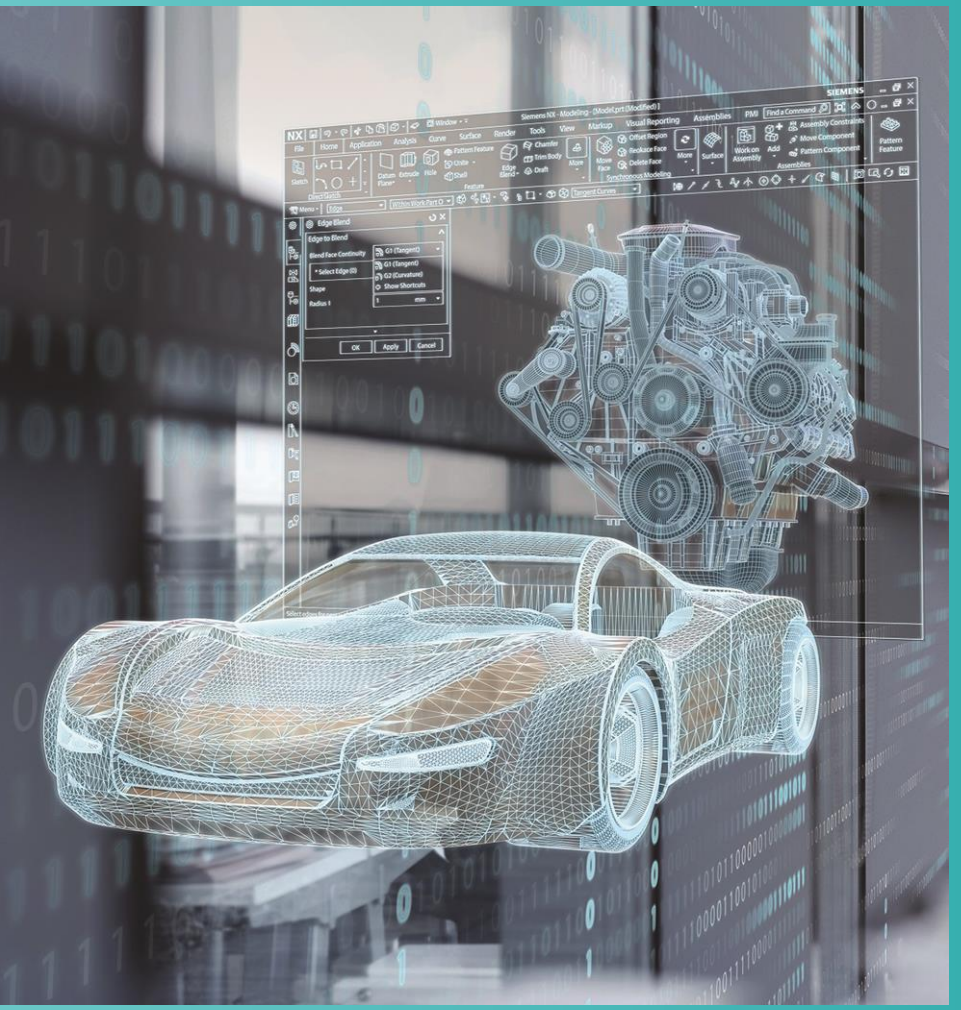
Balancing operability and fuel efficiency in the truck and bus industry

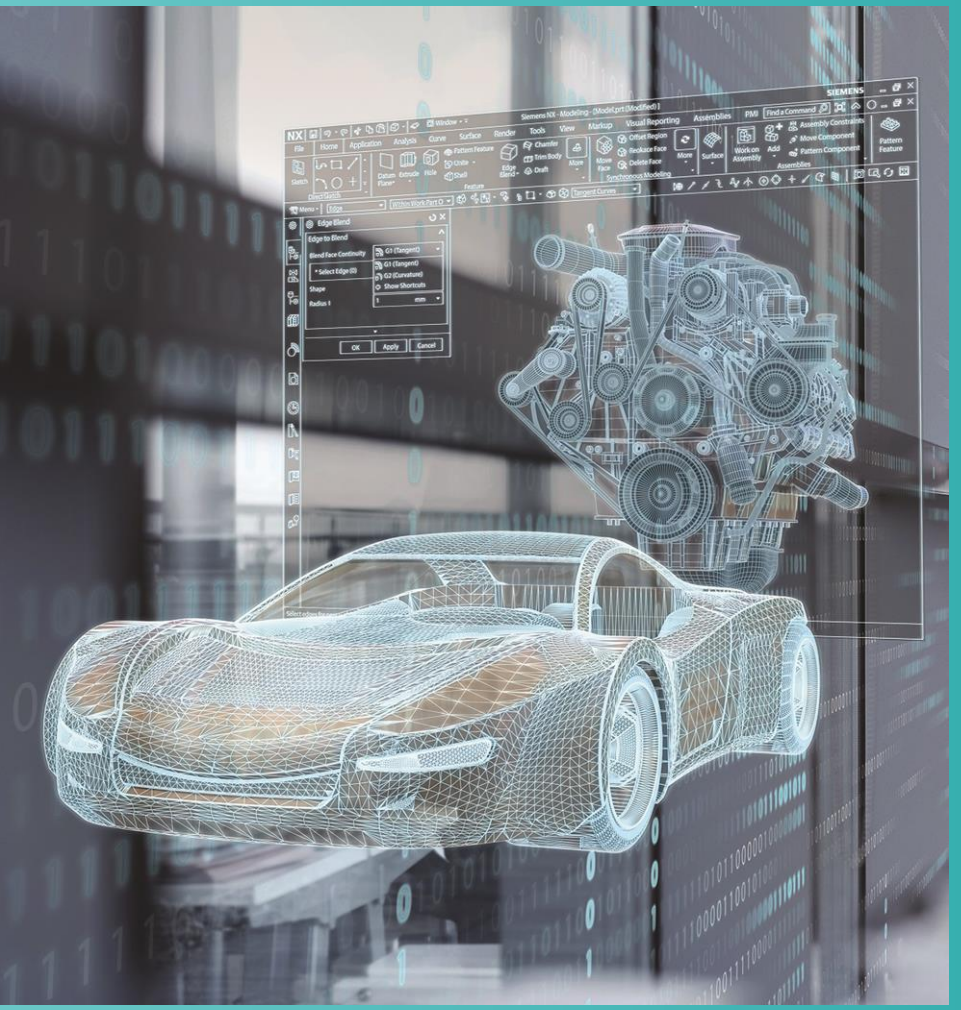
Realize innovation.

Agenda



- The truck and bus industry is evolving
- Model-based systems engineering for truck and bus
- The voice of our customers
- Conclusion

Agenda



- The truck and bus industry is evolving
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The truck and bus industry is evolving

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Stringent emissions regulations

Irreplaceable value of brand attributes

Mass customization and personalization

Worldwide race for innovation

Which implications for truck and bus design?

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Stringent emissions regulations

- Powertrain hybridization
- Vehicle weight reduction
- Systems integration optimization

Irreplaceable value of brand attributes

- Best compromise between fuel economy, performance, drivability, comfort and cost
- Vertical integration

Mass customization and personalization

- Software-intensive systems
- Shift from mechanical to software systems

Worldwide race for innovation

- Growing systems complexity
- Predictive maintenance
- Autonomous driving

One constant. Addressing these engineering challenges …
… without compromising time-to-market, quality and cost

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Predictive Engineering Analytics
Role in systems-driven product development

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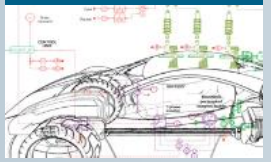
Systems-driven product development

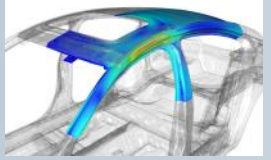
System mockup

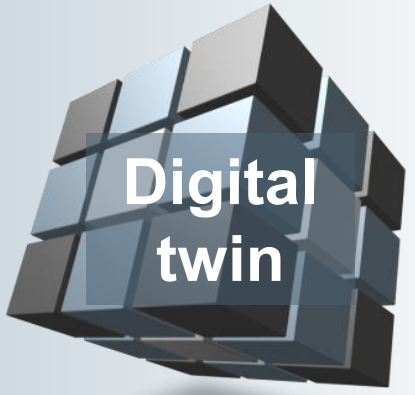
Predictive Engineering Analytics

1D



3D





Exploration - Analytics - Reporting

TEST

CFD

Managed in PLM context - Multi-domain traceability, change and configuration

Introducing Simcenter™ for Predictive Engineering Analytics

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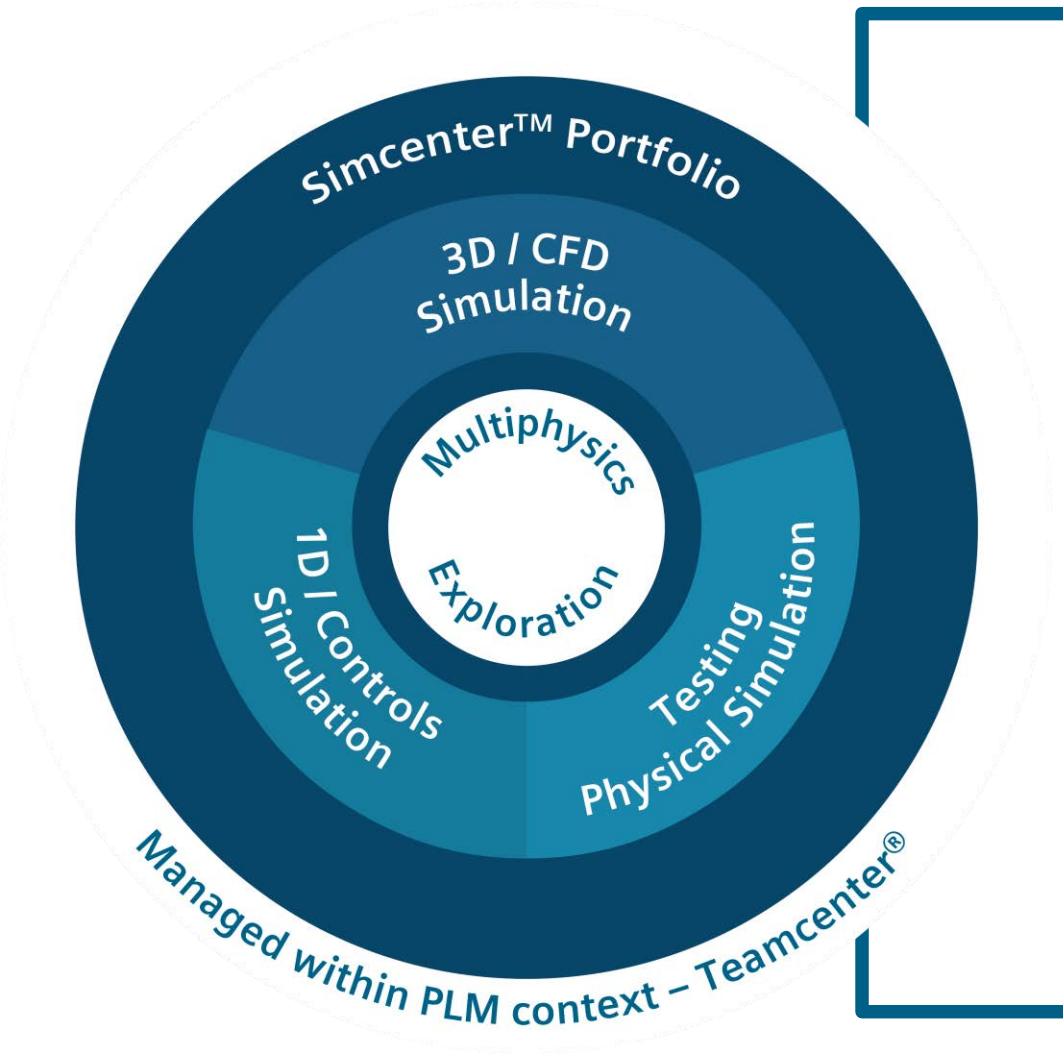

