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EAEC-ESFA 2015

Presenter: Dr. Filip Deblauwe

Addressing performance balancing in fuel economy driven vehicle programs

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- Introduction
- Performance balancing
- Application examples

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- **Introduction**
- Performance balancing
- Application examples

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Fuel efficiency Engineering Challenges

Balancing Emissions, Cost and Brand Performance

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Keep the CO2 emissions objective

- Growing part of electrification/hybridization
- Introduction of waste heat recovery, alternative fuels, CVT and up to 9/10 gears AT…

Vehicle integration is becoming a major issue

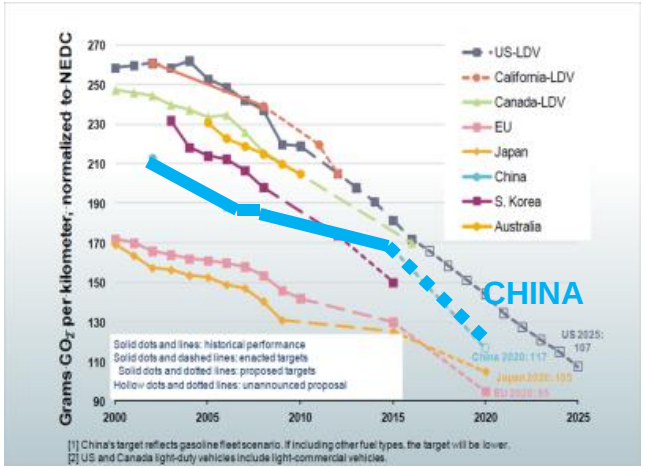
- Growing complexity of technologies
- Growing complexity control systems
- NVH issue with downsizing …

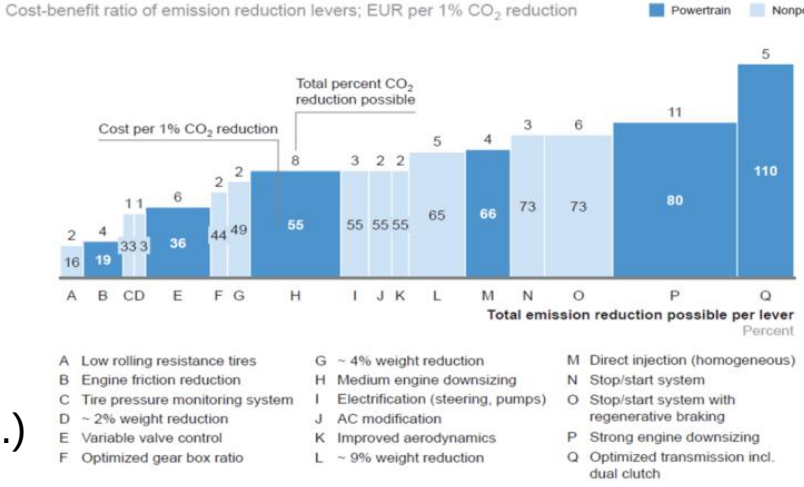
Maintain the Customer Satisfaction & Cost

- Driving experience
- Cost of ownership
- Reliability & Safety

Different solutions around the globe

- Local preferences (AT/MT, Gasoline/Diesel/HEV, ..)
- Difference in legislation





Source: McKinsey & C° - Strategy & Corporate Finance in Automotive- Aug 2013

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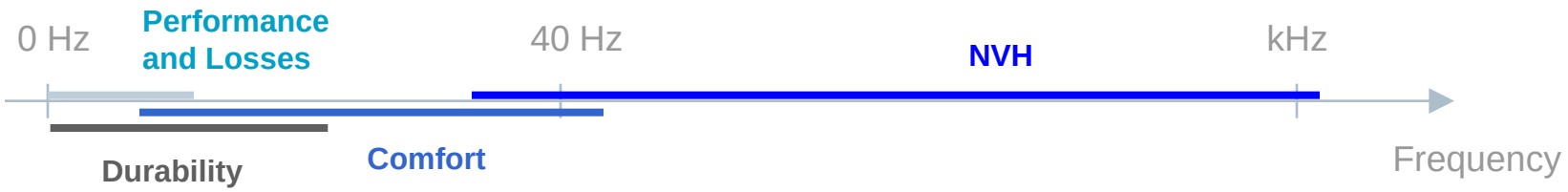
Powertrain Development - Industry Challenges

Performance and Losses
Quasi-steady state and low frequencies. Optimization of ratios and control strategies over a performance cycle. Prediction of heat release leading to heat exchanger sizing. Prediction of losses to improve consumption. The interest in losses has increased dramatically in the past years.

Comfort
Comfort of driver and passengers leads to the interest in low frequencies (<40 Hz). The vehicle will move and vibrate with the drive line dynamics including the engine moving parts. Every controlled subsystem of the drive line is subject to affect the torque provided to the wheels and therefore the vehicle motion.

NVH – Noise, Vibration & Harshness
Generally high frequency (> 40Hz) due to hydraulic dynamics, mechanical contacts, slip control… It leads to noise and durability issues. High frequencies of mechanical parts will involve component deflection leading to the need for FEA to obtain surface velocities.

