

EVALUATION OF HYBRID POWERTRAIN CONTROL STRATEGY IN AN NVH SIMULATOR

Experience sound and vibration of a virtual prototype

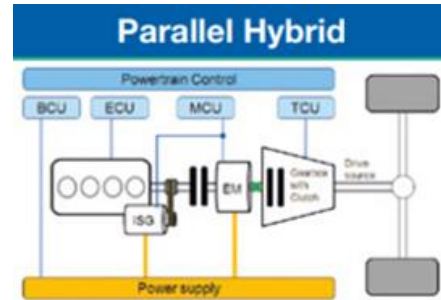


Hybrid Powertrain Control Strategy

Driver Command



Powertrain Control



Operating Condition

requested torque
gear / gear ratio
RPMs
engine on / off
motor on / off

state of charge
temperature
drive mode
...

Hybrid Powertrain Control Strategy

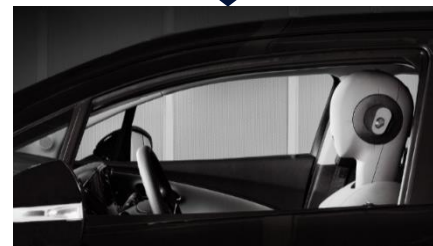
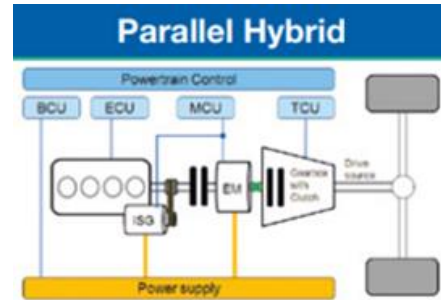
Fuel Economy & Emissions