Simcenter™

Simcenter™ Portfolio for Predictive Engineering Analytics
LMS Imagine.Lab

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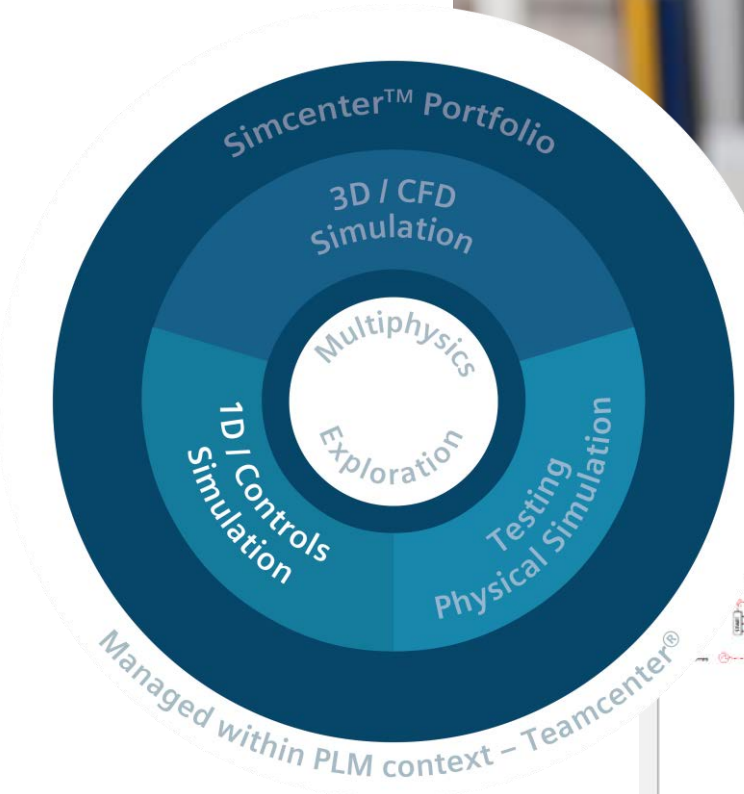
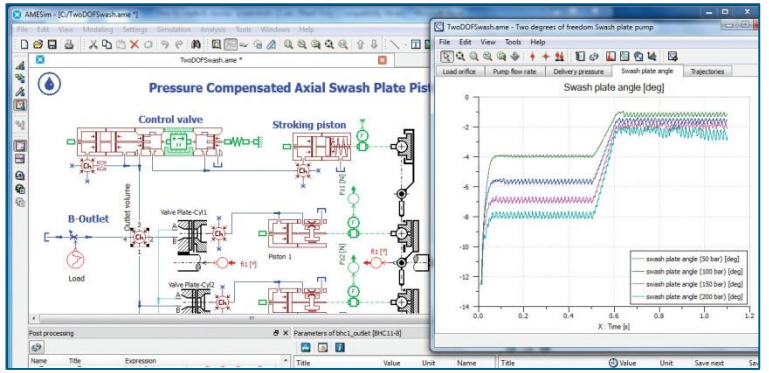
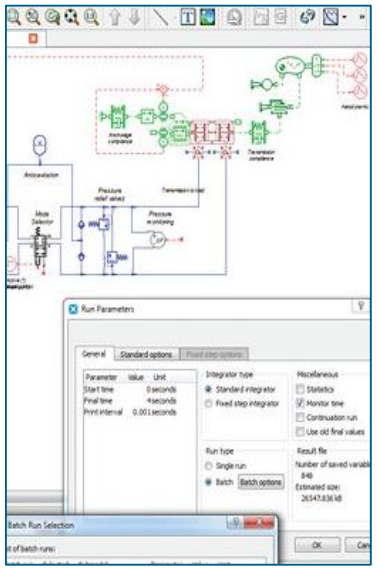
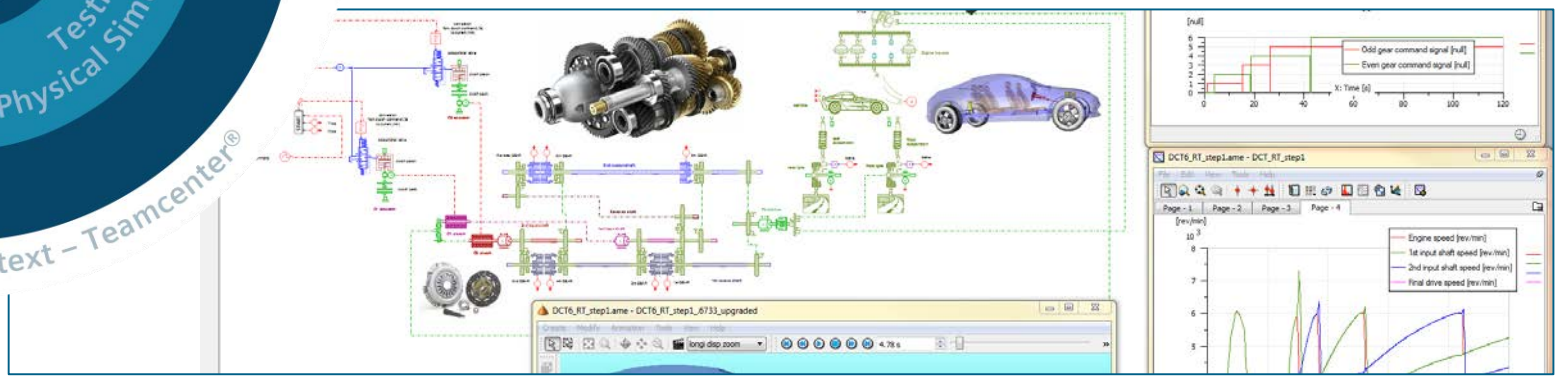


LMS Imagine.Lab Amesim







LMS Imagine.Lab System Synthesis

Simcenter™ Portfolio for Predictive Engineering Analytics
LMS Imagine.Lab

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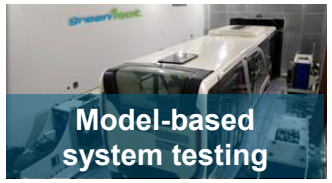


Industry-specific

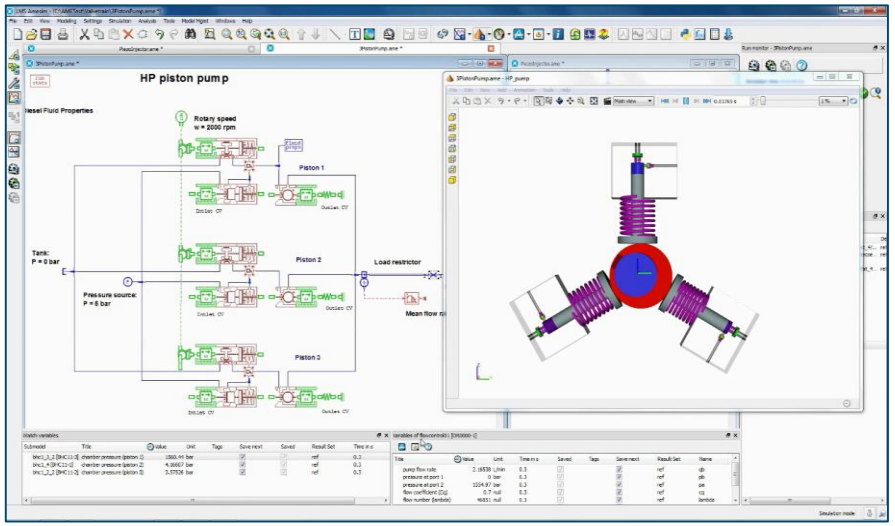
- Internal combustion
- Transmission
- Thermal systems
- Vehicle dynamics
- Electrical systems
- Landing gear & flight controls
- Engine equipment
- Environmental control systems
- Fuel systems
- Electrical aircraft
- Pumps & compressors
- Electrohydraulic valves
- Fluid actuation systems
- Heat exchangers
- Heat pumps / refrigerators

Pre-design

Systems sizing & integration

Performance balancing

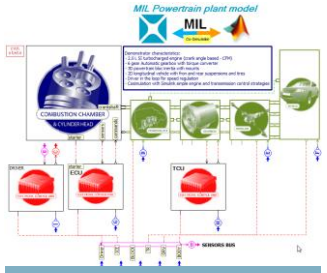
Controls validation



Scalable simulation

Connecting mechanical and controls

Model reduction for real-time simulation

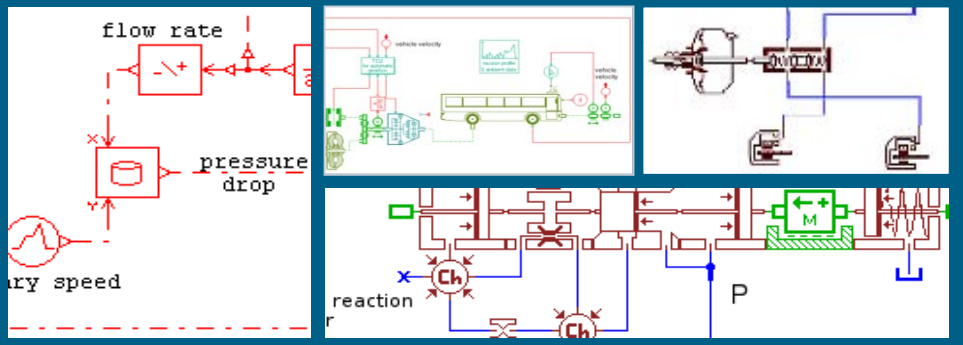


Co-simulation

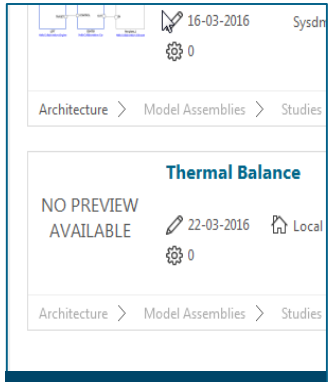
Open & customizable

>30 libraries

>4,000 multi-physics models



Hydraulics
Pneumatics
Thermal
Electrical
Mechanical
Signals



Process & data Management

Engineering services

Experience and global talent for valued customer partnerships

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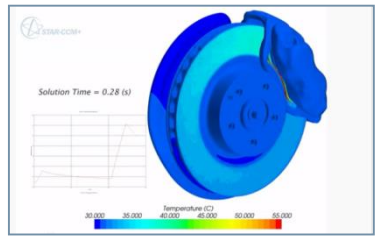
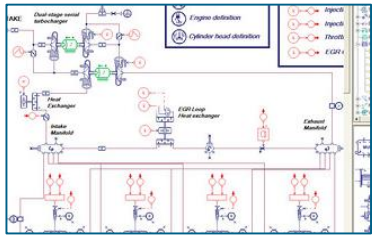
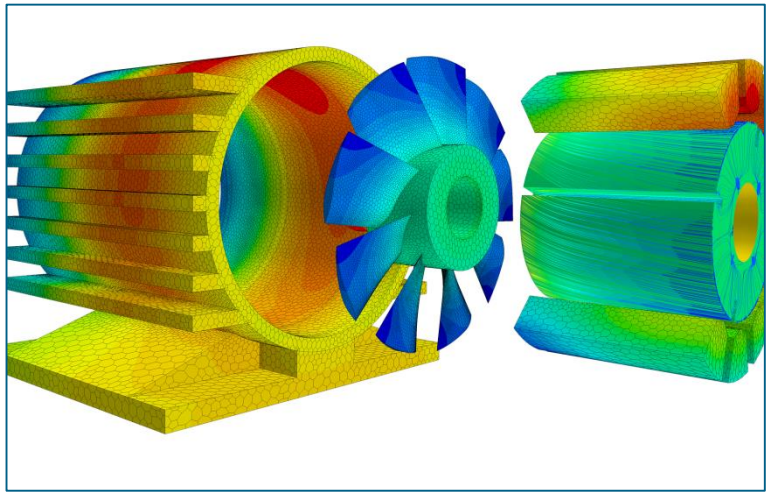
CD-adapco Engineering