Durability and Strength
Design should withstand loads and conditions for the entire expected life time.



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- Introduction
- **Performance balancing**
- Application examples

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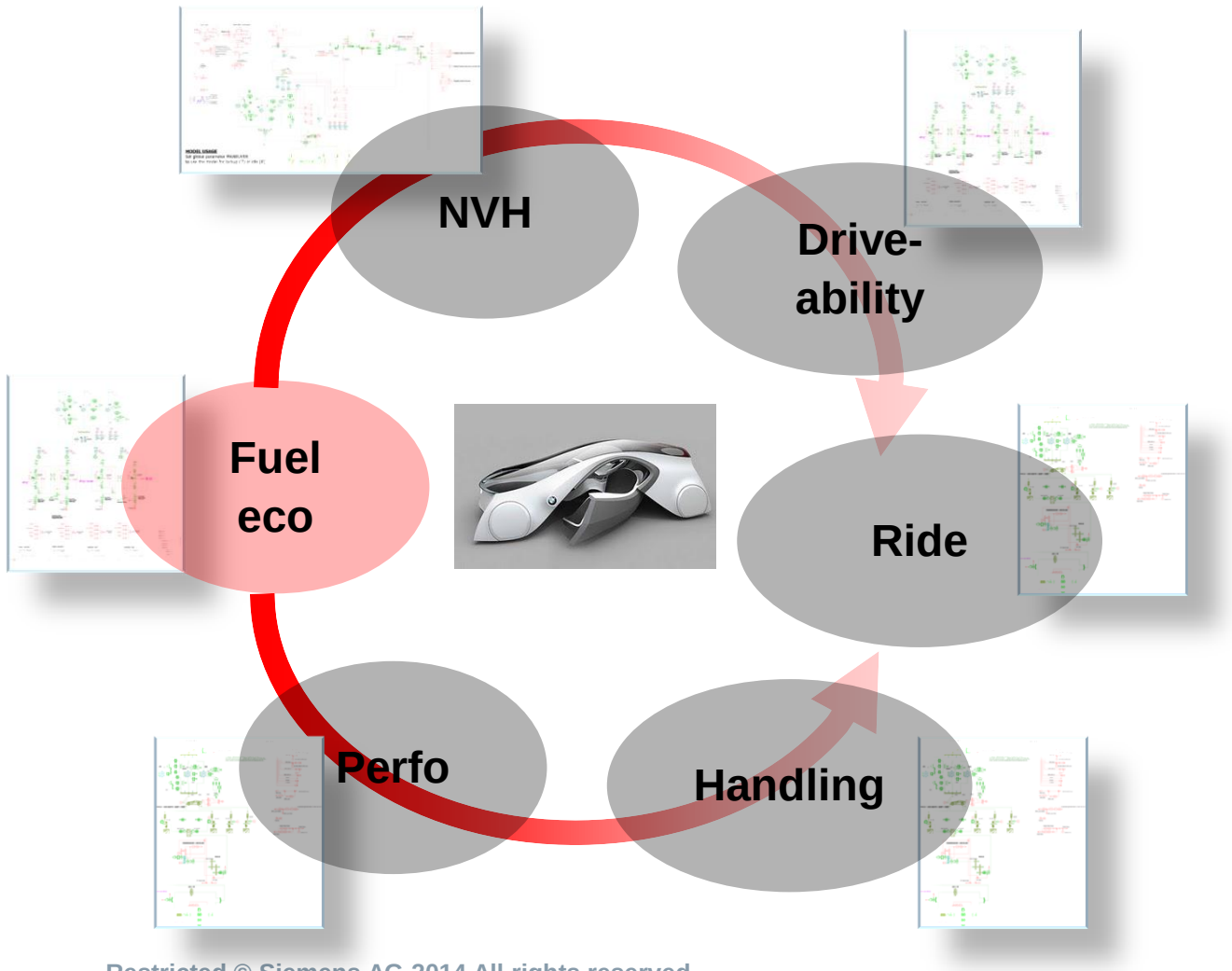
How to handle different vehicle attributes



PROBLEM STATEMENT

- Each attribute requires different model scale to reproduce
- Each attribute requires different evaluation scenarios and metrices
- Some parameters have an influence on multiple attributes and require a balancing exercise

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Driveline NVH Optimization
Balancing with emission, fuel economy, drive ability

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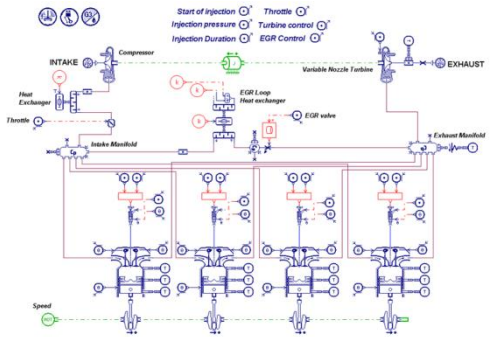
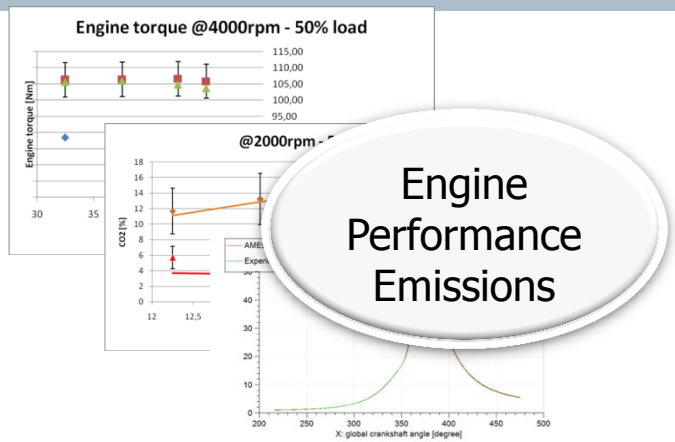