Drivability



Powertrain Control



NVH Performance

Hybrid Powertrain Control Strategy

Fuel Economy & Emissions



Drivability

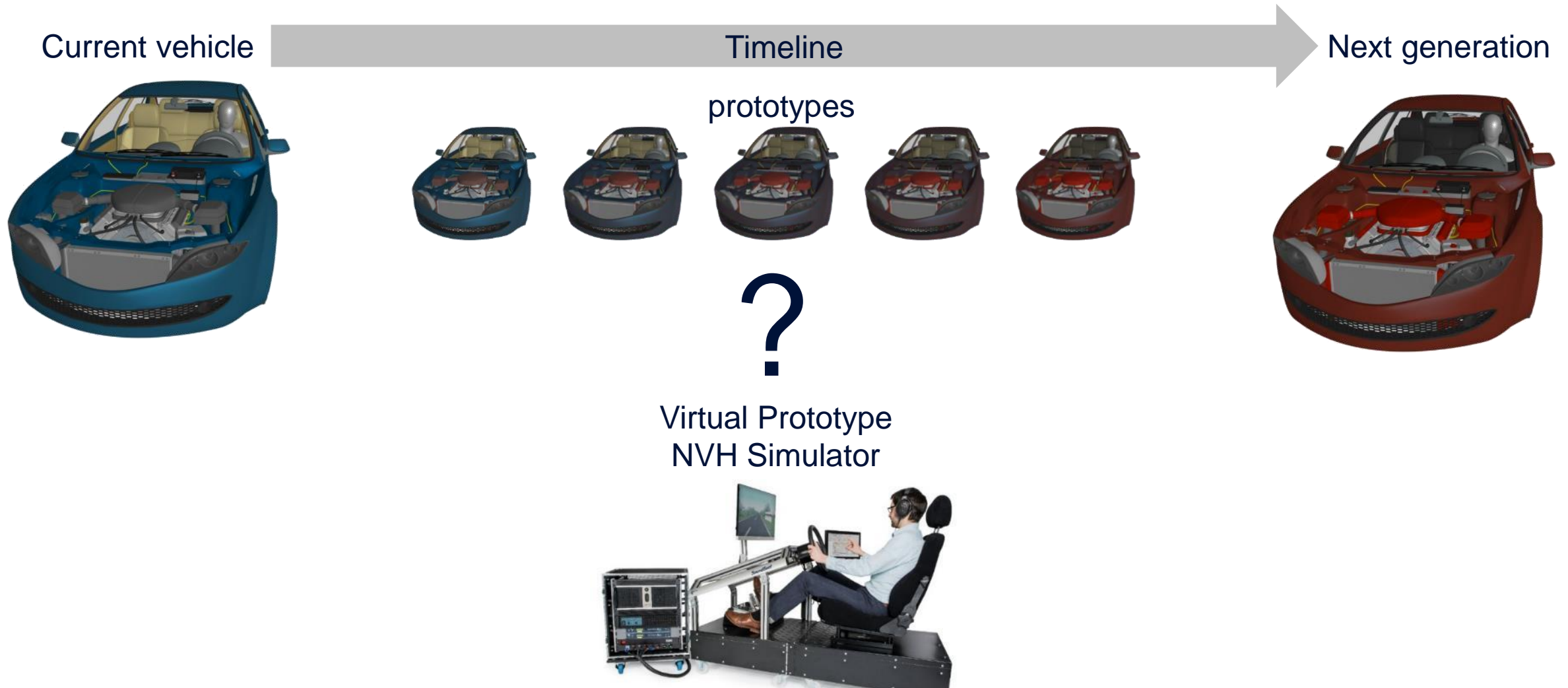


Trade-Off
Conflict



NVH Performance

Motivation – Find trade-off as early as possible



NVH Simulator

**Interactive Simulation
of vehicle interior noise
based on test and CAE data.**



NVH Simulator – Scalable Solution