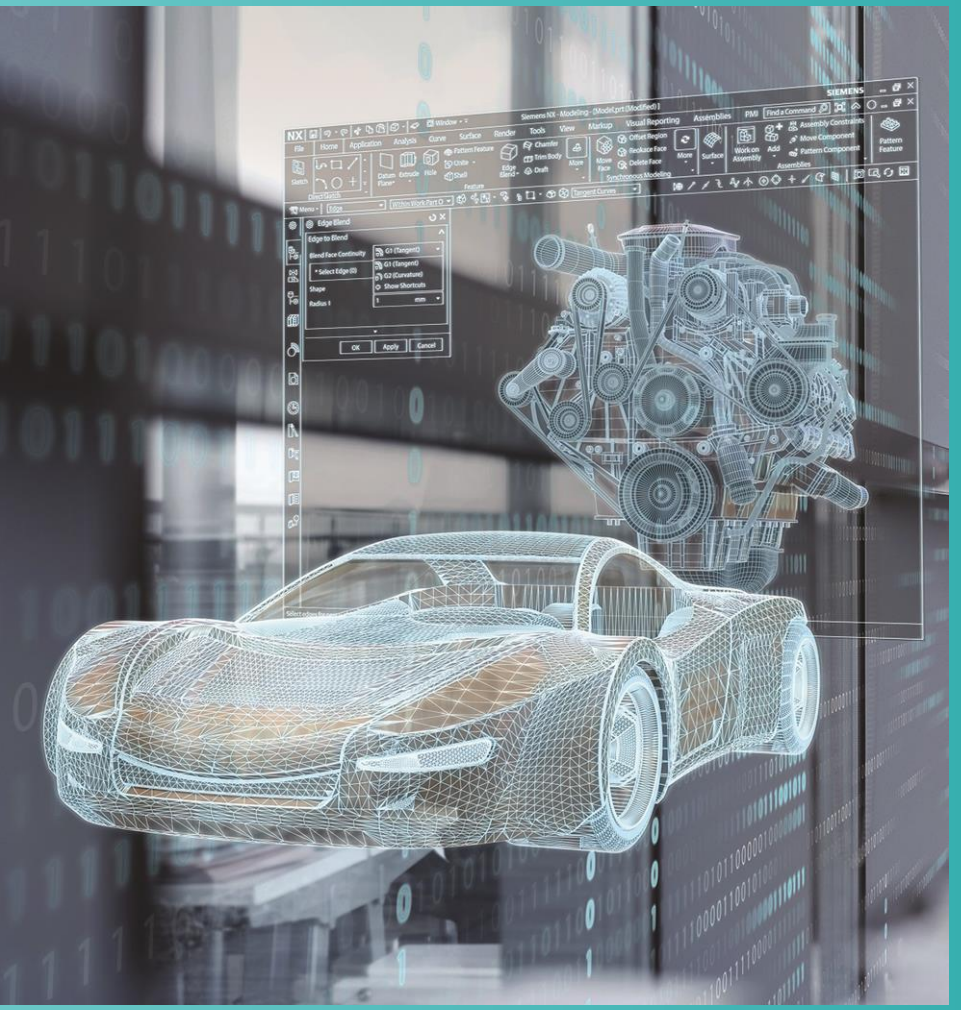






LMS Engineering

Agenda



- The truck and bus industry is evolving
- **Model-based systems engineering for truck and bus**
- The voice of our customers
- Conclusion

Model-based systems engineering for truck and bus design

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CHALLENGE:

Balancing operability, fuel efficiency and other key vehicle attributes

From vehicle synthesis to sub-systems optimization…

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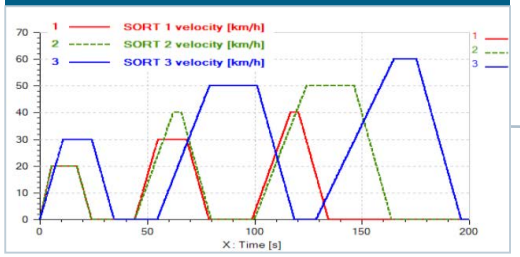
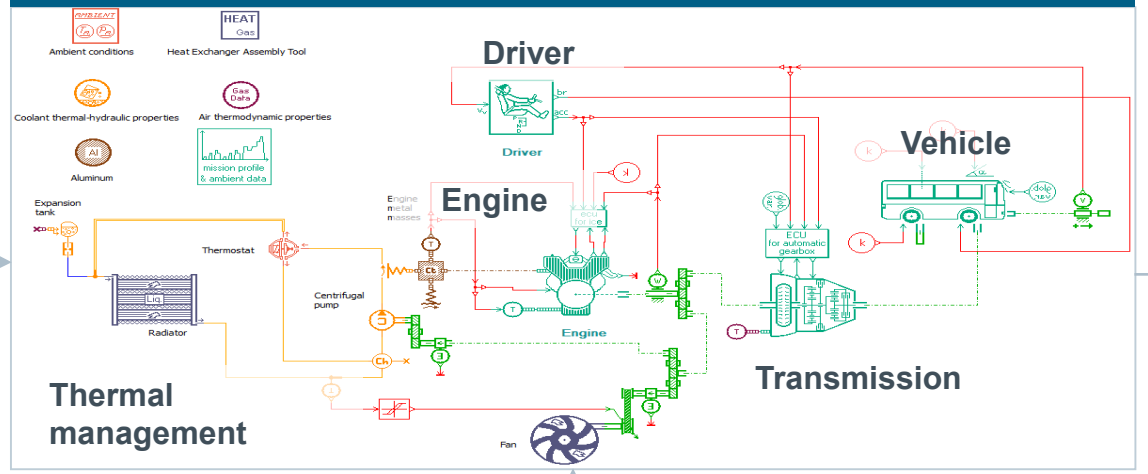
Scenarios



Multiple driving cycles

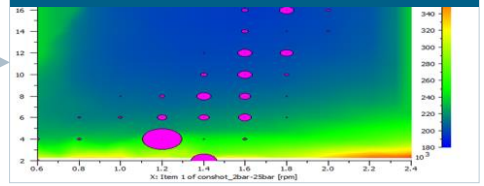
Vehicle model – Synthesis and analysis



Sub-systems models and tools

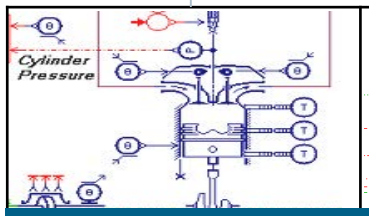
Productivity

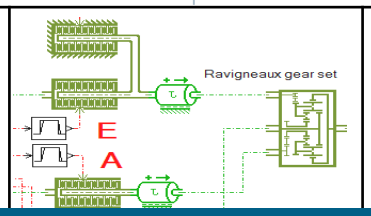
Fuel eco & emissions

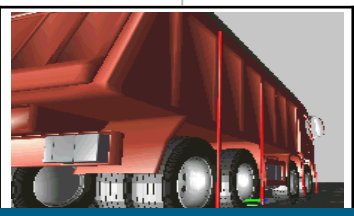


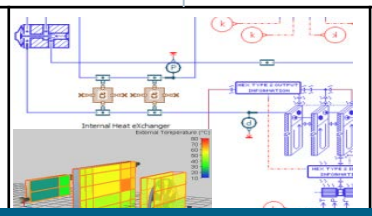
Safety and Comfort

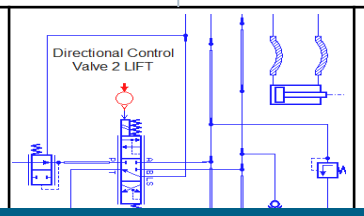
Performance attributes

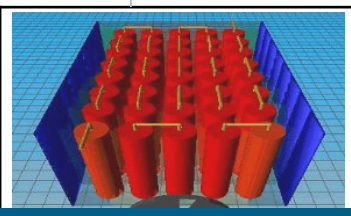


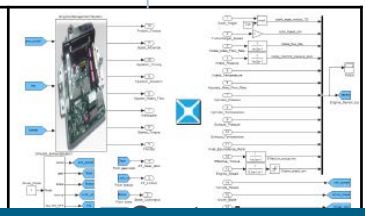












Engine | Transmission | Vehicle | Thermal | Fluids | Electrics | Control

Application 1: hybridization of a bus
Fuel economy estimation

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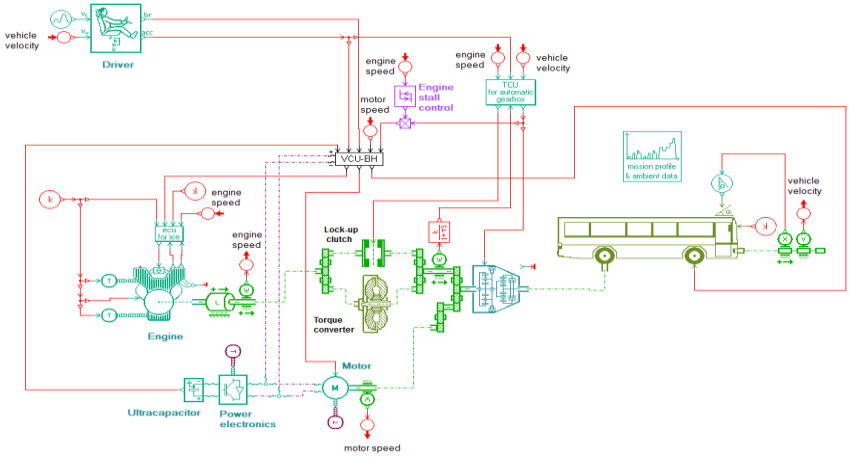
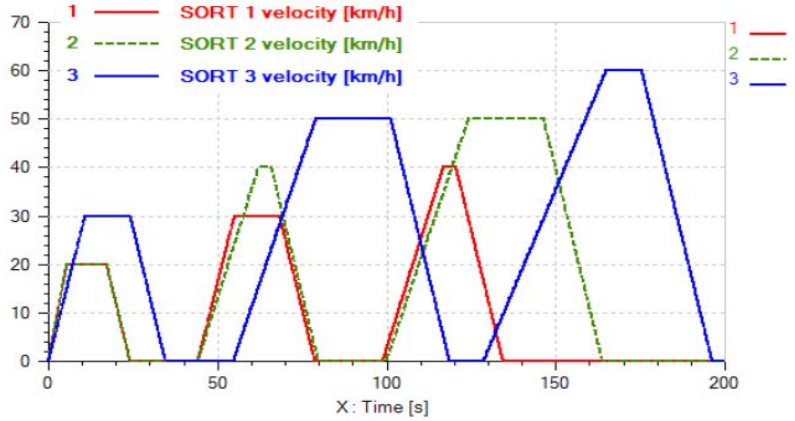
Objectives

- Reduce the operating cost of a city bus by improving the fuel economy
- Shift the engine operating torque to get the optimal efficient range and recover the energy lost during braking



Solution

- Develop an electrified powertrain including an electric motor, an inverter and a super-capacitor
- Estimate the gain in term of fuel economy on the SORT cycle, a specific bus cycle developed by International Association of Public Transport (UITP)



Application 1: hybridization of a bus
Conventional bus

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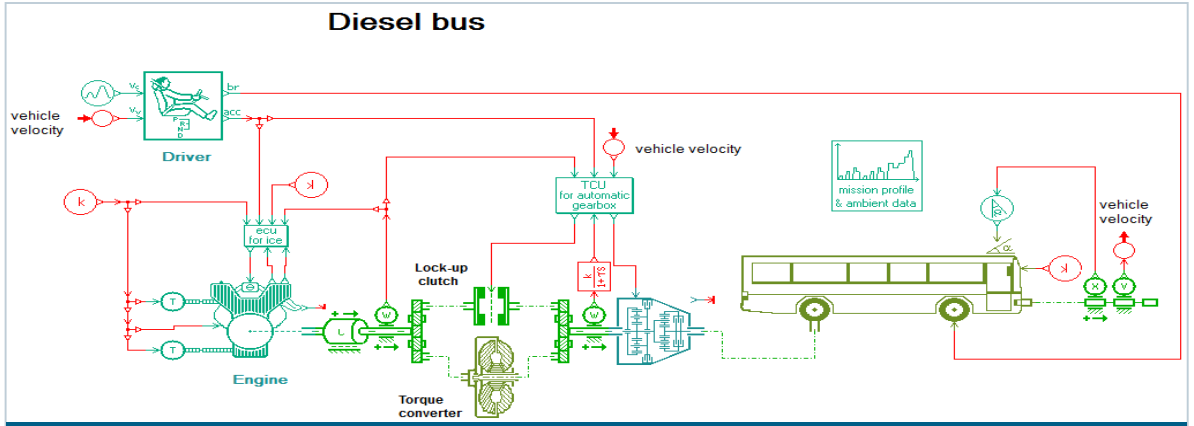
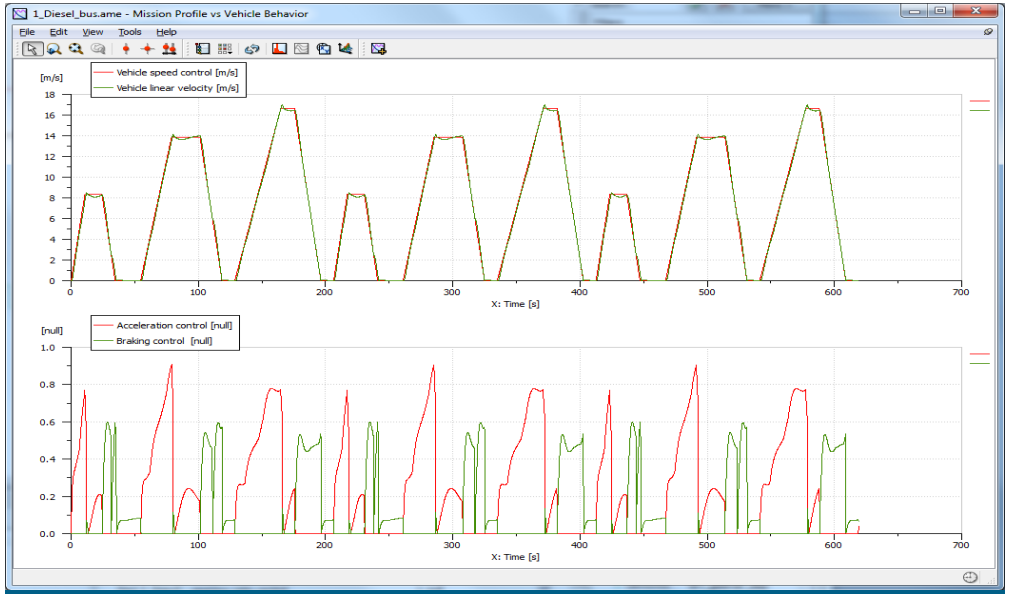
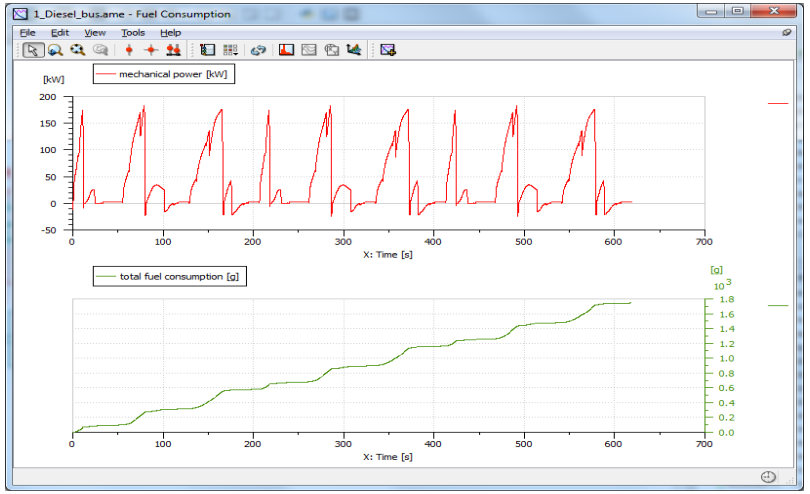


