Co-Simulation for hybrid vehicle control software development

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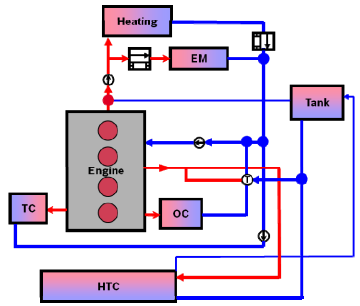
Scope of (Co)Simulation

Support the development of innovative
energy management control strategies for passenger cars

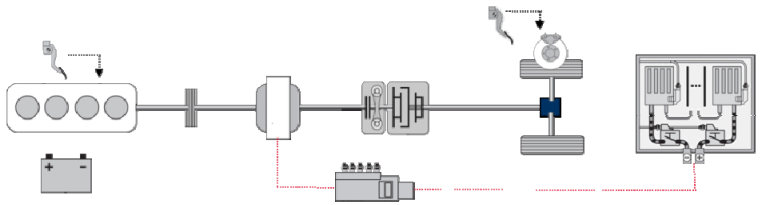
Domains under investigation:

Combined control strategy

Thermal system control strategy



HEV Powertrain control strategy



Motivation for (Co)Simulation

- Good reproducibility and fast repeatability of experiments
  - Required especially for traffic simulation & warm-up experiments
- Investigation of real world systems with limited availability
  - Not all HEV / thermal topologies are available as real systems
- Time & costs savings by “Virtual Controller Prototyping”
  - Run control strategy model on a rapid prototyping system in a vehicle

Using (Co)Simulation makes us faster and saves money!

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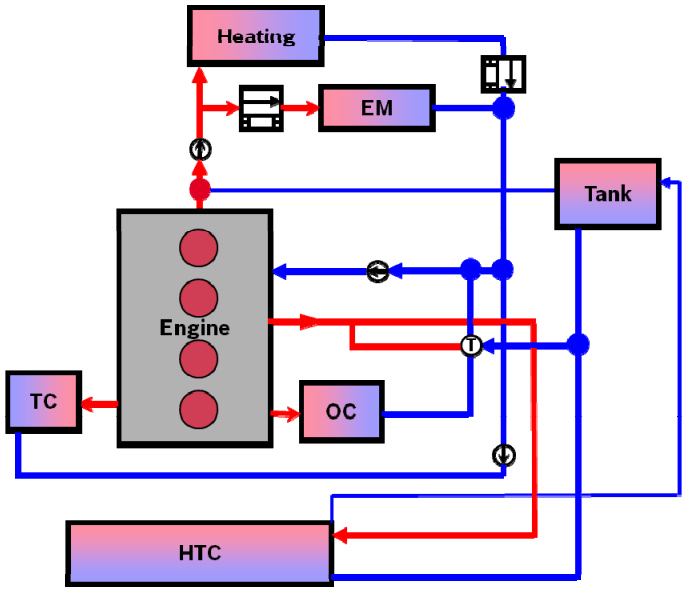
Development: Thermal System Control Strategy



EM E-Machine
TC Turbo Charger
HTC High Temperature Cooler
OC Oil Cooler

Function:

- Optimized thermal management with prioritization of comfort and fuel consumption

Considered information:

- Engine load and speed
- Cooling/Exhaust system temperatures/flowrates
- Influence on powertrain control

Requirements for the Simulation:

- Engine model with thermal behavior
- Detailed cooling/ exhaust system model
- Powertrain model including friction
- Model of control strategy software