Desktop Simulator



SoundSeat



steering wheel & seat vibration

SoundCar



context

Vehicle Simulator



virtual reality moving platform

Mobile Simulator

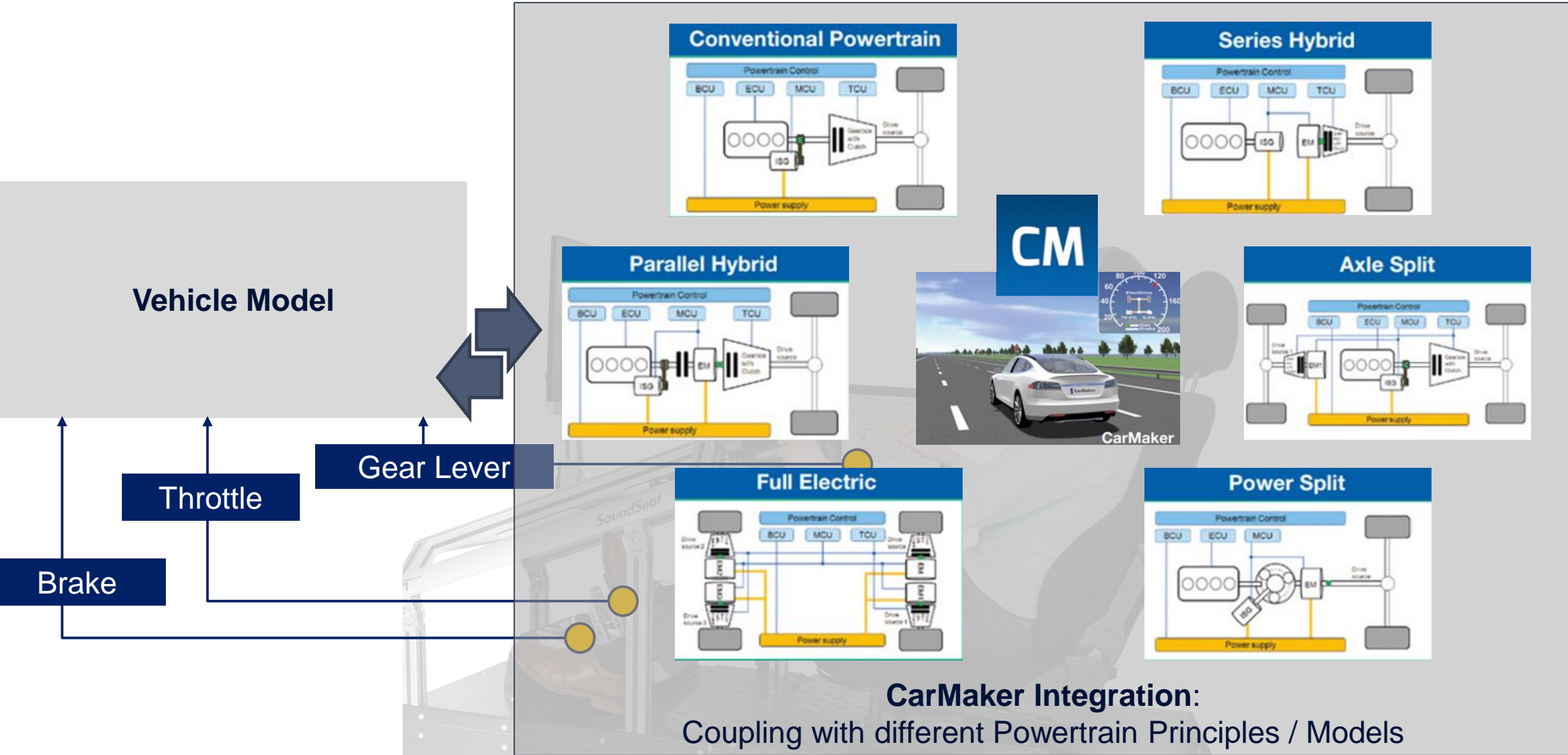


real driving experience

NVH Simulator – Powertrain Model

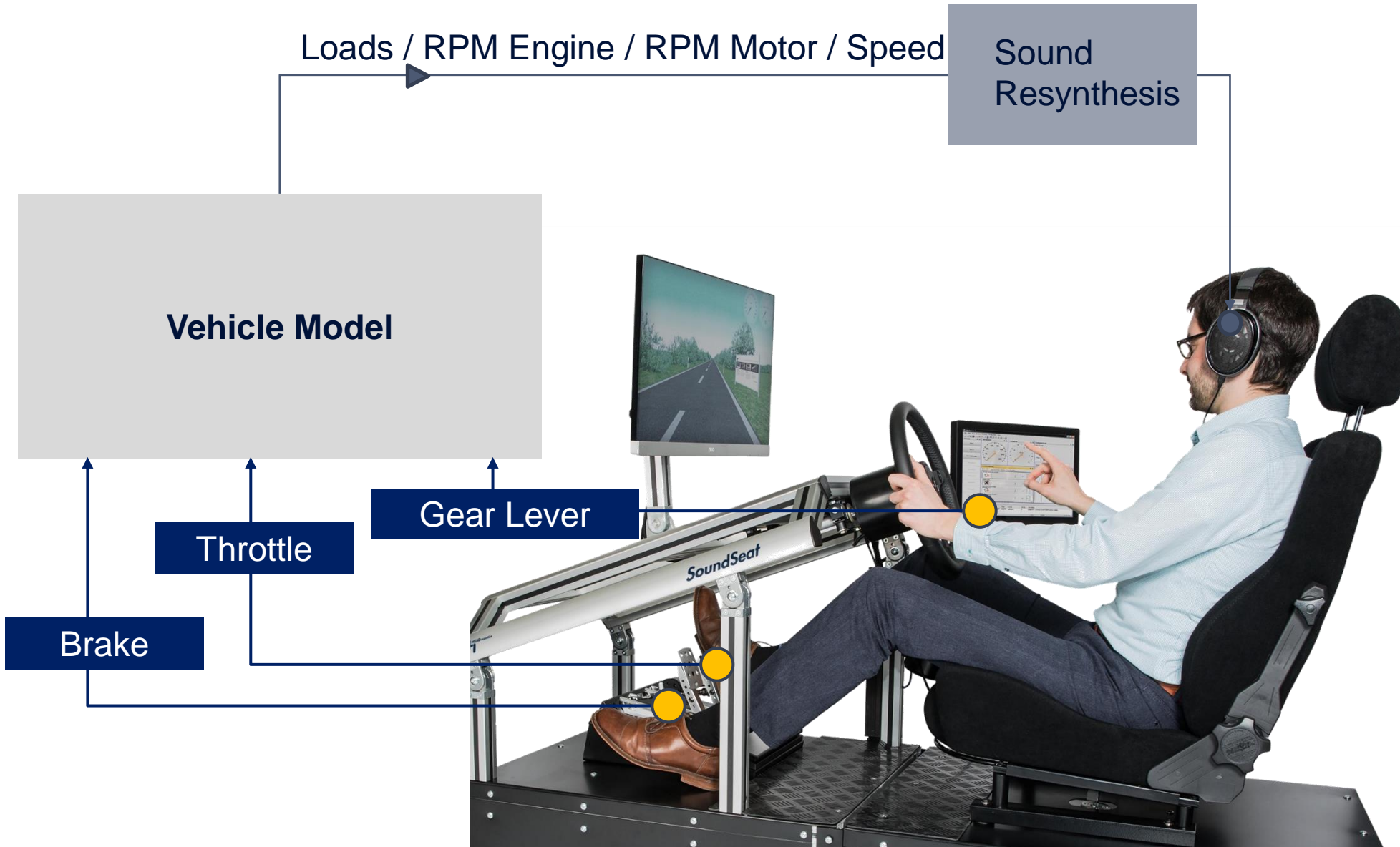


Interface to IPG CarMaker

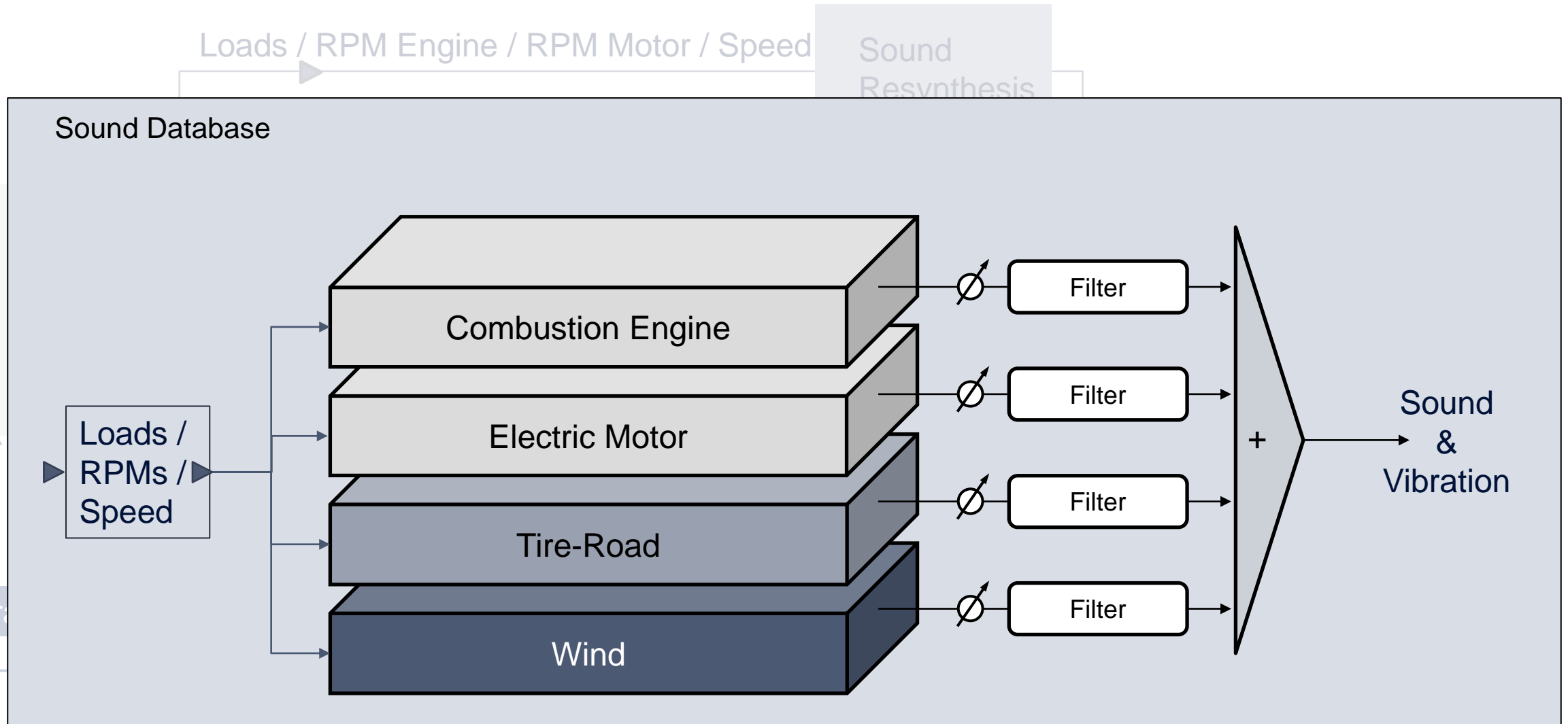