LMS Amesim model of the diesel bus



Mission profile and driver command

Mechanical power and fuel consumption



Application 1: hybridization of a bus
Hybrid electric bus: map-based model for electrics

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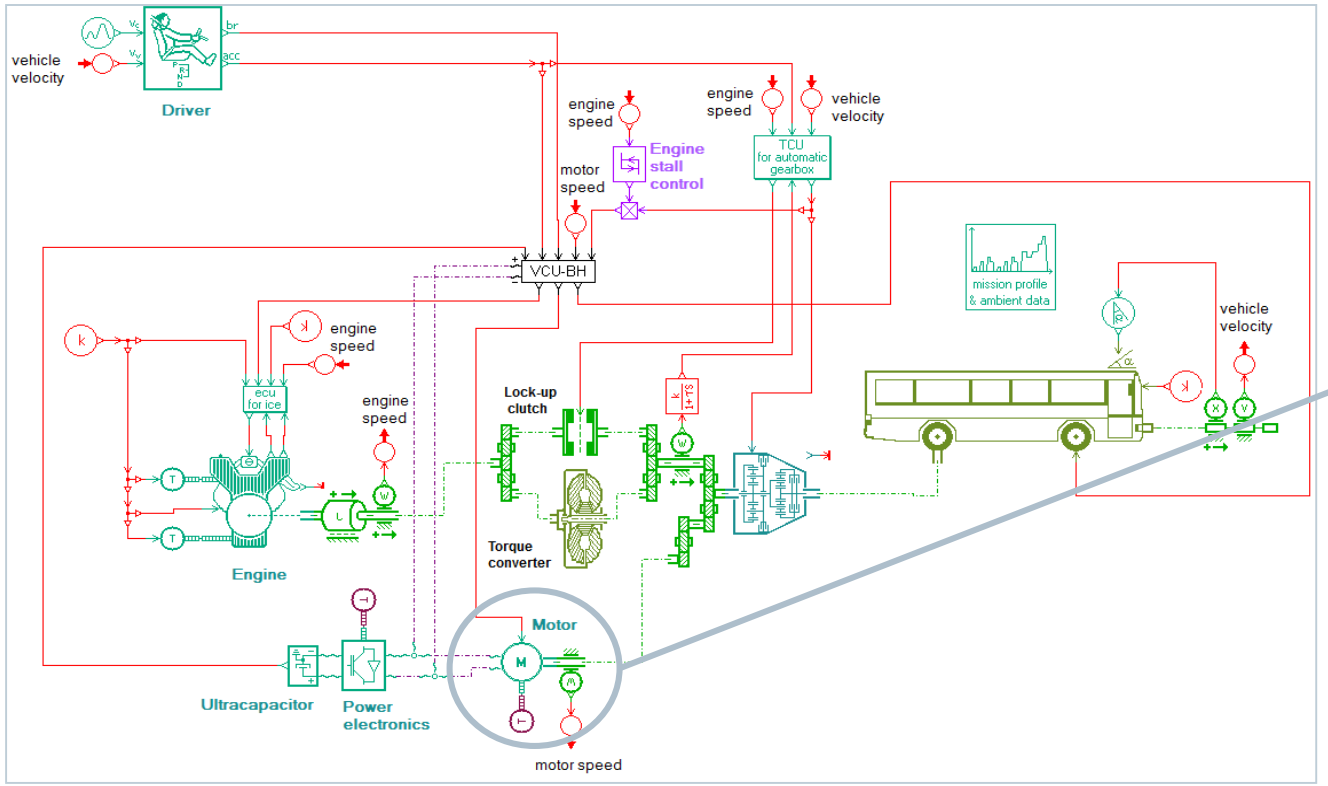
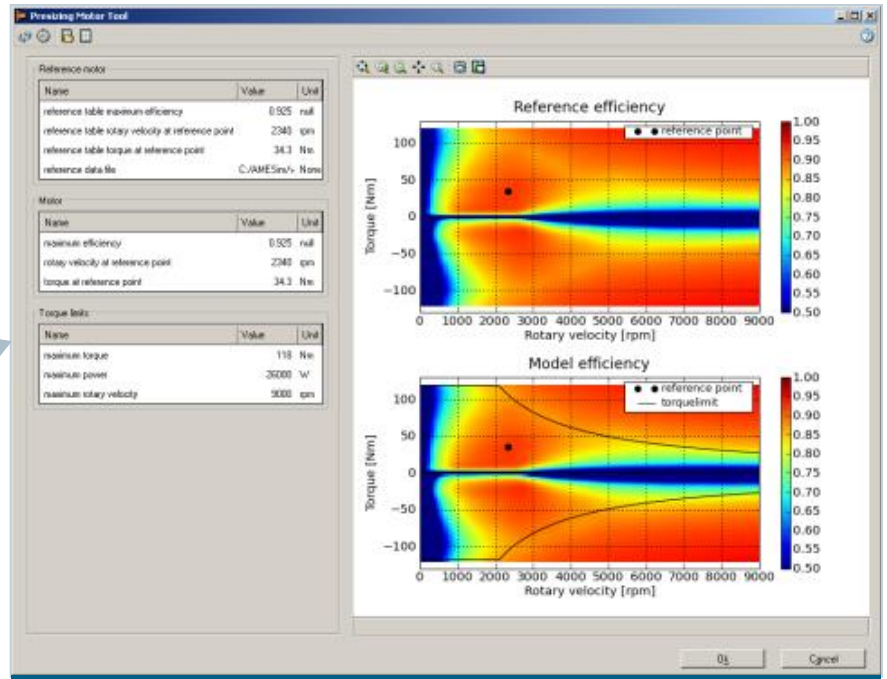


LMS Amesim model of the hybrid bus



Tabulated electrical machine for pre-sizing with rescaling tool
and GUI (maximum torque and efficiency)

Application 1: hybridization of a bus
Hybrid electric bus: functional model for electrics

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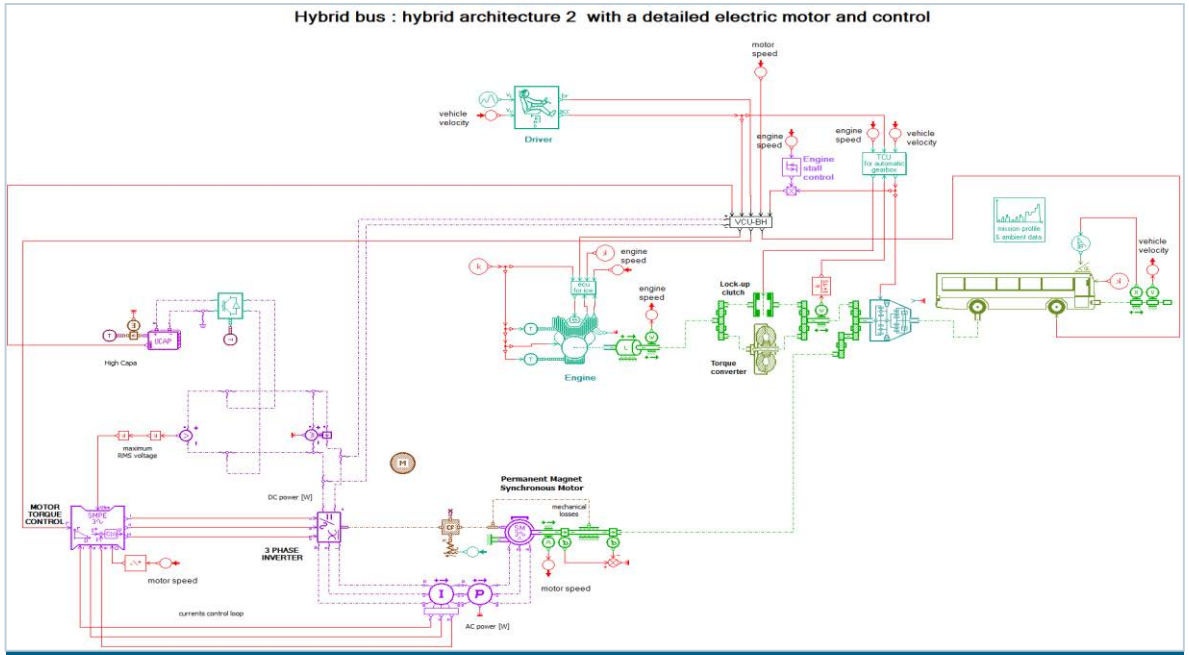
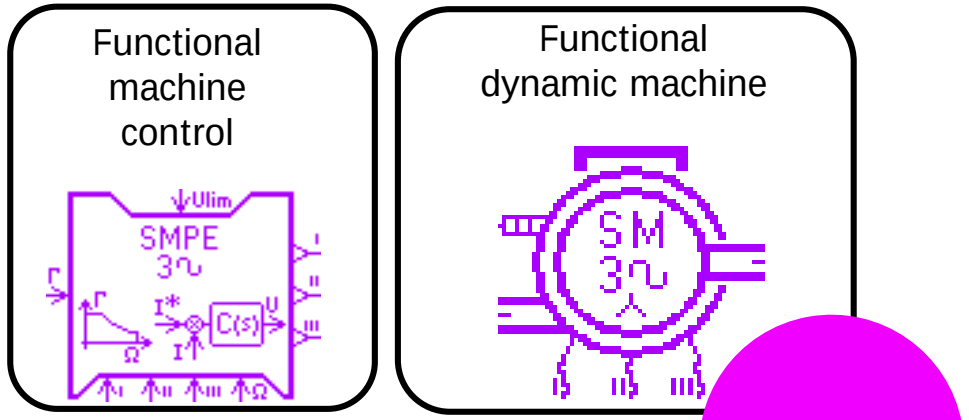


LMS Amesim model of the hybrid bus



Functional electrical modeling for mechanical dynamics, control analysis and losses estimation

Application 1: hybridization of a bus
Hybrid electric bus: comparison with diesel vehicle