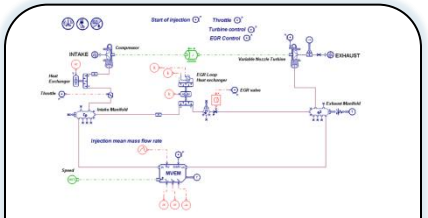
HF (crank angle) engine model

Bore, stroke, # cyl
Spark advance, Valve timing
A/F ratio, …

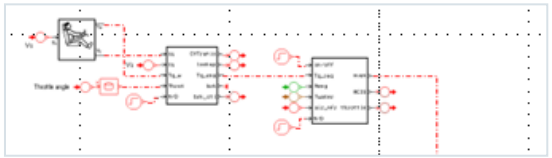
IMEP, BMEP
Torque release
Heat release
Emissions



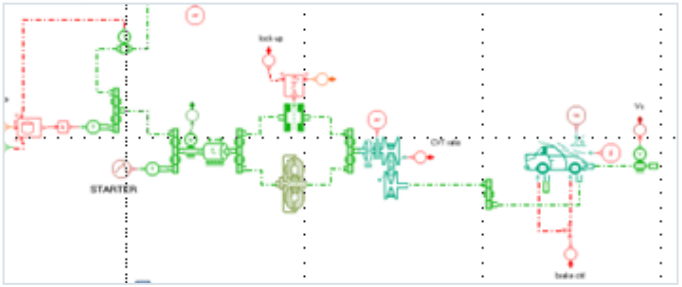
Engine
Performance
Emissions



Mean value engine

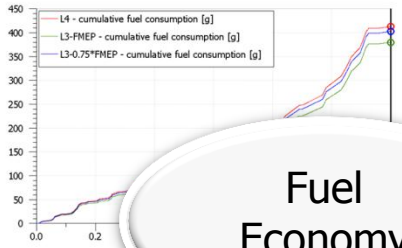


Driver & basic control



Full Vehicle

Fuel Consumption



Fuel
Economy

F(vehicle, TM, …)
F(engine parameters)

Driveline NVH Optimization
Balancing with emission, fuel economy, drivability

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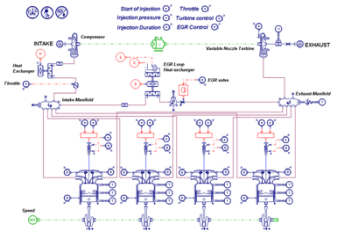
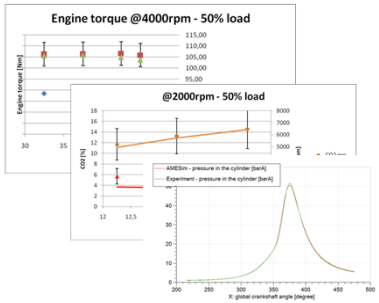


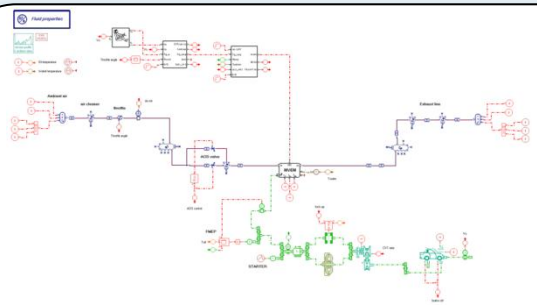
HF (crank angle) engine model

Bore, stroke, # cyl
Spark advance, Valve timing
A/F ratio, ...

IMEP, BMEP
Torque release
Heat release
Emissions



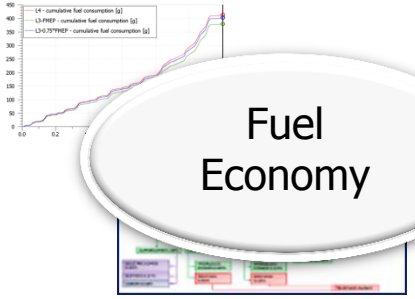
Engine
Performance
Emissions



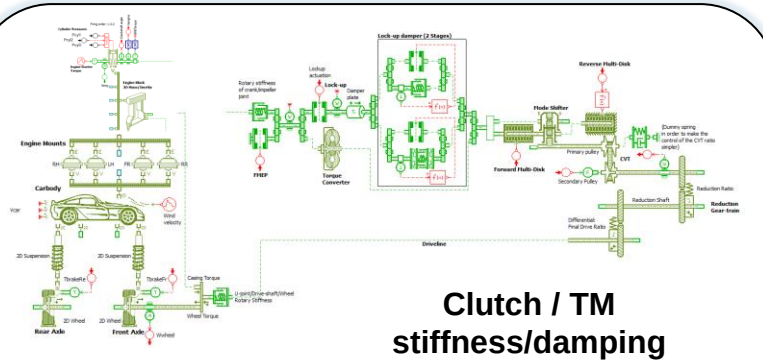
Driver, Vehicle

Fuel Consumption

F(vehicle, TM, ...)
F(engine parameters)