CarMaker Integration:
Coupling with different Powertrain Principles / Models

NVH Simulator – Sound Resynthesis



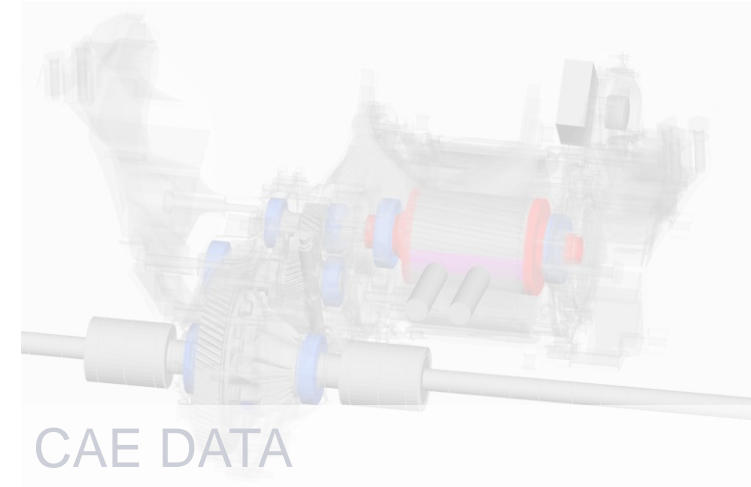
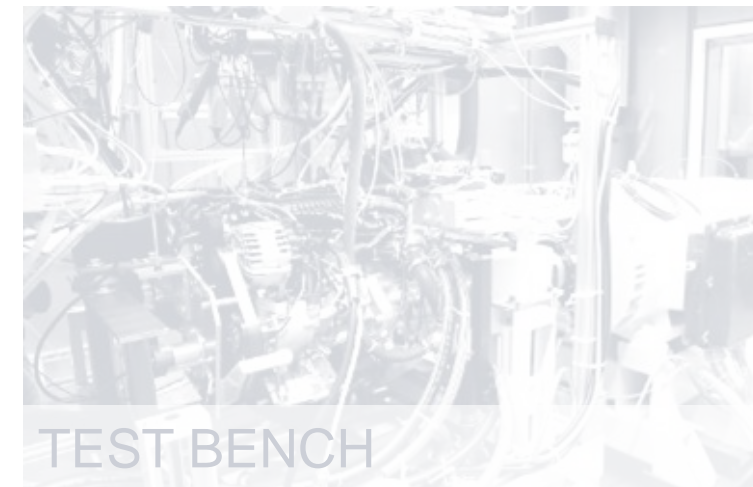
NVH Simulator - Sound Database



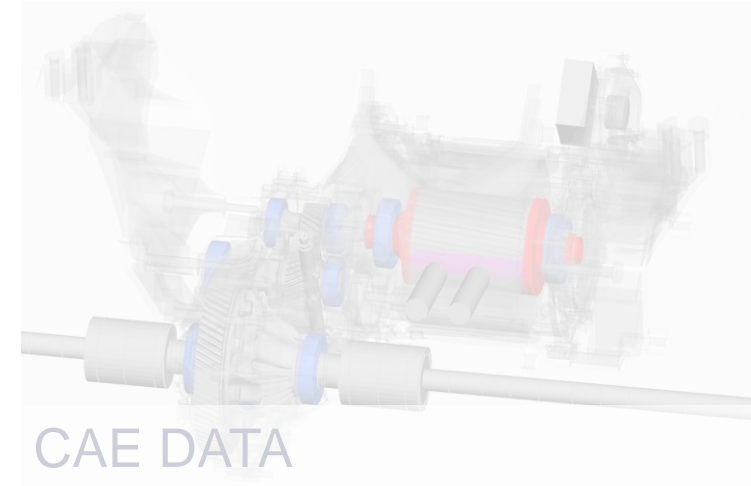
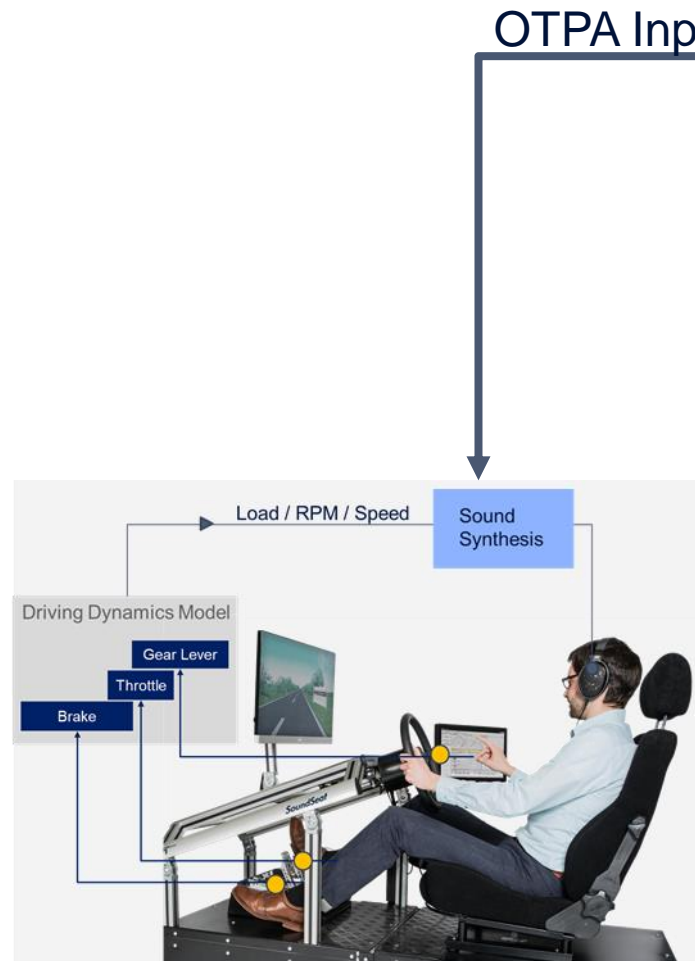
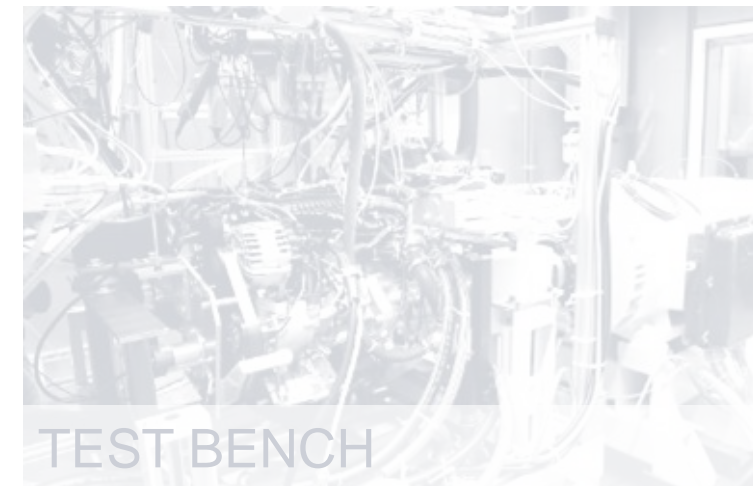
Where does the acoustic data come from?