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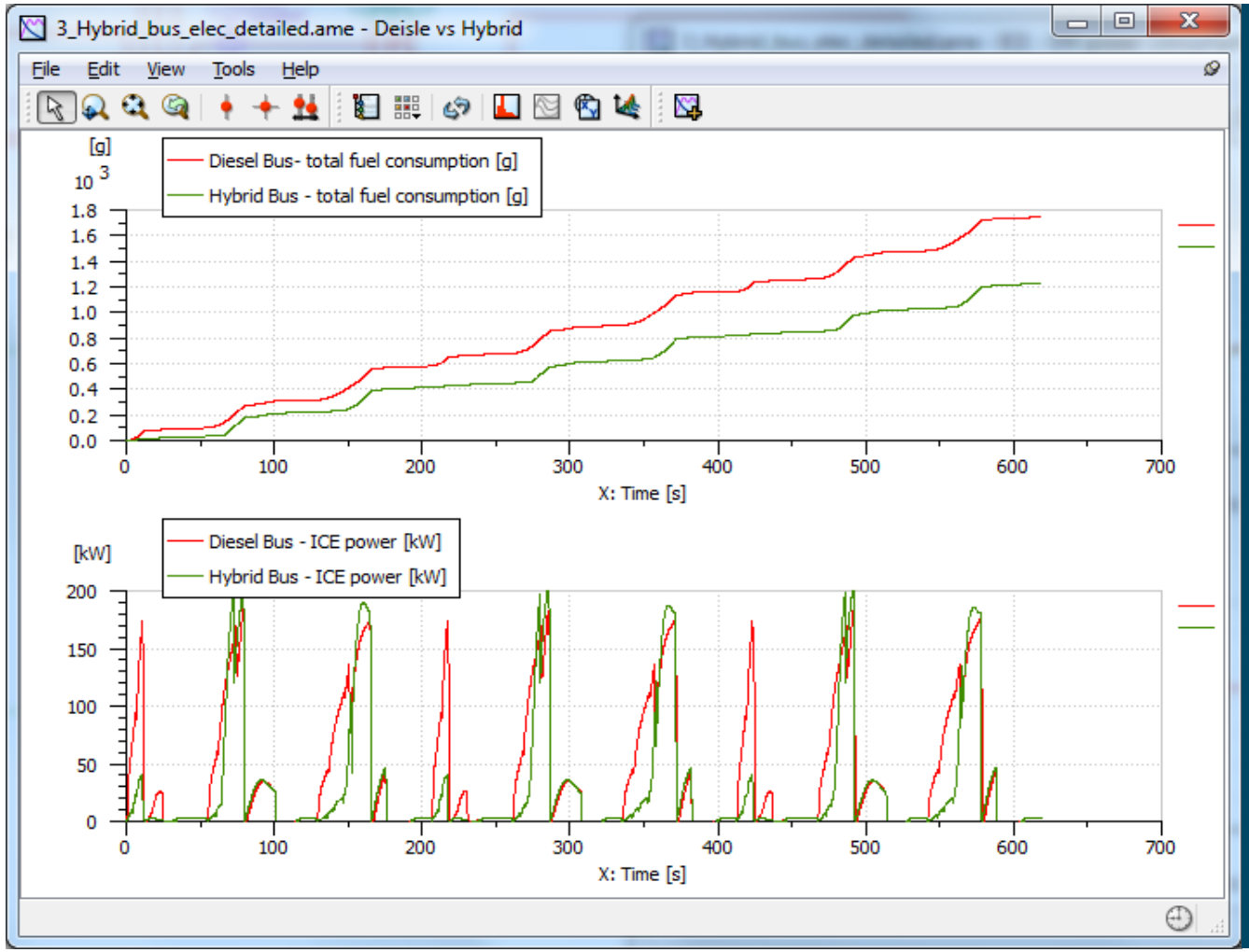

Fuel consumption reduction and ICE power

Application 2: manual transmission Efficiency analysis

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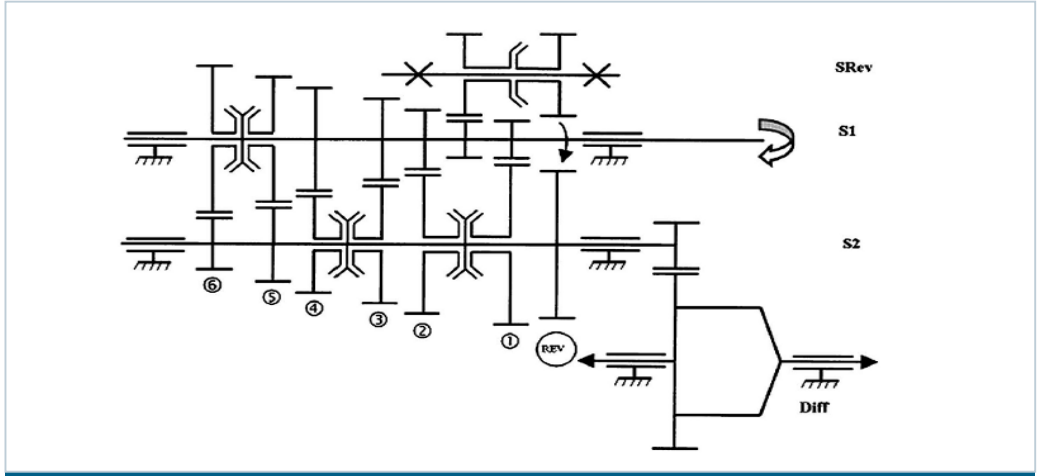
Objective:

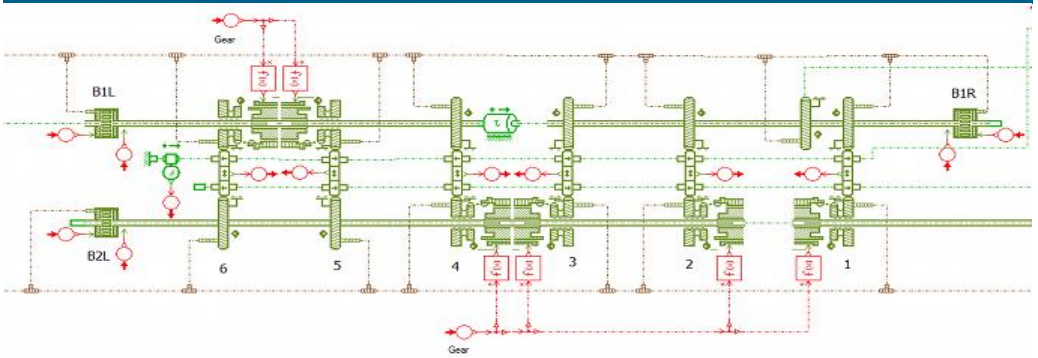
- Analyze the power losses and monitor the global efficiency of a mechanical transmission in function of the vehicle speed

Requirements:

- Account for the power losses each family of component: roller bearing, journal bearing, gear contact, oil paddling, ring friction…



Mechanical transmission layout and portion of the corresponding LMS Amesim model



Application 2: manual transmission
Losses calculation

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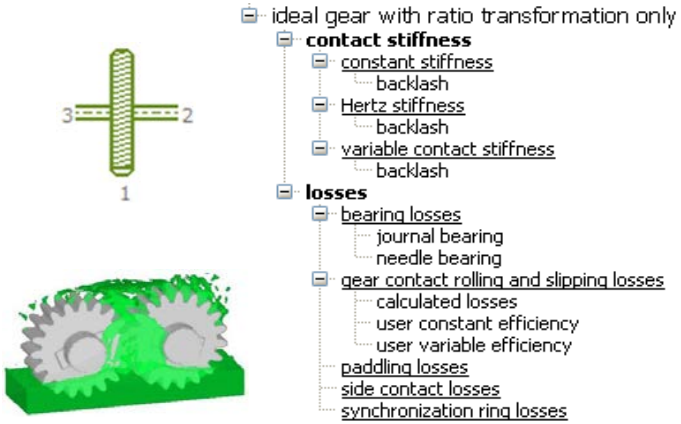
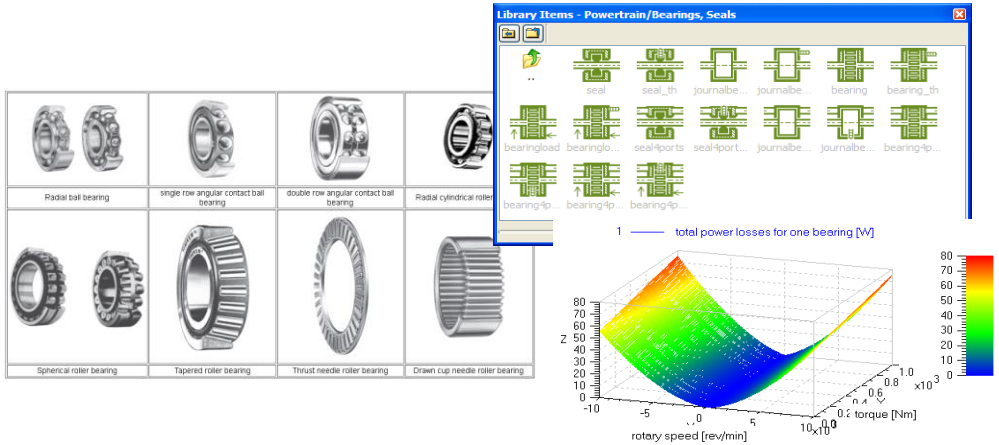
Gear trains

- Different levels of complexity:
  - Simple transformer ratio
  - Constant losses
  - Variable losses defined with tables
  - Calculated contact losses based on geometry
  - Paddling and side contact losses
  - Clearance and contact stiffness



Bearings

- Different levels of complexity:
  - Tabulated losses
  - Detailed losses based on geometry and loads
  - With/Without thermal impact
  - Bearing losses due to oil & material deformations
  - Models based on semi-empiric equations and manufacturers coefficients
  - Generic formulation, NTN or Timken equations



Application 2: manual transmission Results

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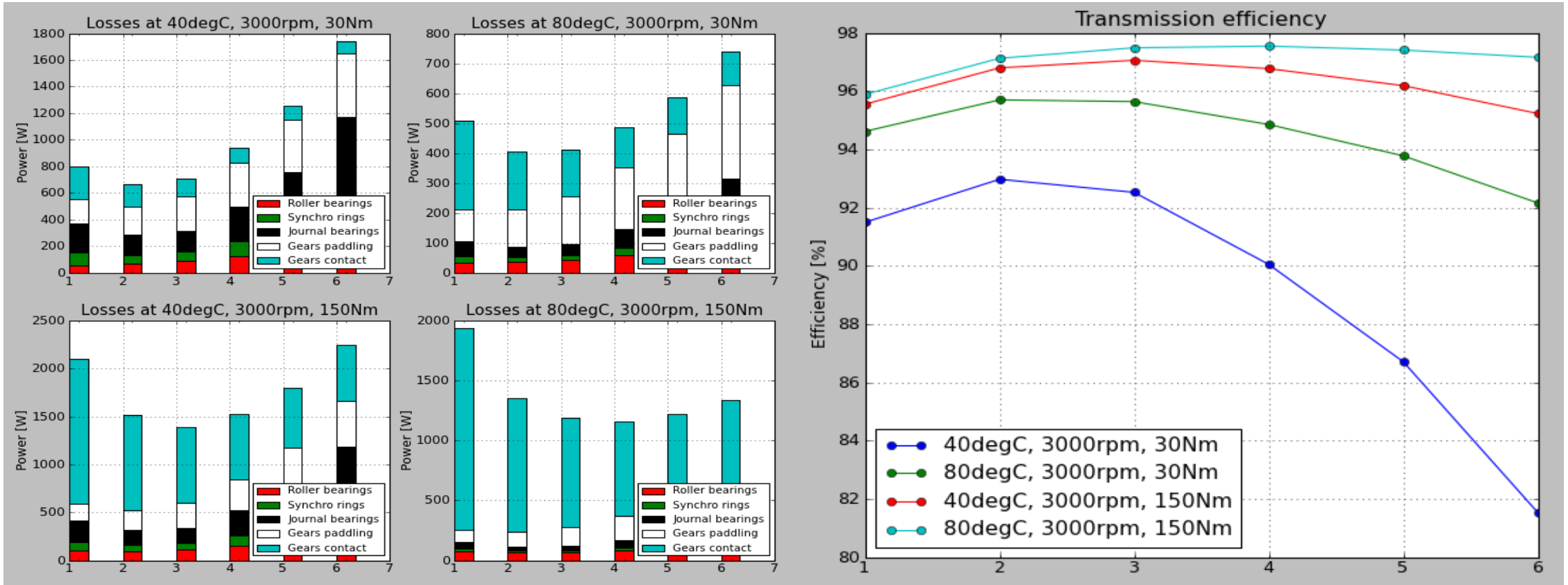

Visualization of losses and global driveline efficiency: batch run is performed to reach 24 stationary points: 6 gears, 2 input torques, 2 temperatures, 1 engine rotary velocity

Application 3: truck with closed-loop fan control
Enhance fuel consumption prediction