Fuel
Economy



Engine mounting

Clutch / TM
stiffness/damping
(non-linear)

Transient drive ability
Shock & Jerk, Shift shoc

Engine torsional
driveline excitation:
Idle

Drive ability
Vibration Comfort

Driveline NVH Optimization
Balancing with emission, fuel economy, drivability

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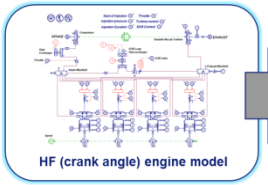
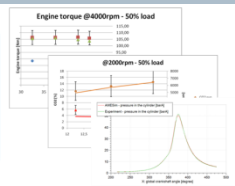
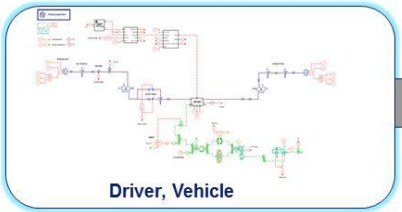


Bore, stroke, # cyl
Spark advance, Valve timing
A/F ratio, ...

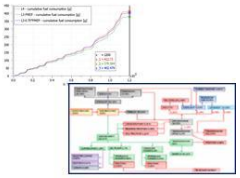
IMEP, BMEP
Torque release
Heat release
Emissions

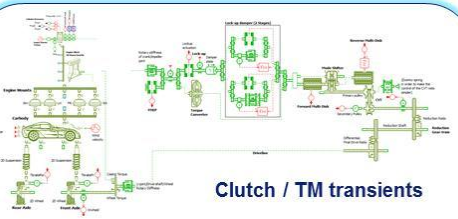




Fuel Consumption

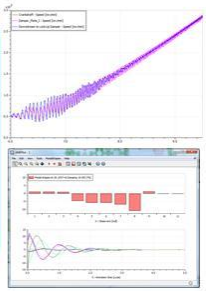
F(vehicle, TM, ...)
F(engine parameters)

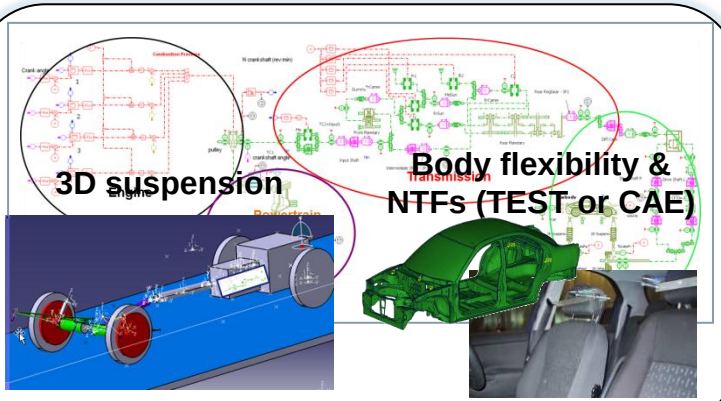




Engine torsional
driveline excitation:
Idle, booming (vibration)

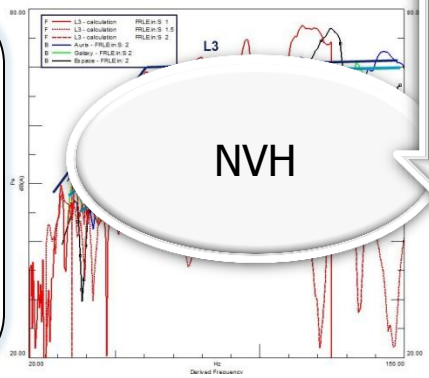
Transient drivability
Shock & Jerk, Shift shock





Suspension dynamics
Noise path contributions

Vibration comfort
Interior low frequency noise



Engine
Performance
Emissions

Fuel
Economy

Drive ability
Vibration comfort

NVH

Balancing Energy Management and Thermal Comfort

Integrated test and simulation solution for vehicle energy management

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In Vehicle Testing

Climatic Vehicle Cell, Robot Driver, Dedicated instrumentation

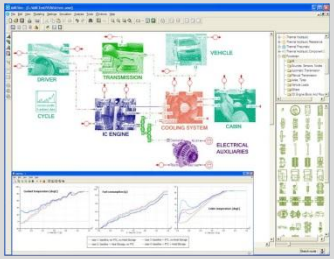
Integrating Test and Simulation

Validate & update models
Virtual sensors from models

In-depth systems analysis

Systems in real boundaries
Virtual integration of new systems Weak spots & optimization