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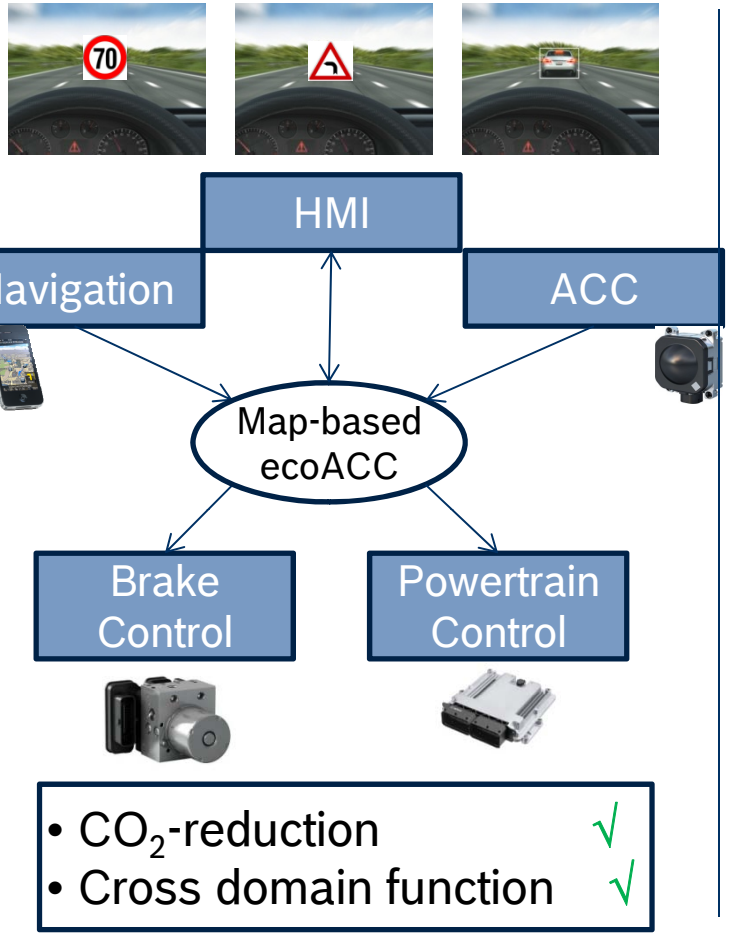
Development: Map-based *eco*ACC (HEV)



Function:

- Vehicle increases, decreases and holds speed autonomously

Considered information:

- Desired vehicle behavior from HMI
- Track information from navigation
- Traffic information from radar

Requirements for the Simulation:

- Radar system model, traffic model
- Navigation system model
- Powertrain model
- Model of control strategy software

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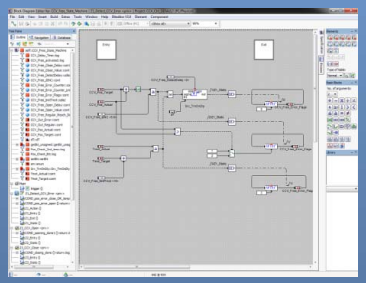
Optimization Thermal System Control Strategy (HEV)

load, speed

Control Software Model

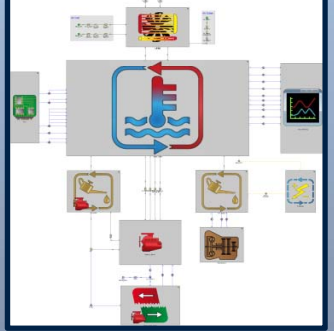


ASCET V6.1

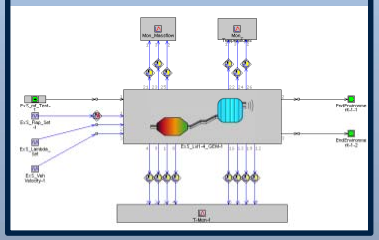
actuator
sensor

Plant Model

Thermal system Lubrication



Exhaust System



temperatures, fuel consumption

make

Rapid-Prototyping-HW

Tasks:

- Optimization of the thermal system (HW & SW)
- Testing of optimized SW version in a concept car