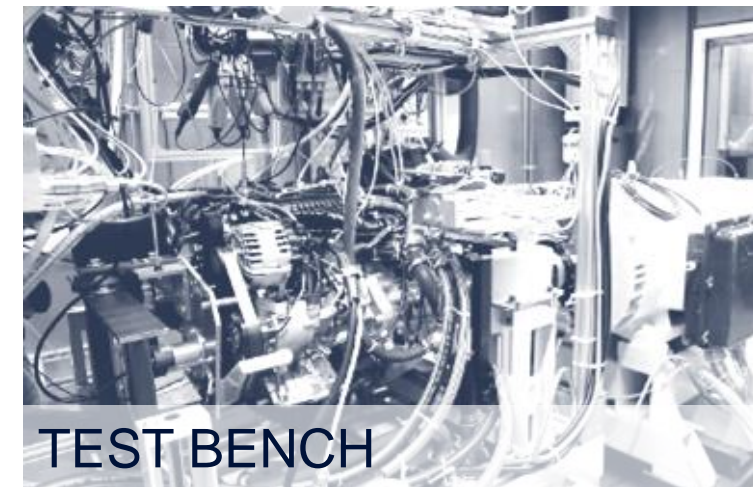
Interior Measurements
OR BTPA Input



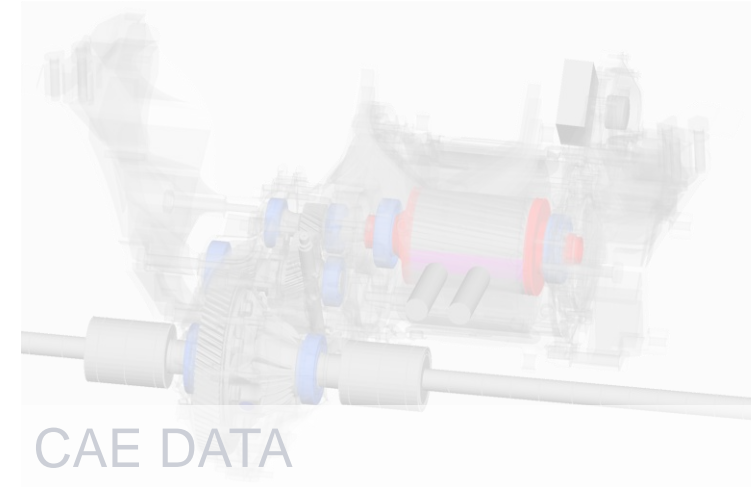
Where does the acoustic data come from?