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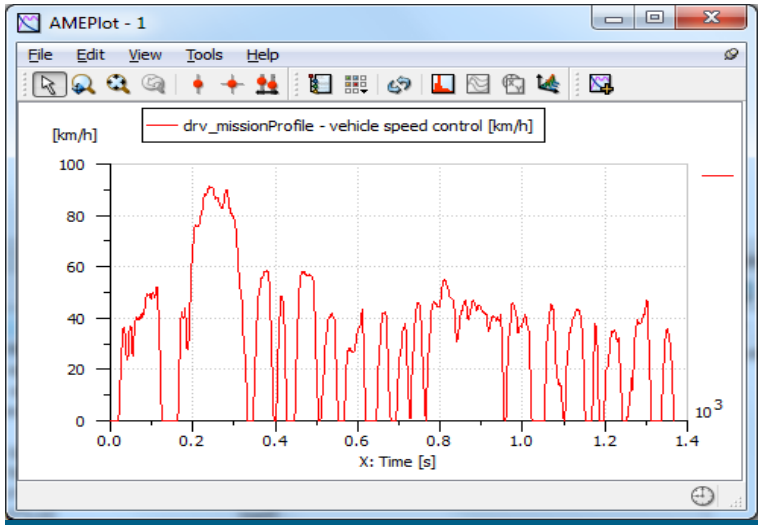
Objective

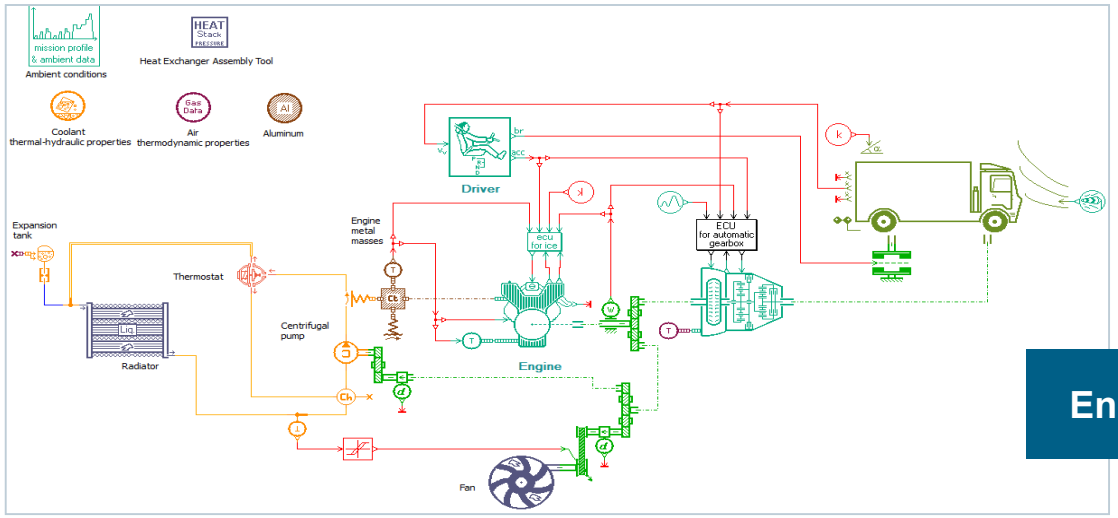
- Analyze the fuel consumption of a truck including the power consumption of auxiliaries and especially the engine cooling fan (up to 15% of the engine power)

Requirement

- Captured thermal dynamics of the engine cooling system and enable closed-loop fan control



FTP-72 or UDDS cycle



Energy management model of a truck

Application 3: truck with closed-loop fan control
Step 1: vehicle performance/fuel consumption simulator

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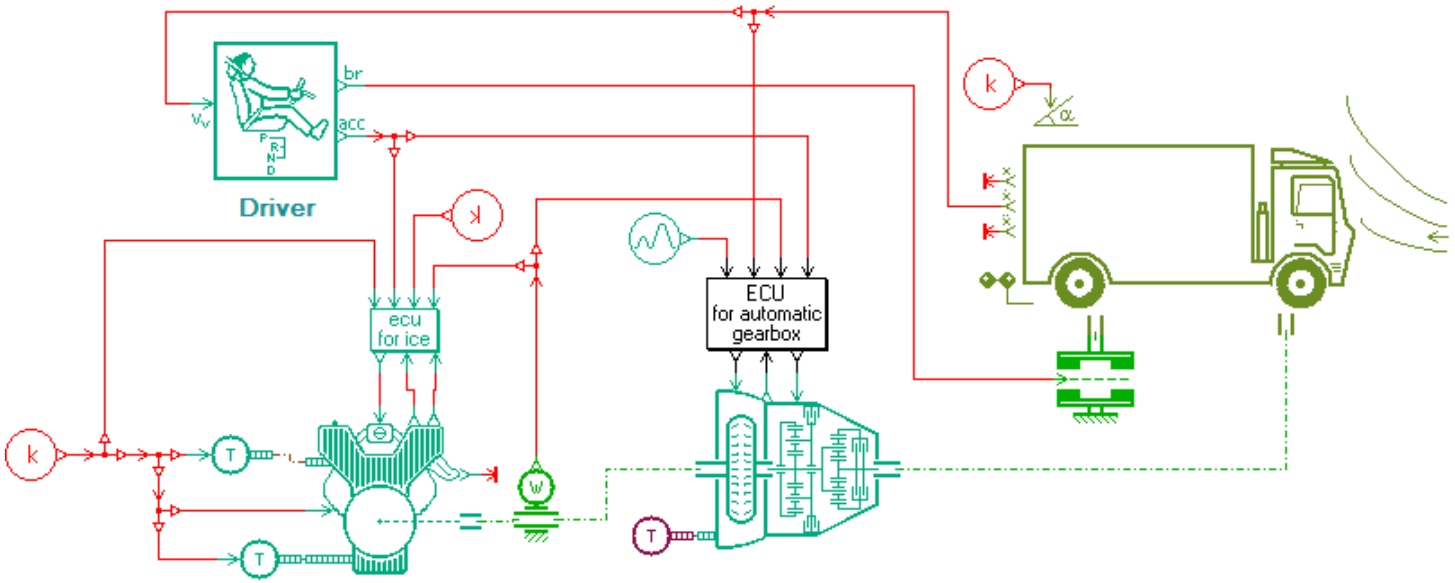
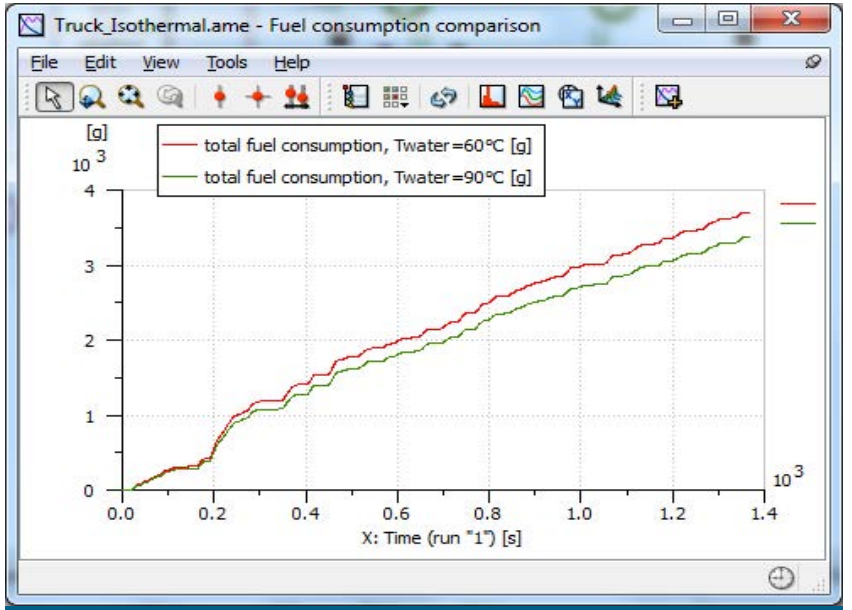
Objective

- Impact of engine temperature on fuel consumption

Requirement

- Iso-thermal simulation





Dependence of fuel consumption on the engine temperature: at low temperature, friction is high leading to increased the fuel consumption

Application 3: truck with closed-loop fan control
Step 2: thermal dynamics of the engine cooling system

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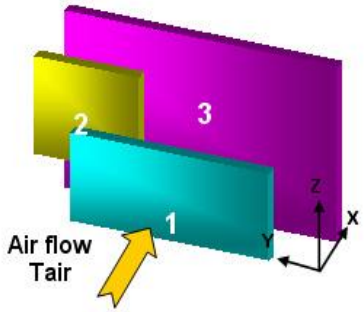
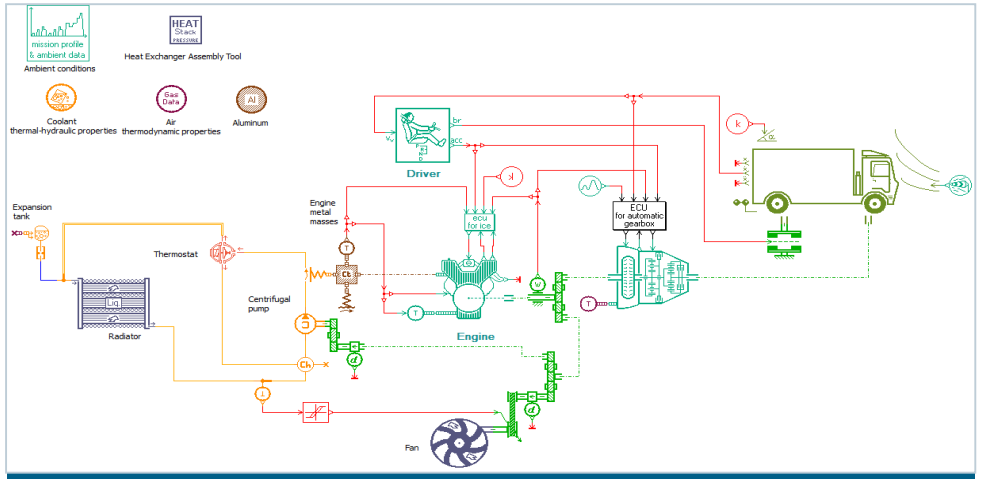
Objective

- Estimate the power consumption of the engine cooling fan

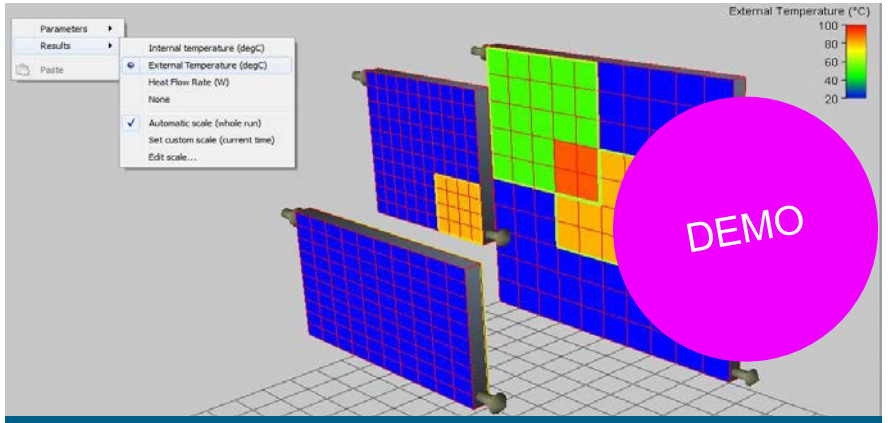
Requirement

- Capture thermal dynamics of the engine cooling system and enable closed-loop fan control





Fan control depends on engine coolant temperature. When the fan is activated, it consumes energy



Heat exchanger stacking: study the trade-off between different configurations

Application 3: truck with closed-loop fan control
Step 2: thermal dynamics of the engine cooling system