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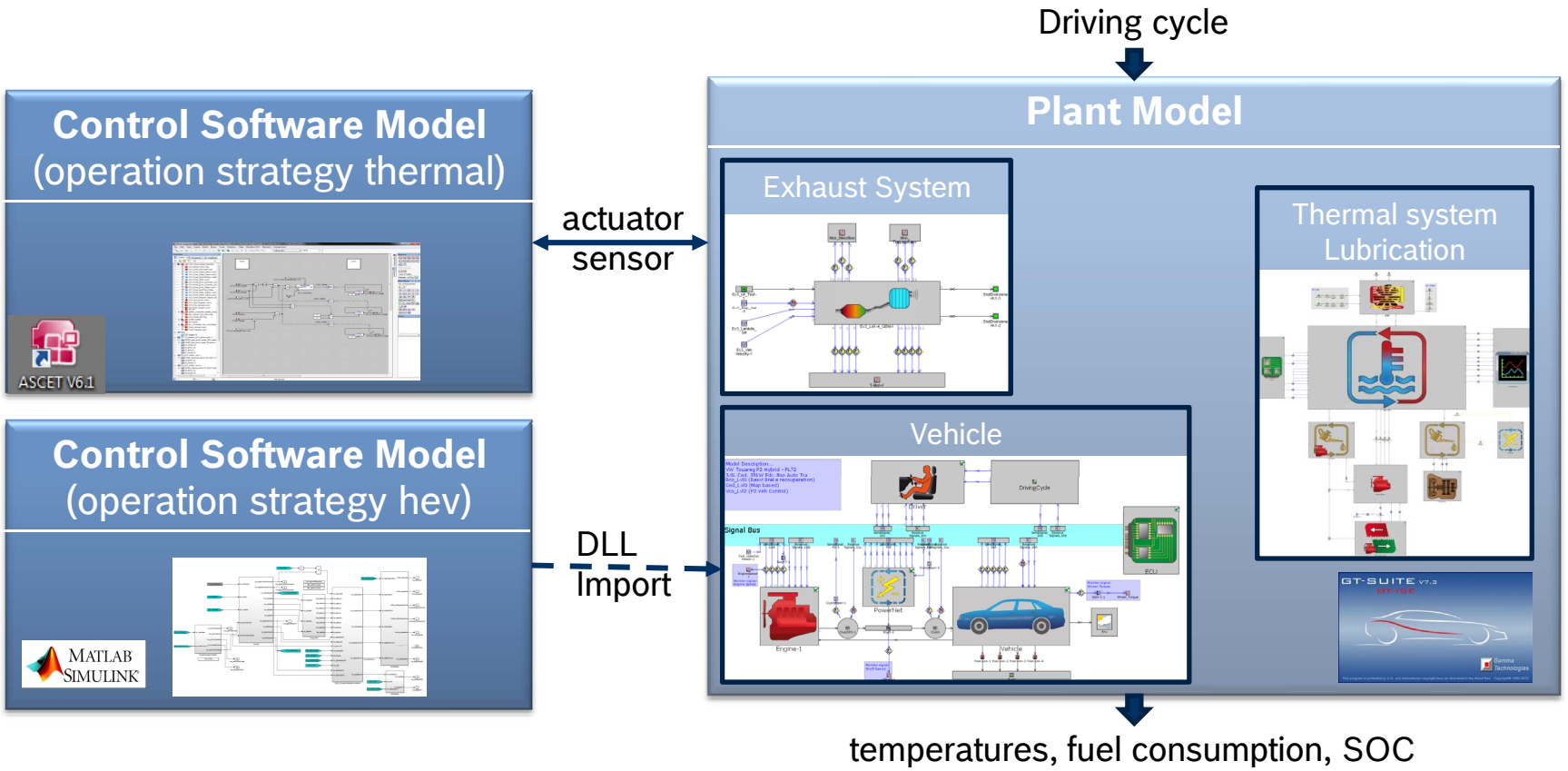
Combined HEV & Thermal Strategy Optimization