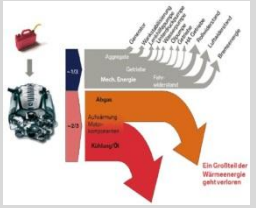
Simulation



- Plant model
- Control
- Multi level
- Multi physics

Analysis

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



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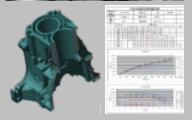
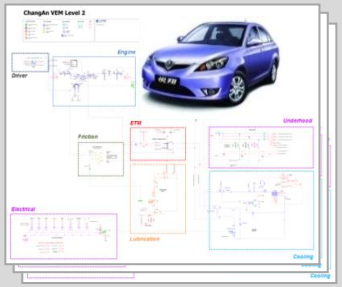
Balancing Energy Management and Thermal Comfort

Frontloading Performance optimization for Vehicle Energy Management

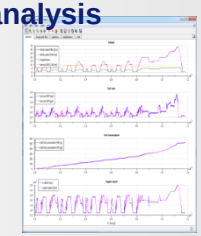
Inputs: Tests, CAD…



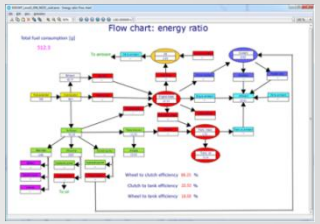
Vehicle Energy Management Model



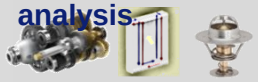
Fuel eco, subsystems interactions analysis