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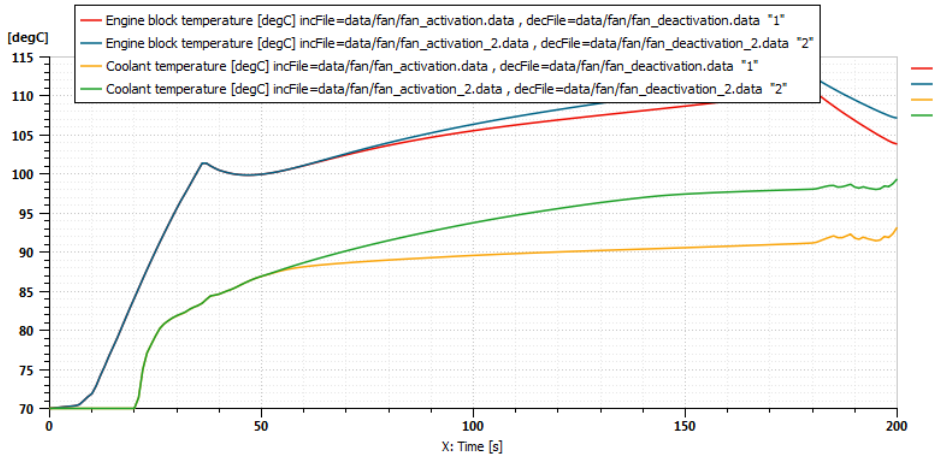
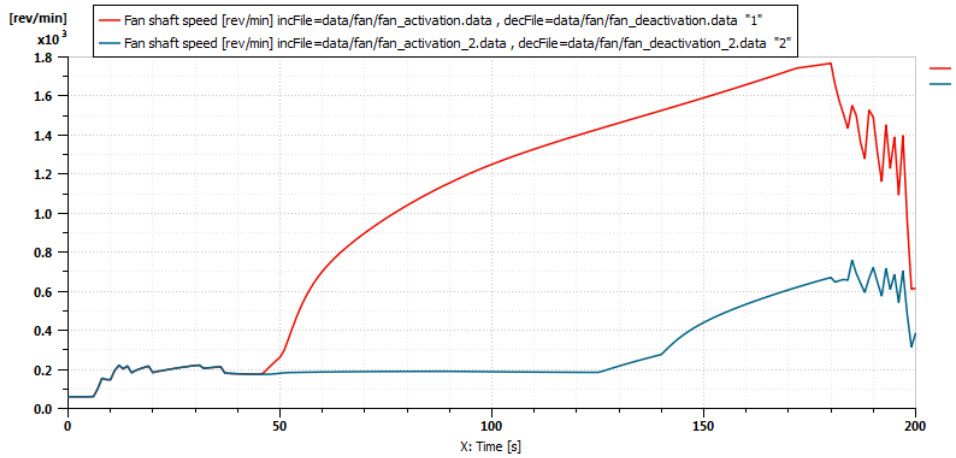
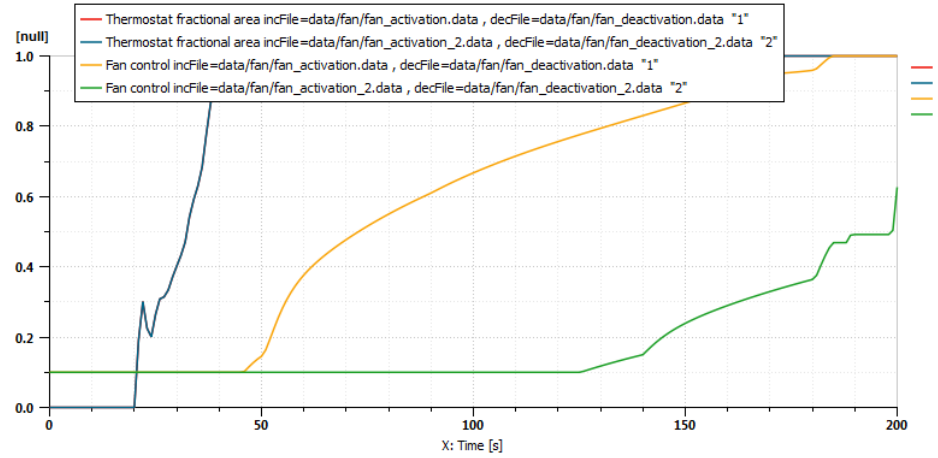
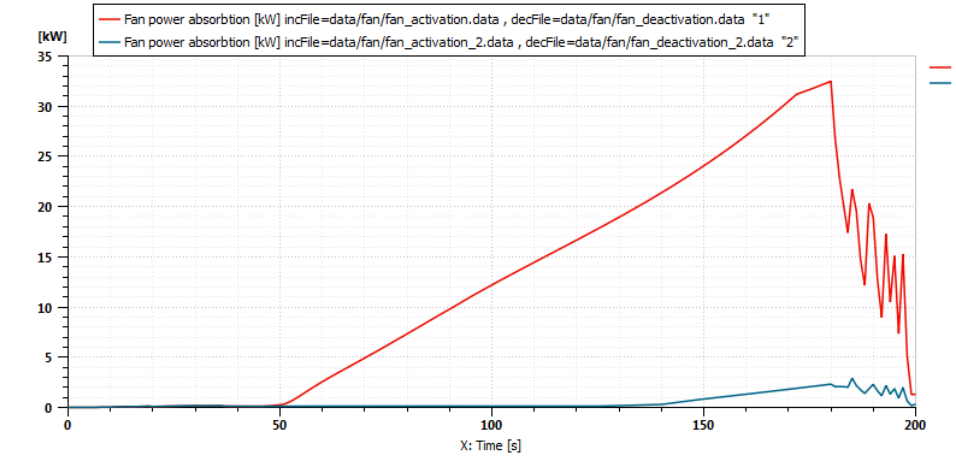




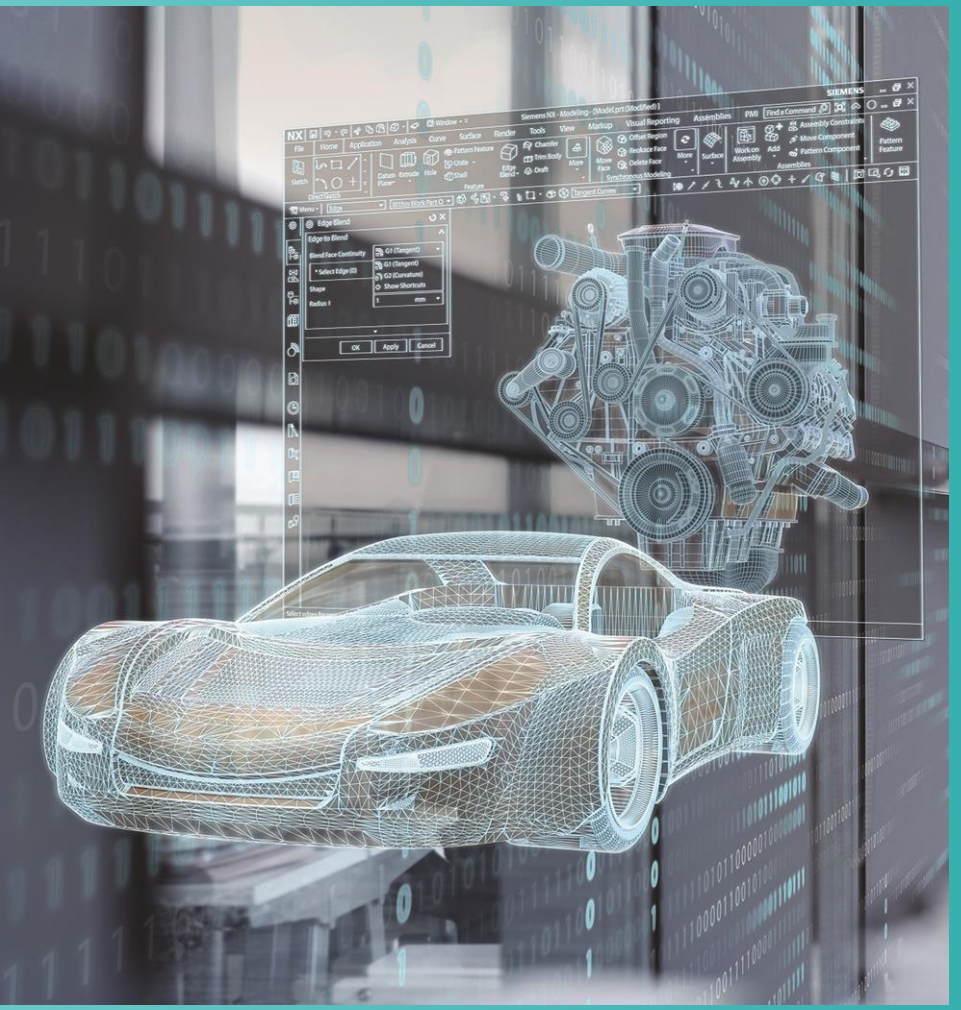




Engine thermal management: coolant temperature, thermostat opening and fan control

Fan power consumption depends on fan control

Agenda



- The truck and bus industry is evolving
- Model-based systems engineering for truck and bus
- **The voice of our customers**
- Conclusion

Voith Turbo

Making greener city buses using LMS Imagine.Lab Amesim

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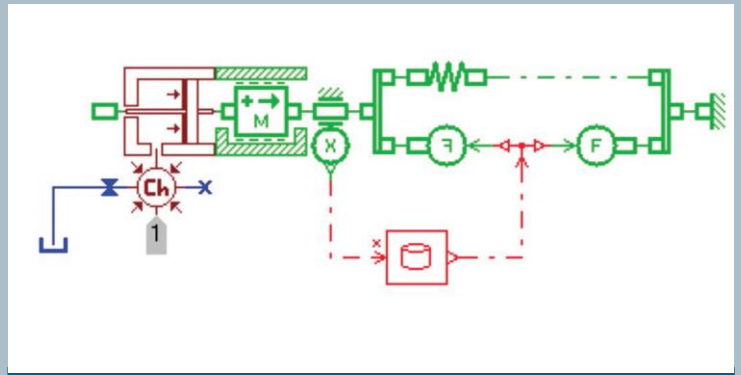
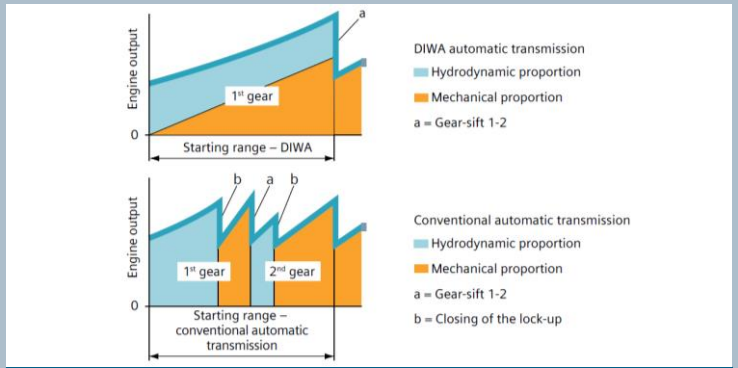
Ingenuity for life

- **Reduced testing time and number of prototype iterations**
- **Developed improved design for hydraulic valves**
- **Enabled continuous improvement to the design and development processes**

Enhance automatic transmission by acting on hydraulic valves



LMS Imagine.Lab Amesim model



Automatic transmission analysis

- Use 1D multi-domain system to predict dynamic behavior of systems and subsystems
- Leverage scope and quality of LMS Amesim libraries

Link to the story

"[LMS Amesim] definitely helped to streamline the design and development of our transmission systems, making them readily available for the transportation market."

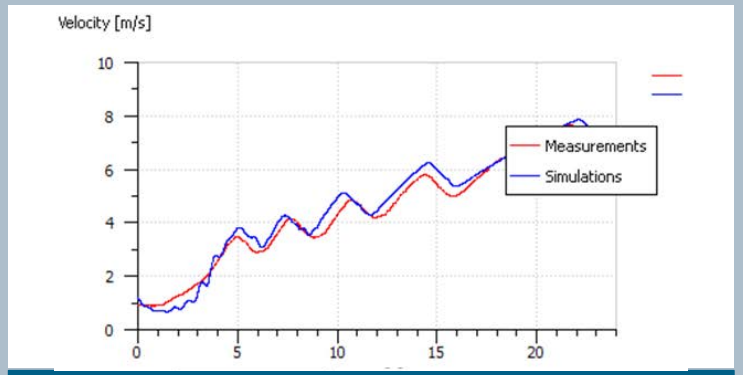
Bernhard Höfig, Mechatronics and Simulation

Scania
Reducing driveline modeling time using LMS Imagine.Lab Amesim

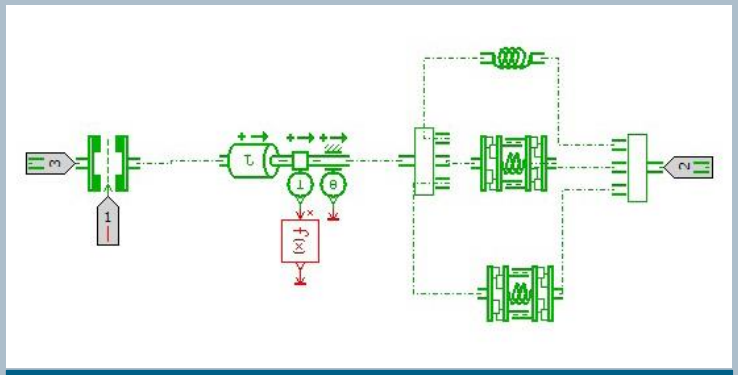
SIEMENS
Ingenuity for life

- **Reduced modeling time by a factor of 2 to 10**
- **Accelerated CPU time**
- **Streamlined development processes**