Task: Investigate CO2 benefit of combined thermal and HEV strategy optimization

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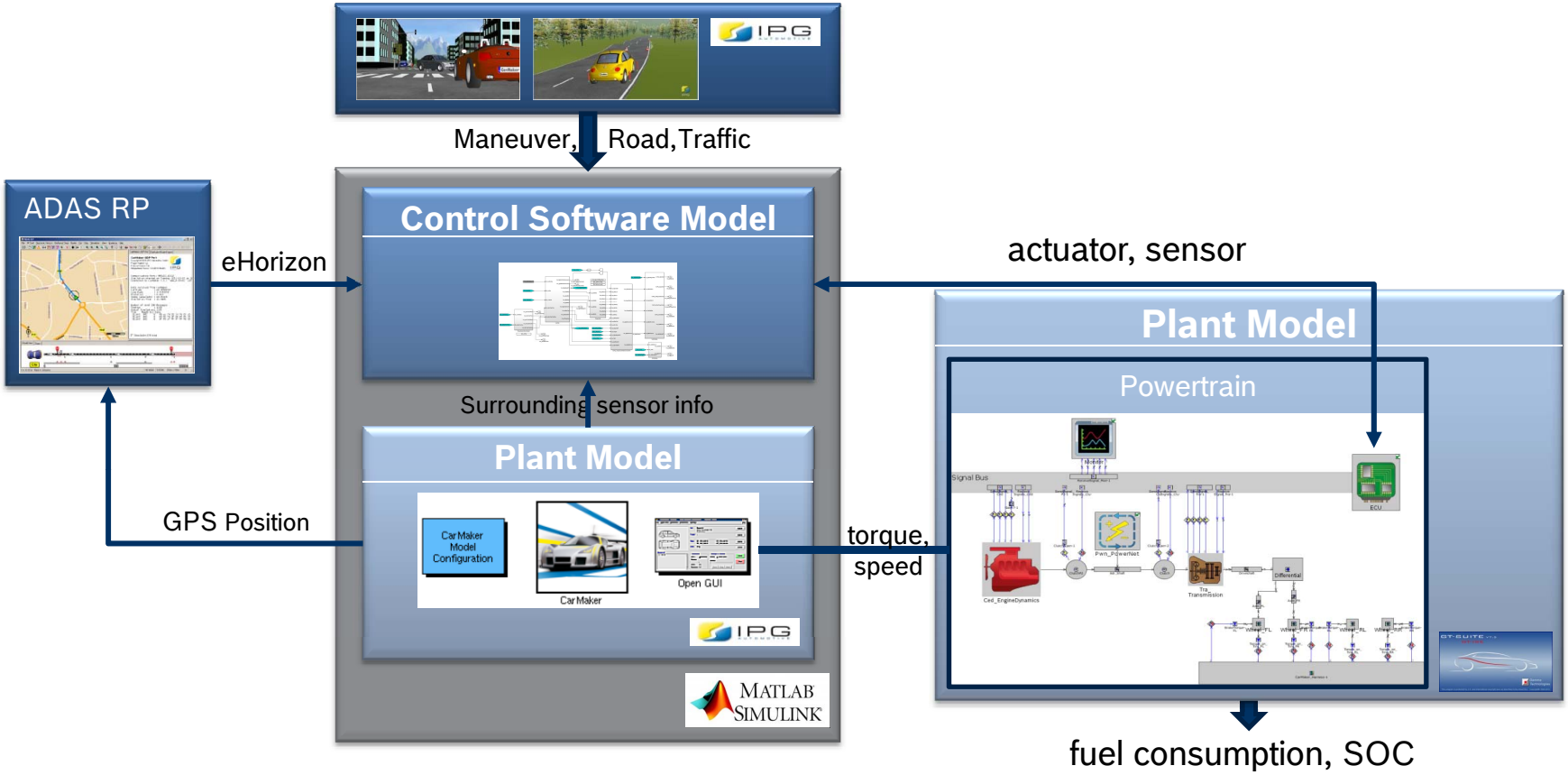
Simulation Environment for Map-based *eco*ACC