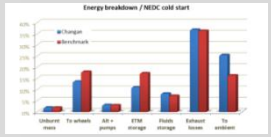


Energy transfers analysis

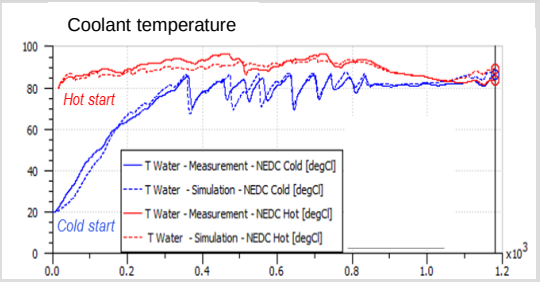


Sensitivity / new technology analysis

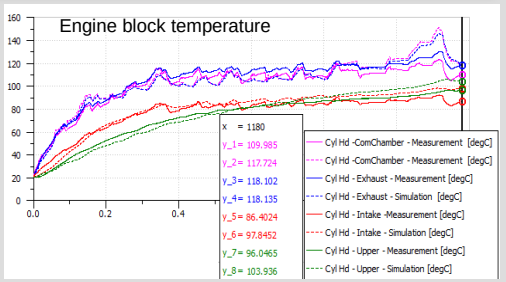




In-situ energy measurements



High fidelity subsystem models, including transient scenario's



High fidelity for fuel economy in both cold start and hot start conditions

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Multi-attribute Balancing

Balancing drivability with performances and fuel economy attributes

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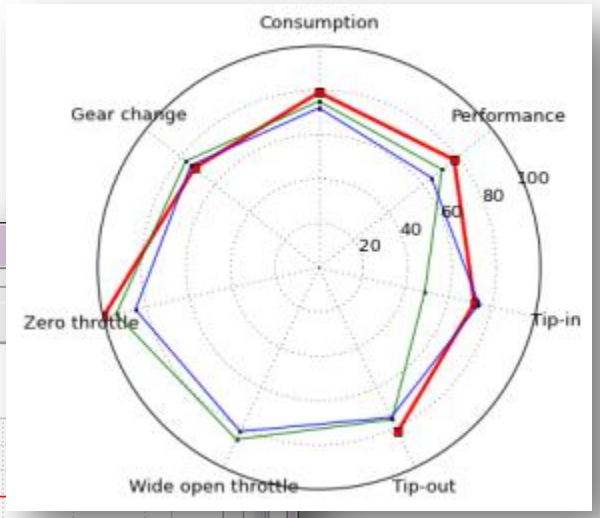
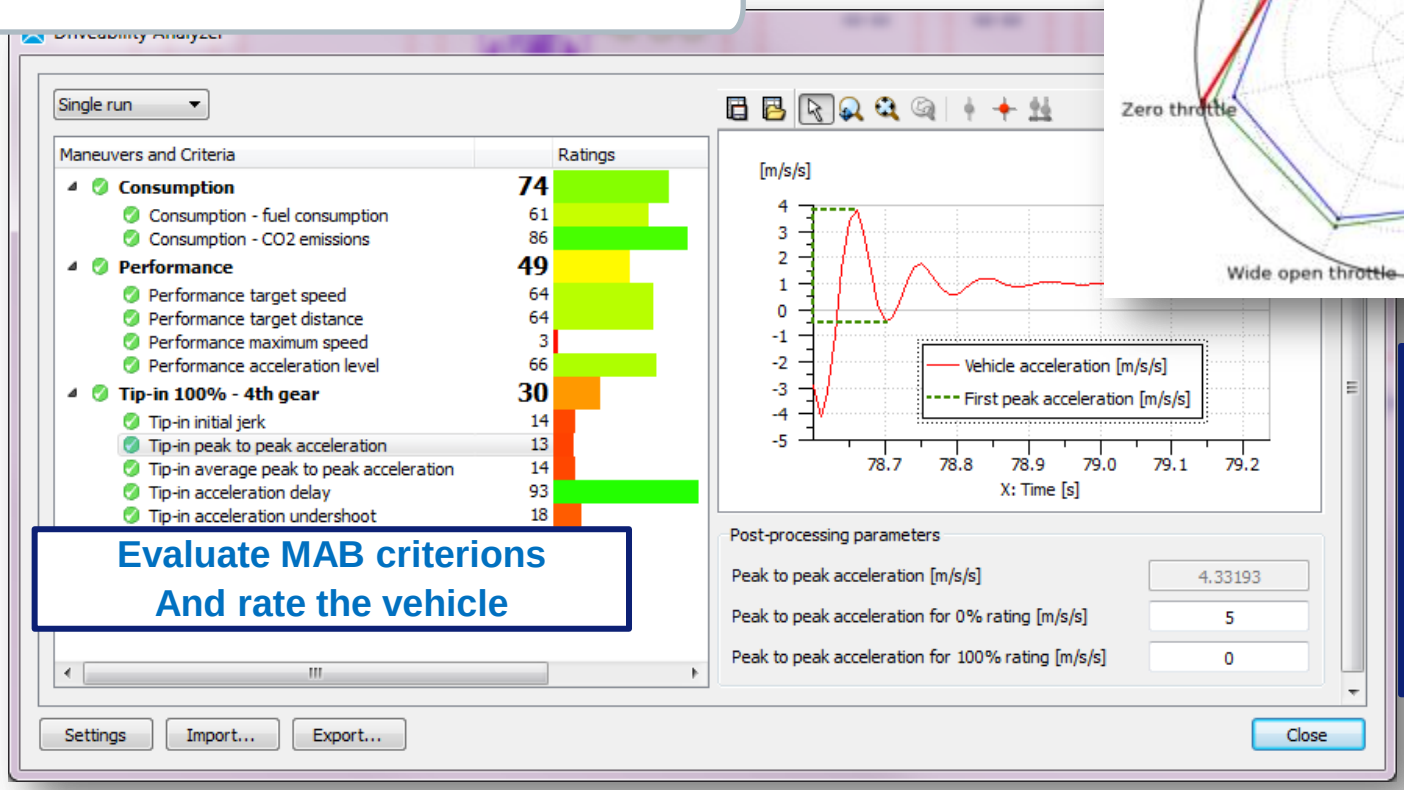
Process

- Define scenarios and targets
- Build the vehicle model and simulate it
- Evaluate and rate the vehicle behavior





Evaluate MAB criterions
And rate the vehicle

Balance attributes

- Fuel economy
- Emissions
- Drivability (NVH)

Compare

- Different vehicles
- Different design choices
- Different parameter set

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- Introduction
- Performance balancing
- **Application examples**

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RENAULT makes the driveability of conventional and electric vehicle objective with LMS Imagine.Lab AMESim

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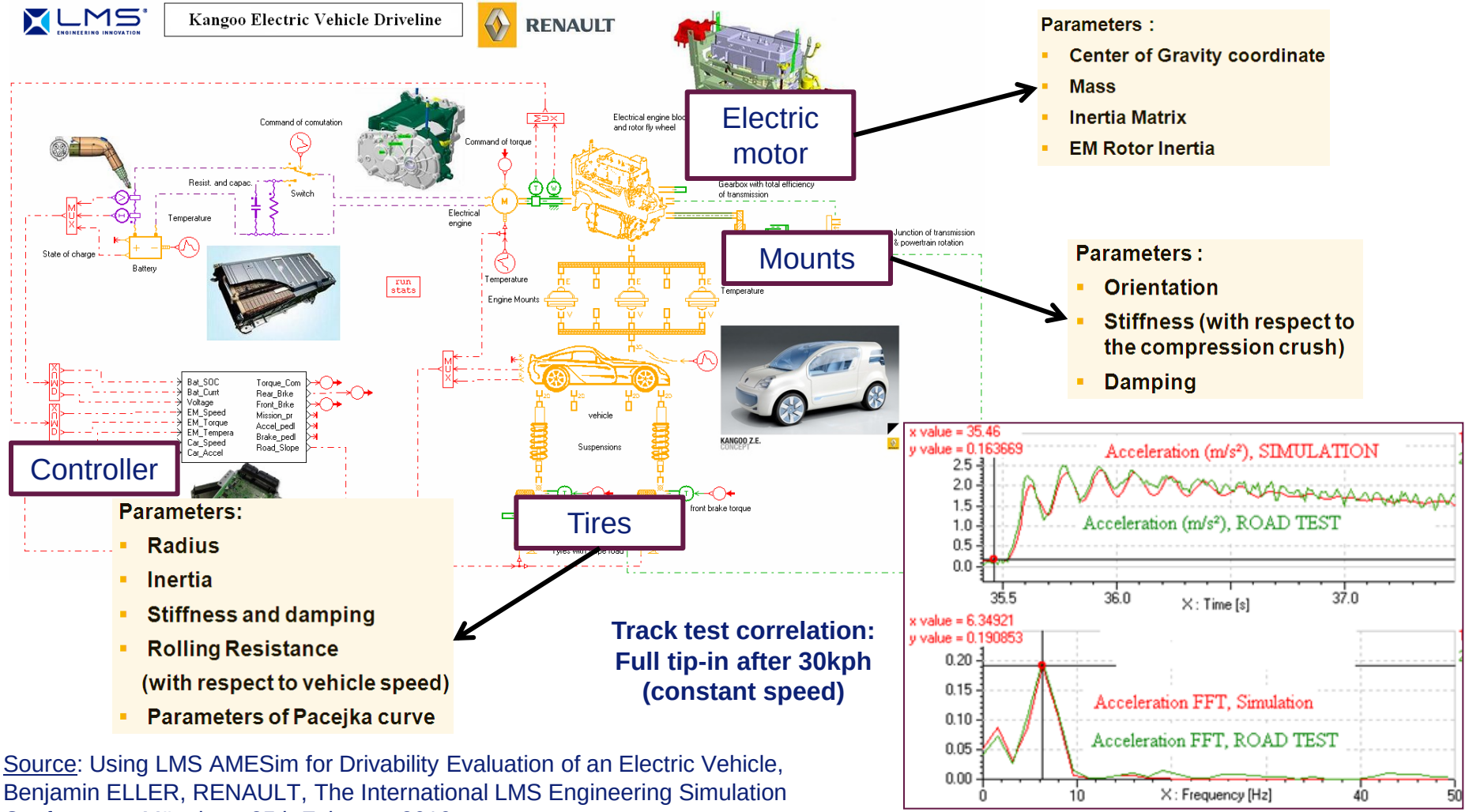