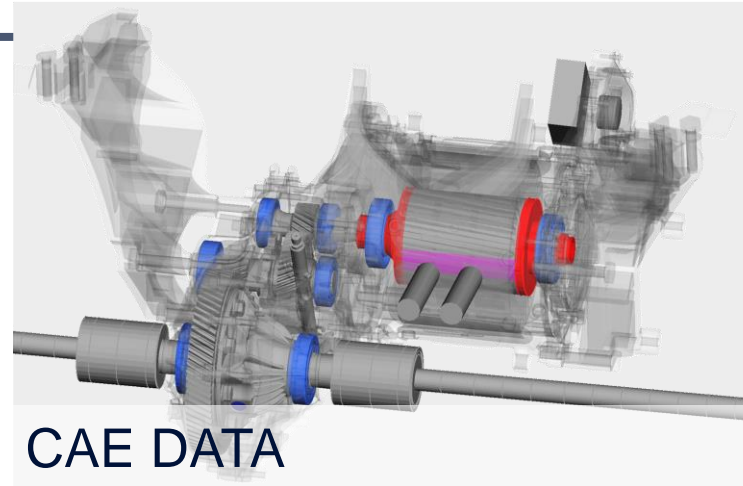
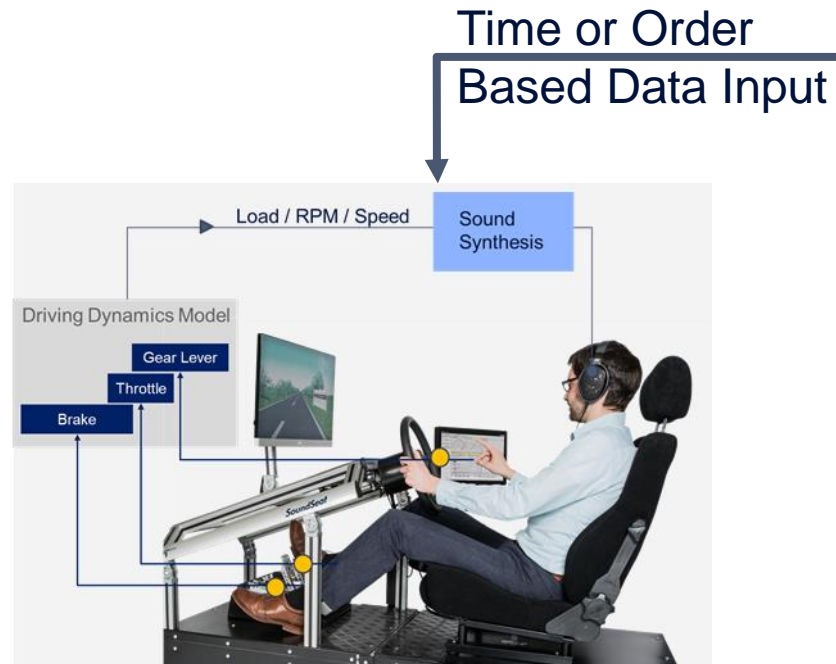
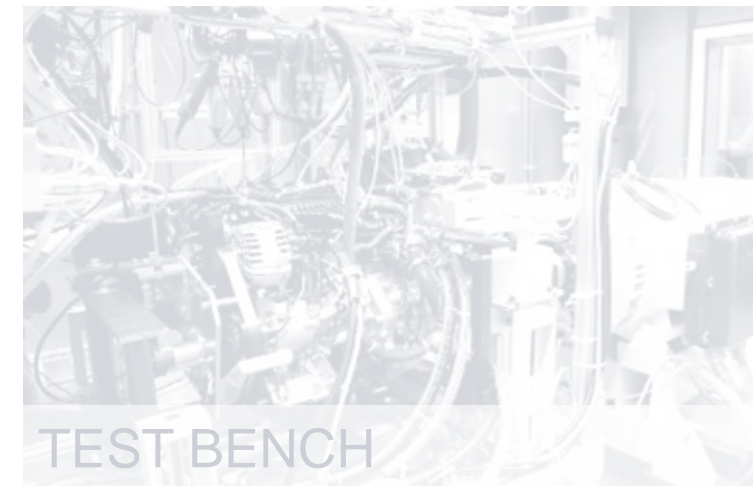
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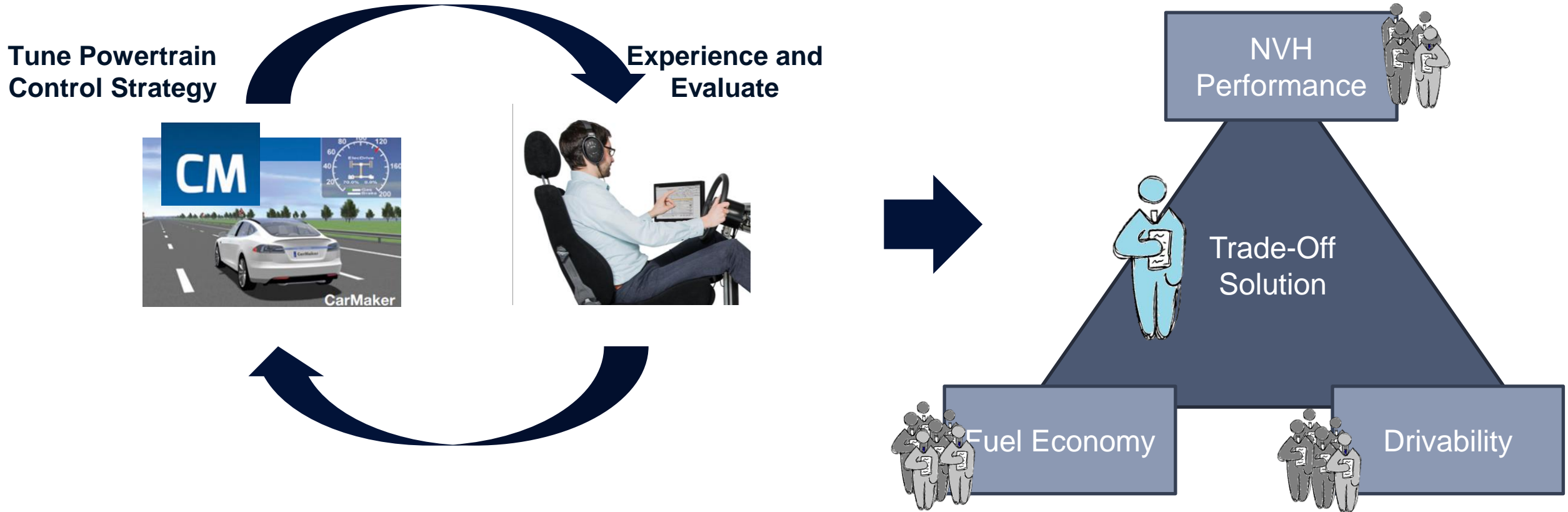
BTPA Input
Synthesis with vehicle model



Where does the acoustic data come from?