Tasks: Optimize & develop predictive powertrain control strategy

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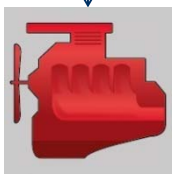
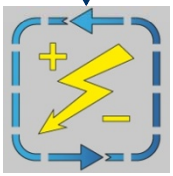
Parameterization

Use data from calibration departments

EngineDyno XLS

MotorDyno XLS

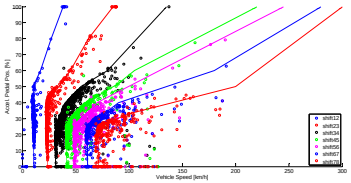




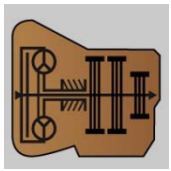
Perform special vehicle measurements

Vehicle.dat

Script

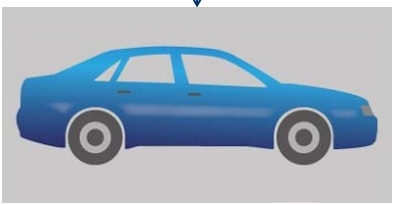


Shift strategy



Use catalogue data geometric data

Leergewicht (abhängig von der Ausstattung)	
nach DIN 70020	1980 - 2115 kg
nach 70/156/EWG [1]	2055 - 2190 kg
Zulässige Achslast vorne [2]	1210 kg
Zulässige Achslast hinten [2]	1355 kg
Zulässiges Gesamtgewicht [2]	2485 kg
Dachlast	
Zulässige Dachlast [3]	100 kg



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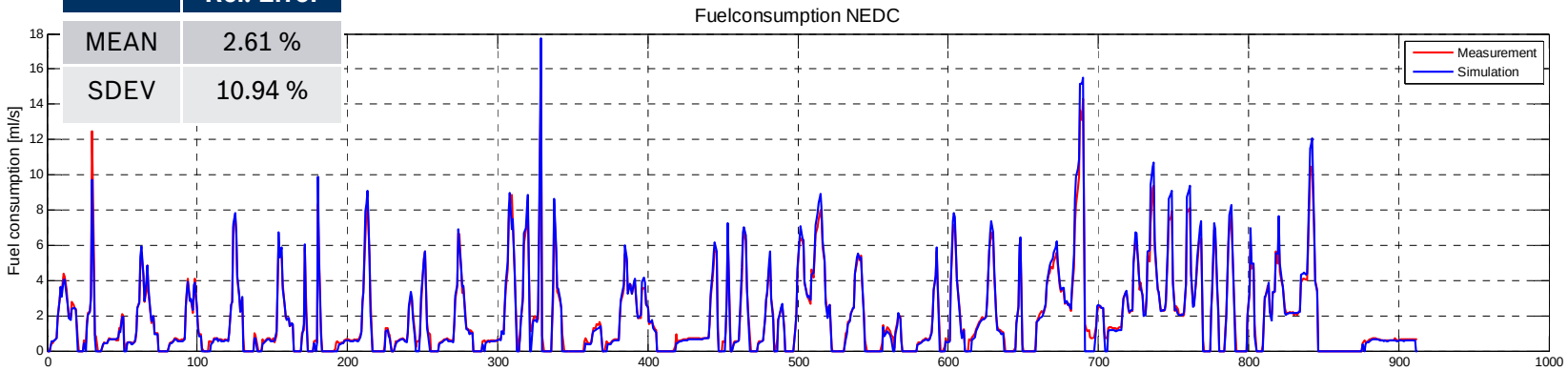
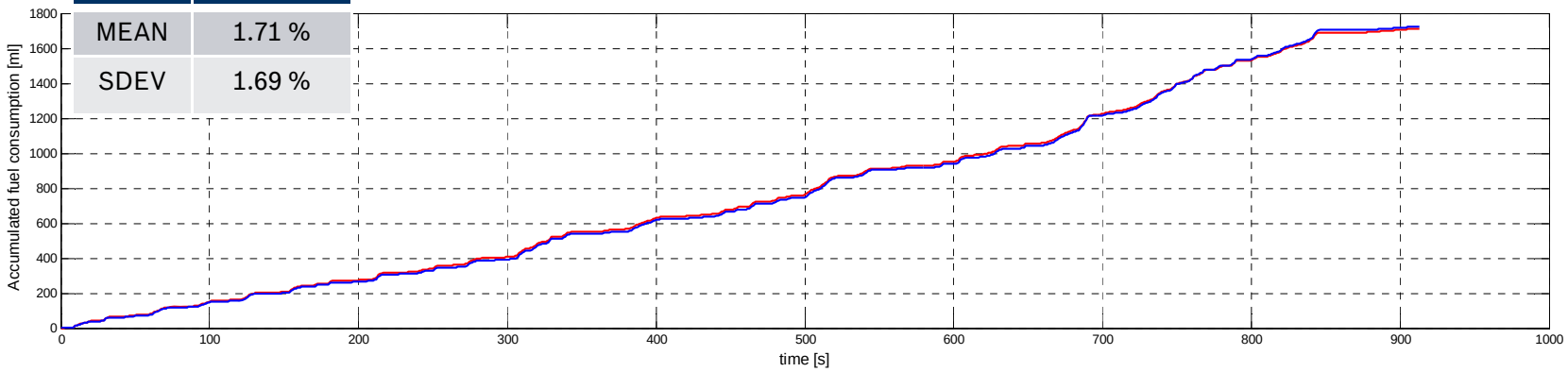
Validation: Fuel Consumption