Source: Using LMS AMESim for Drivability Evaluation of an Electric Vehicle, Benjamin ELLER, RENAULT, The International LMS Engineering Simulation Conference , München, 25th February 2010

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Drivability optimization in context of fuel economy
Early concept phase investigations of powertrain/vehicle behavior using 1D/3D simulation and Test

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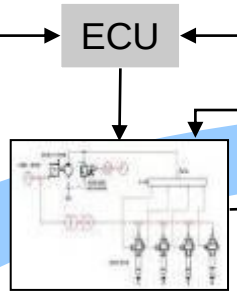
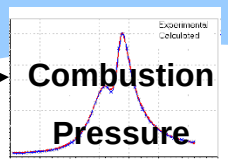
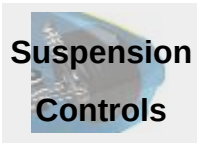
1D Simulation

- Combustion process and parameters
- Coupling to ECU
- Control models for gearbox, torque converter, active suspension



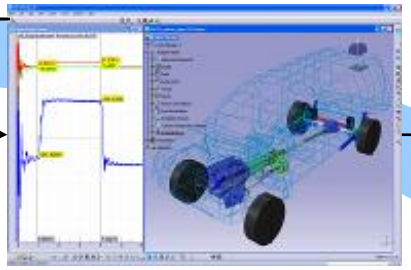




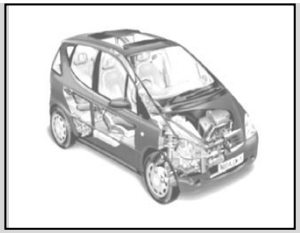
3D Simulation & Test

Detailed MBD model: powertrain, driveline, chassis and suspension

Integrated controls for gearbox, active suspension…



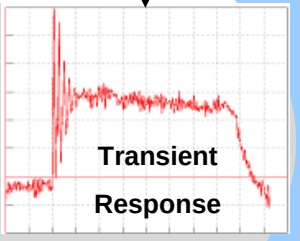
Driver Input - Throttle



Driveability:

Tip-in –Tip-out, WOT

Gear shift…



ECU Controller
Combustion parameters
Suspension controller
Gearbox controller

Combined Optimization Driveability
Combustion - Controls – Vehicle

Engine Mount layout
Driveline stiffness
Suspension layout

TOYOTA

"Development of High-Fidelity Combustion Driven Vehicle Models for Driveability Using Advance Multi-Body Simulations", JSAE 2007-1-1634

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Low frequency driveline booming
Solution approach – 1D engine/TM + 3D & experimental chassis&body

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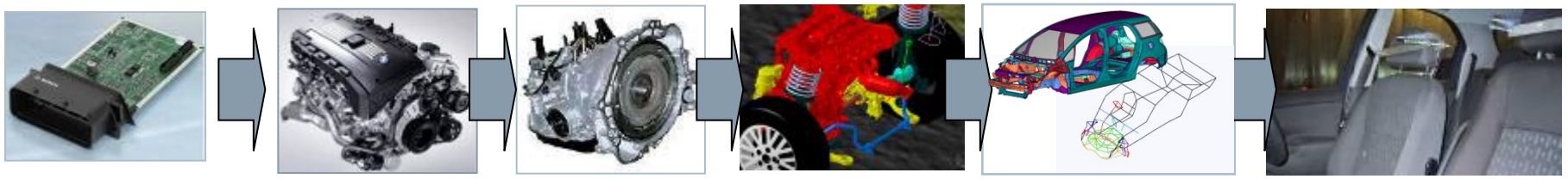
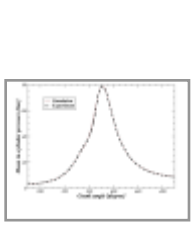
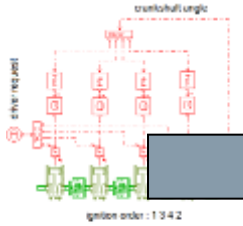
ECU/TCU | Engine | T/M | Mounting | body | Cavity