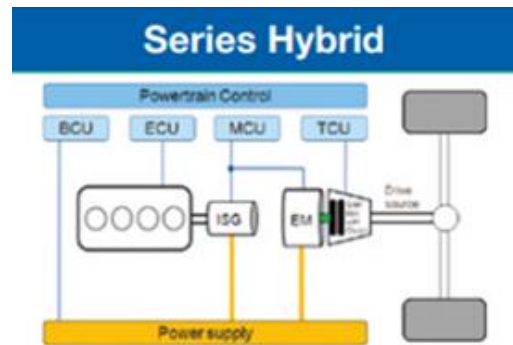
Workflow



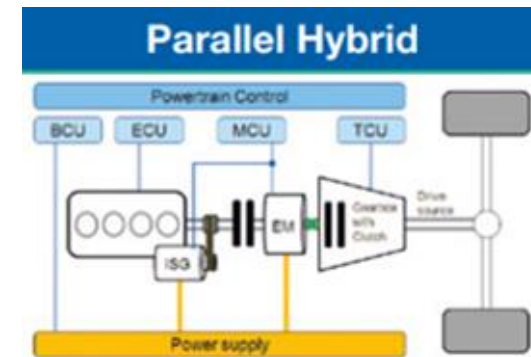
Example 1: Hybrid Vehicle

Early concept phase

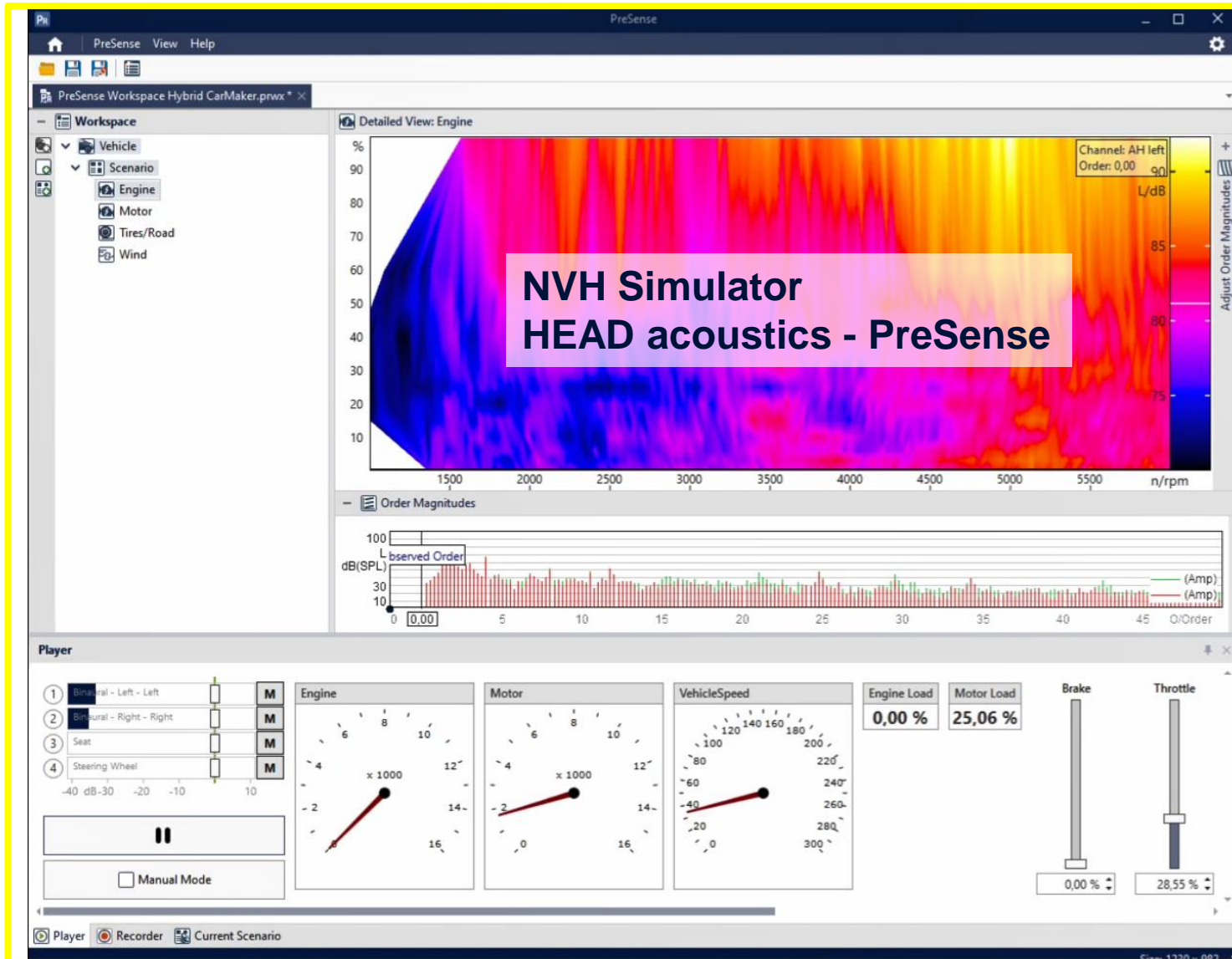
- Powertrain noise from testbench
- Road noise and wind noise from current model



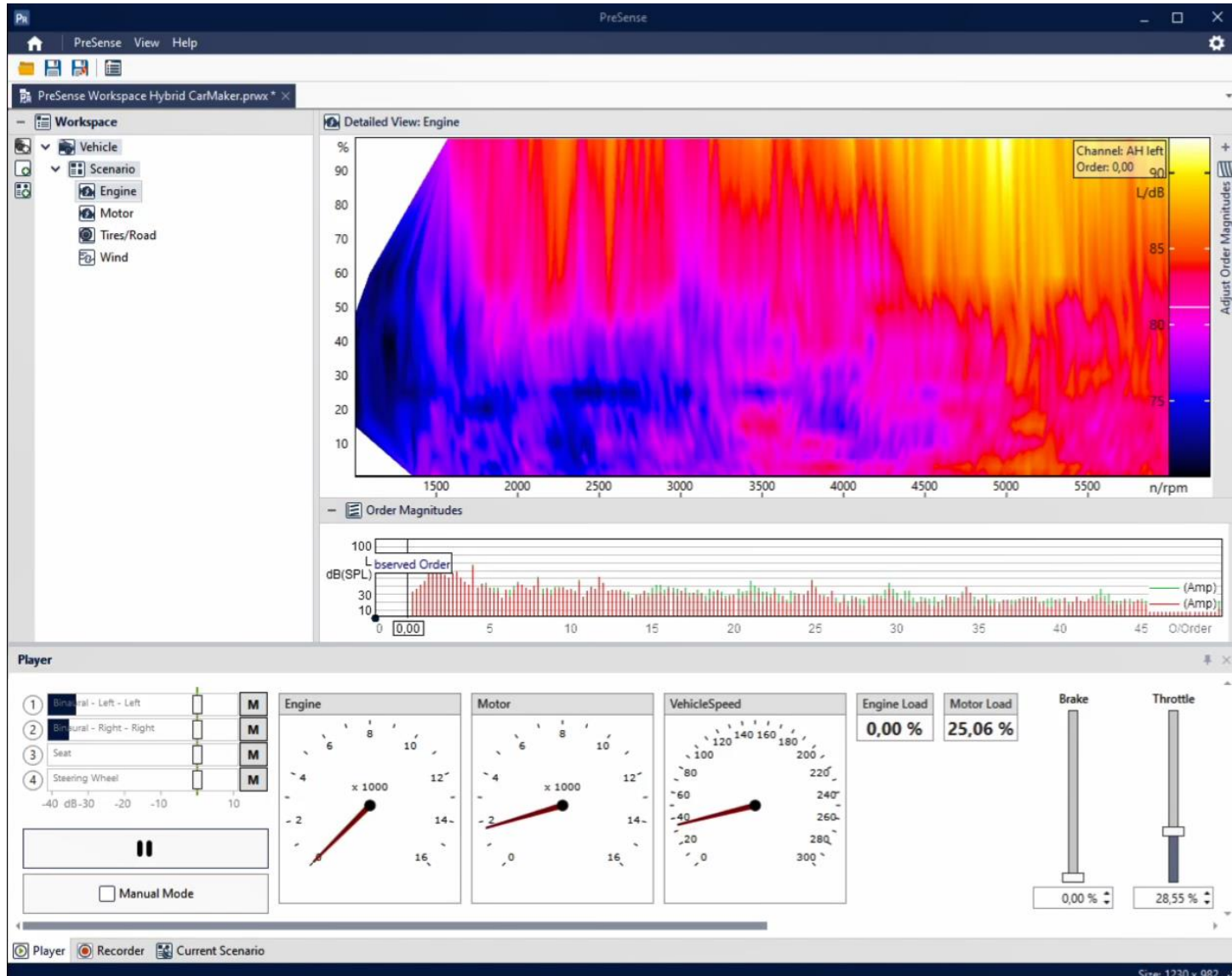
vs.