	Rel. Error
MEAN	2.61 %
SDEV	10.94 %



	Rel. Error
MEAN	1.71 %
SDEV	1.69 %



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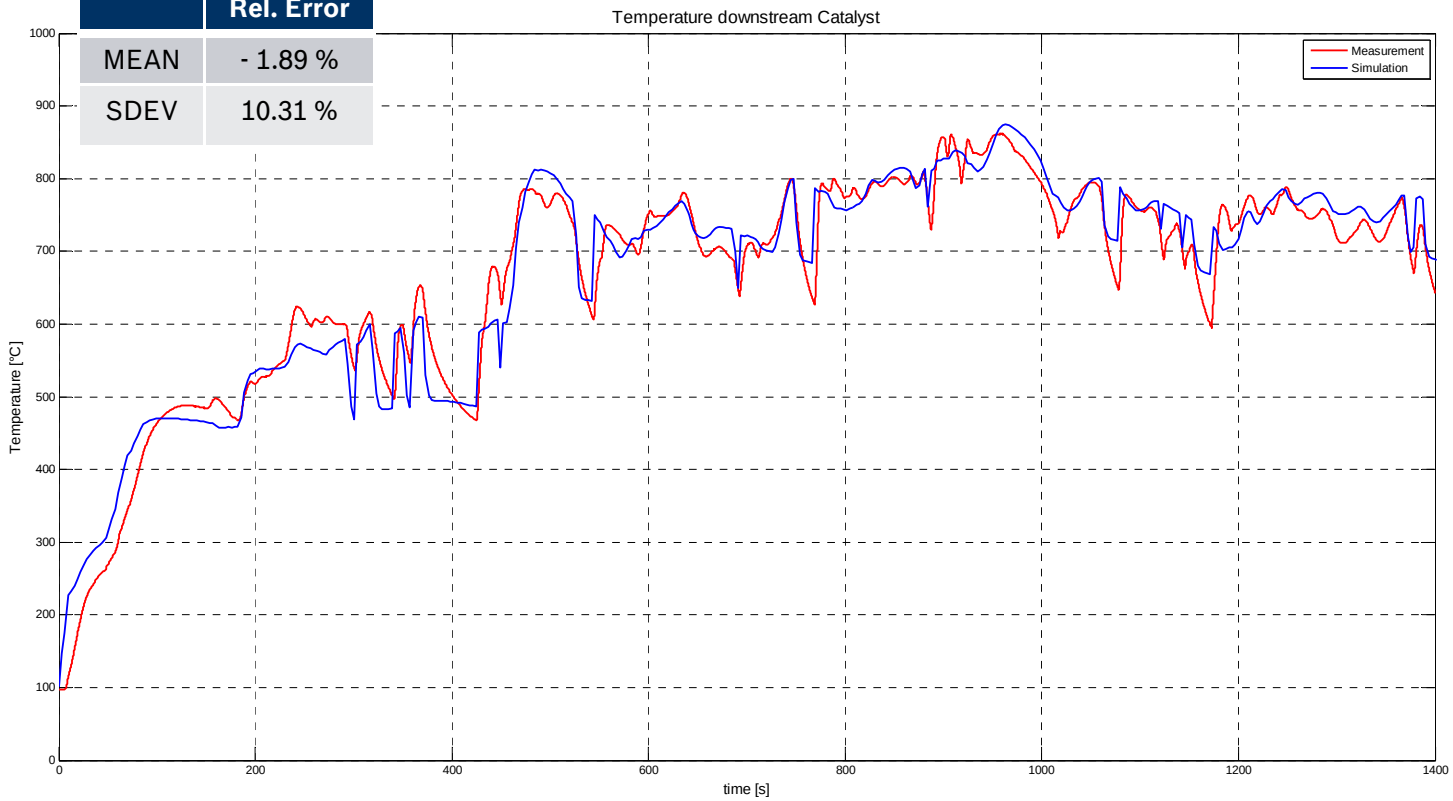
Validation: Exhaust Temperature