Analyzing drivability, NVH, comfort and vehicle performance



Drivability analysis



Clutch model in LMS Imagine.Lab Amesim

- Study drivability, gearbox losses and oil flow, NVH comfort and pneumatic actuation
- Perform fast simulations using real-time capabilities

Link to the story

“LMS Amesim allows Scania to first understand the main issues, and then reduce modeling time […]. Moreover, we can run some simulations faster than the real time”

Fredrik Birgersson, Senior Engineer

Dongfeng Commercial Vehicle

Optimizing engine control strategies with LMS Imagine.Lab Amesim

SIEMENS
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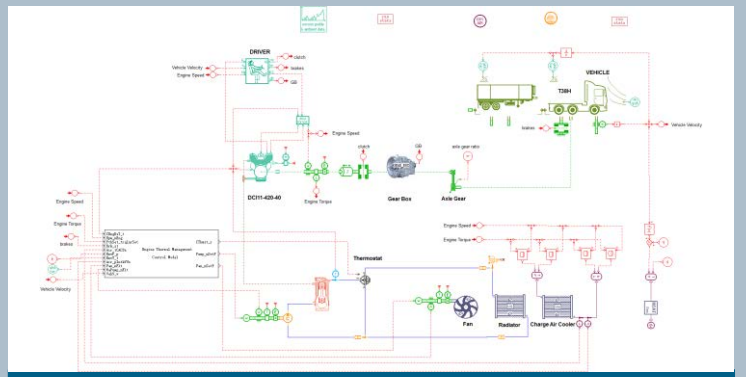
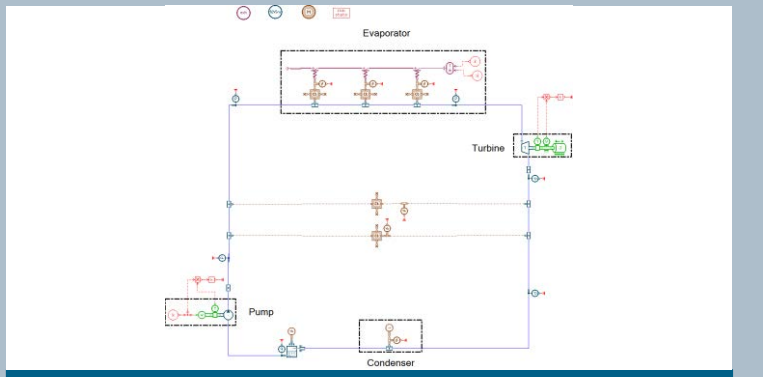
- **Optimized engine cooling controls strategies**
- **Analyzed behavior of the combustion, cooling and lubrication subsystems**
- **Studied Rankine cycle technology before the first prototype was available**

Boosting fuel efficiency with innovative energy recovery technology



Co-simulation LMS Amesim and Simulink®



Rankine cycle loop model

- Design an efficient engine cooling system with advanced controls strategies
- Analyze the impact of the exhaust heat recovery technology

Link to the story

“Our research and development activity around the Rankine cycle technology wouldn’t be possible without the two-phase flow library of LMS Amesim...”

Zhang Xin, Controls Engineer

University of Belgrade, Faculty of Mechanical Engineering

Analyzing hybrid transit bus fuel economy with LMS Imagine.Lab Amesim

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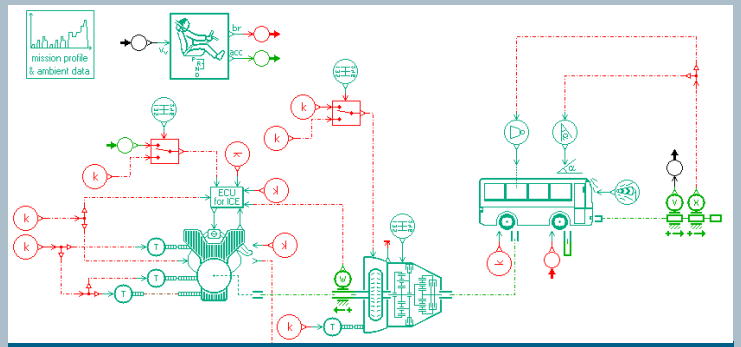
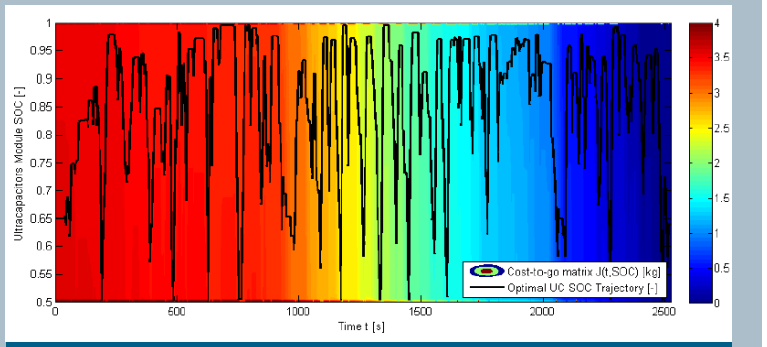
Ingenuity for life

- **16% fuel consumption reduction assessed with LMS Amesim**
- **Identified set of test data required for fuel consumption simulations**
- **Fuel economy compared for several hybrid control algorithms**

Real conventional bus identification and virtual hybridization



Conventional hybrid bus LMS Amesim model



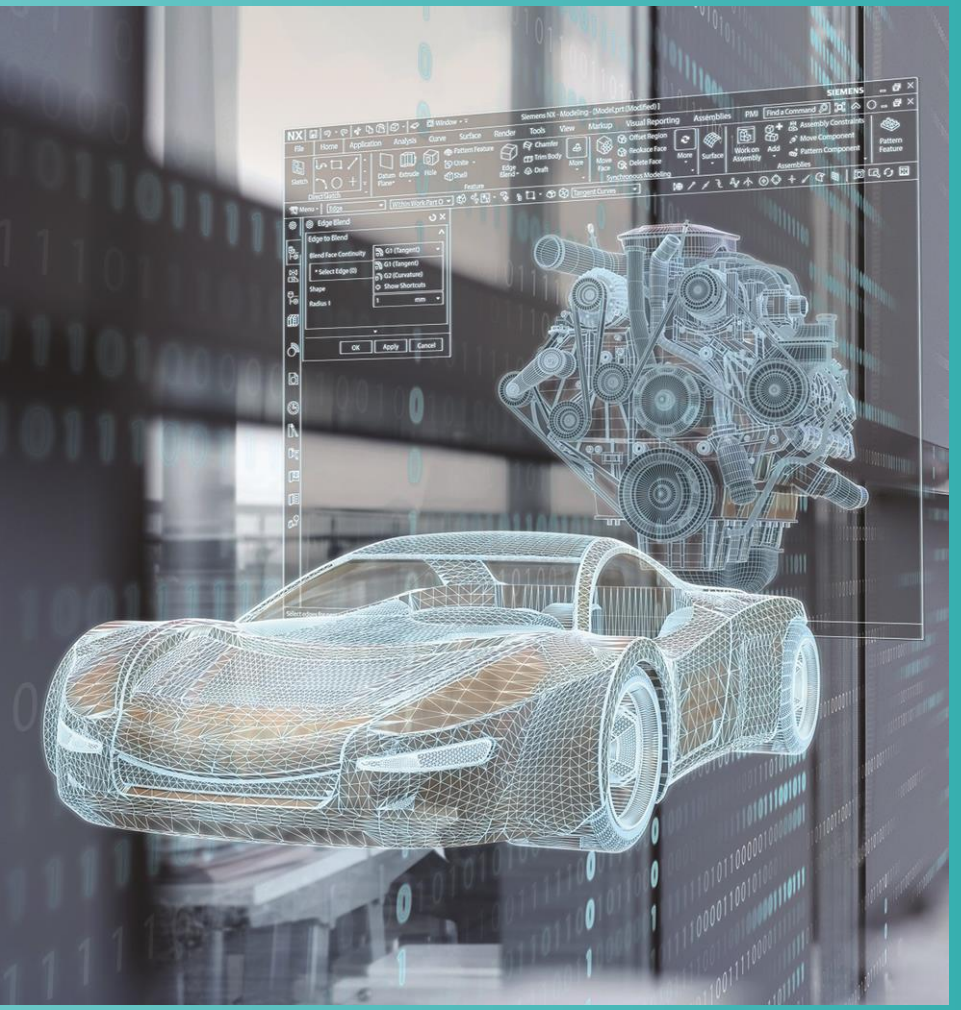
Optimal state of charge (SOC) trajectory

- Import real driving vehicle and powertrain measurement data into LMS Amesim
- Compare ultra capacitors-based hybrid vehicle with conventional one

"LMS Amesim provides a graphical programming interface and an extensive set of validated components organized in different libraries for modeling and analyzing system performance."

Marko Kitanović, M.Sc., Teaching and Research Assistant, Internal Combustion Engines Department

Agenda



- The truck and bus industry is evolving
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- **Conclusion**

Model-based systems engineering solutions
Unique value proposition for truck and bus design

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Reduce development cost with fewer prototypes

Analyze vehicle/powertrain architectures earlier in the development cycle

Virtually assess systems interactions

Study the influence of control strategies on fuel consumption, emissions and performances

Balance critical attributes: fuel economy, performances, passenger comfort and drivability

Find the best comprise to fit both regulations and market requirements

Explore how the Simcenter portfolio can help you optimize designs and deliver innovations faster, with greater confidence

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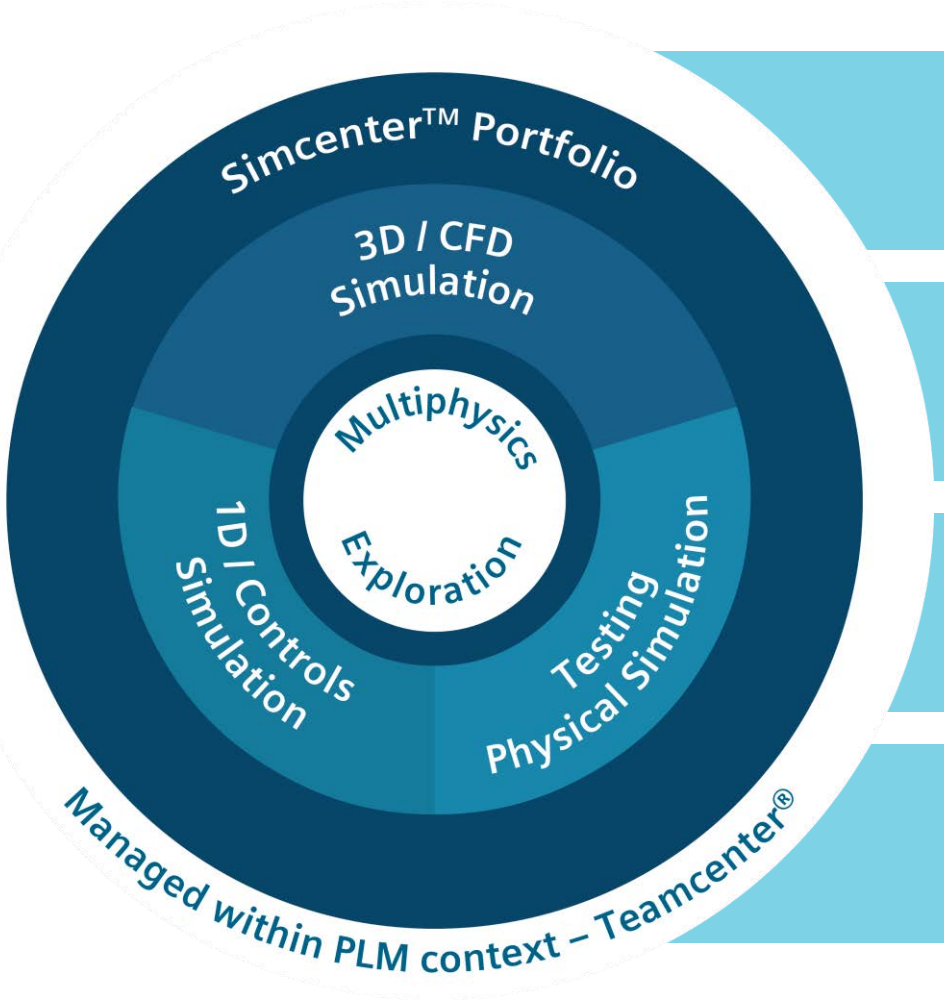

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