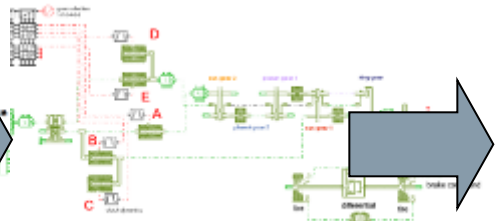




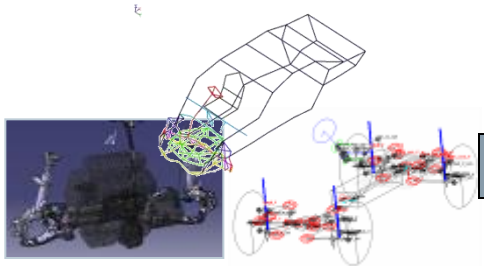
Cylinder Pressure

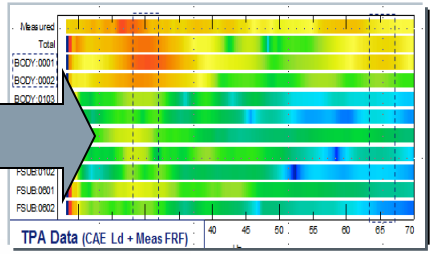


engine



Transmission and driveline





Combustion Pressure

Engine+T/M Model

Driveline+Chassis & Vehicle

Acc/Noise response

ECU / TCU

Clutch+T/M+TC

Driveline properties

Geometric & mount design

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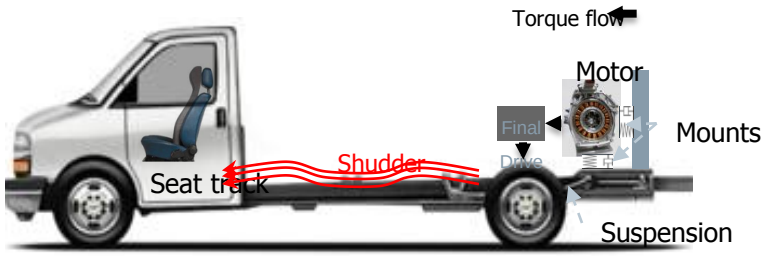
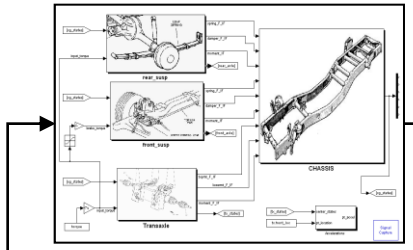
Electric Vehicle Drivetrain Shudder Controls



Multi-body dynamics model with Controls

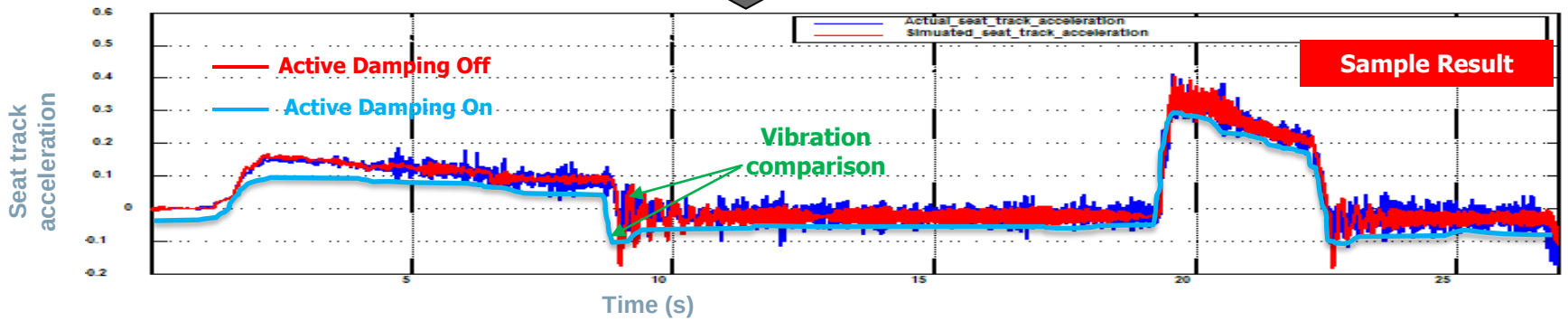


From Supplier
(S-function)

Motor Control

From LMS
(High Level Strategy)

Many "What if" scenario analyses were performed with Active Damping On and Off



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- Introduction
- Performance balancing
- Application examples

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Thank you

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