	Rel. Error
MEAN	- 1.89 %
SDEV	10.31 %



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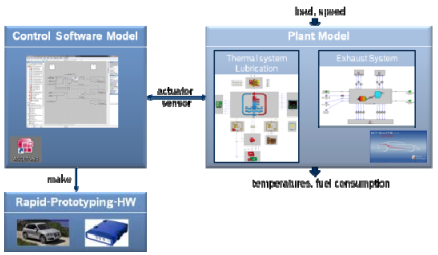
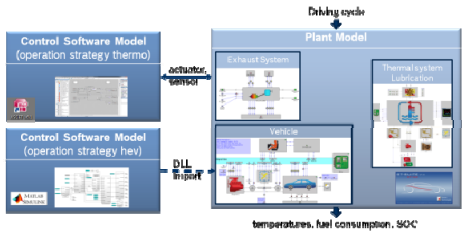
Summary

- There are use case specific simulation environments for

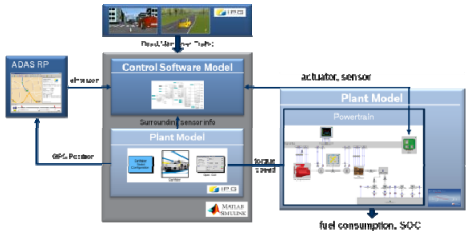
Thermal Strategy



Combined Strategy



Predictive Strategy



- GTSuite is applied for plant models
- CarMaker is applied for radar sensor models & maneuver, traffic simulation
- ASCET & Simulink are applied for control software models

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Conclusion

- GT Suite fulfills our requirements for a scalable simulation/modeling environment for plant models

- To cover all use cases several tools have to be integrated to one useful simulation application
  Requirement: Standardized interfaces for tool interoperability

- Reuse of subsystem models coming from different tools is essential
  Requirement: Standardized ex-/import features for model exchange

Continue development in tool interoperability & model exchange features

Co-Simulation For HEV Control SW-Development

Thank you for your attention!

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