Example 1: Hybrid Vehicle



Example 1: Hybrid Vehicle



Example 1: Hybrid Vehicle

The image displays the PreSense NVH simulator interface, which is used for analyzing and simulating noise and vibration in a hybrid vehicle. The main window is titled "PreSense View Help" and shows a "Workspace" with a tree view containing "Vehicle", "Scenario", "Engine", "Motor", "Tires/Road", and "Wind". The "Detailed View: Engine" is active, showing a 2D plot of "Order Magnitudes" (y-axis, 10 to 90) versus "n/rpm" (x-axis, 1500 to 3500). The plot is color-coded by magnitude, with a color bar on the right labeled "Channel: AH left" and "Order: 0,00". Below the plot is a "Player" section with a "Manual Mode" checkbox and a "Recorder" button. The "Player" section also includes a list of input channels: "Binaural - Left - Left", "Binaural - Right - Right", "Seat", and "Steering Wheel".

Overlaid on the simulator is a 3D model of a steering wheel and pedals. To the right, a smaller window shows a 3D rendering of a car on a road, with a "Start" button and a "18.70 s" timer. Below this, a detailed dashboard is visible, featuring several gauges and indicators:

- Engine Load:** 0,00 %
- Motor Load:** 25,06 %
- Vehicle Speed:** A speedometer showing 0 to 300 km/h.
- Engine RPM:** A tachometer showing 0 to 16 x 1000 RPM.
- Motor RPM:** A tachometer showing 0 to 16 x 1000 RPM.
- Electrical System:** A diagram showing "ElecDrive" with "Battery" (49%) and "Fuel" (79%) indicators. Below it, "kWh / 100 km" is 89.43 and "l / 100 km" is 0.00.
- Power and Gear:** A gauge for "% PWR" (0 to 80) and a "Gear" indicator showing "CHARGE 3 BOOST".
- Steering Wheel Angle:** A gauge showing "Steering Wheel Angle [deg]" from 0 to -800.
- Clutch, Brake, Gas:** Three vertical sliders for "Clutch", "Brake", and "Gas".
- Gearbox:** A gear selector showing "P", "R", "N", "D" and a "Gear" indicator.

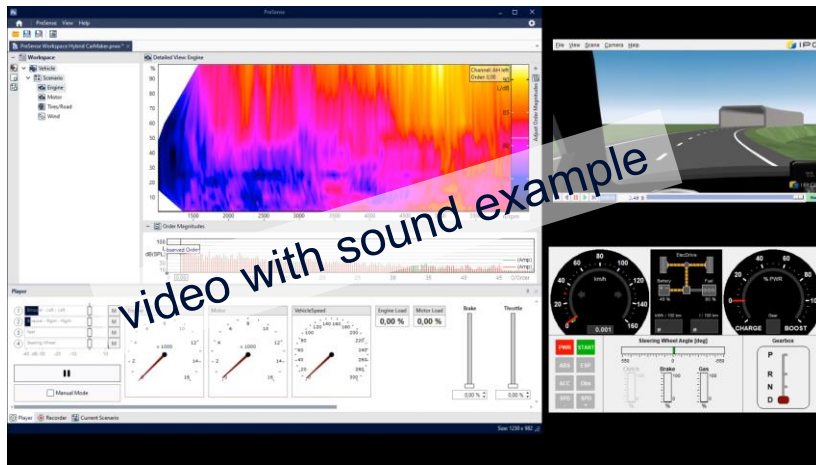
Two blue arrows point to the dashboard: one labeled "Gas, Brake" pointing to the sliders, and another labeled "RPMs, Loads, Speed" pointing to the tachometers and load gauges.

Example 1: Hybrid Vehicle

Early concept phase

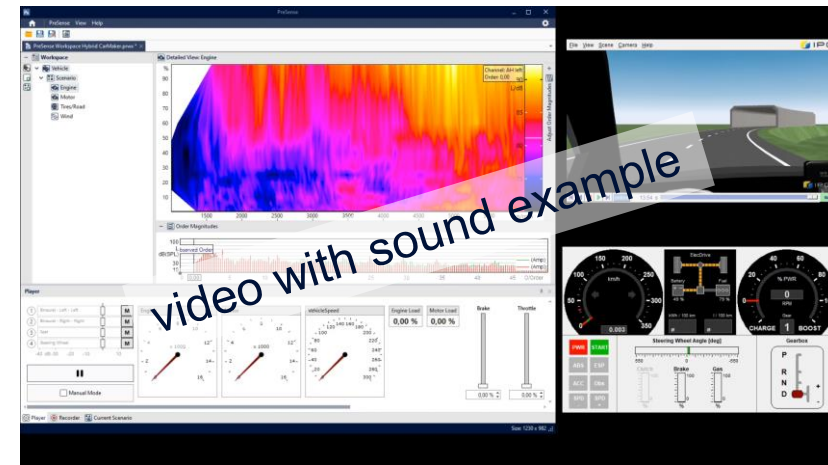
- Powertrain noise from testbench
- Road noise and wind noise from current model

Series Hybrid



VS.

Parallel Hybrid



Example 2: Combustion engine with CVT

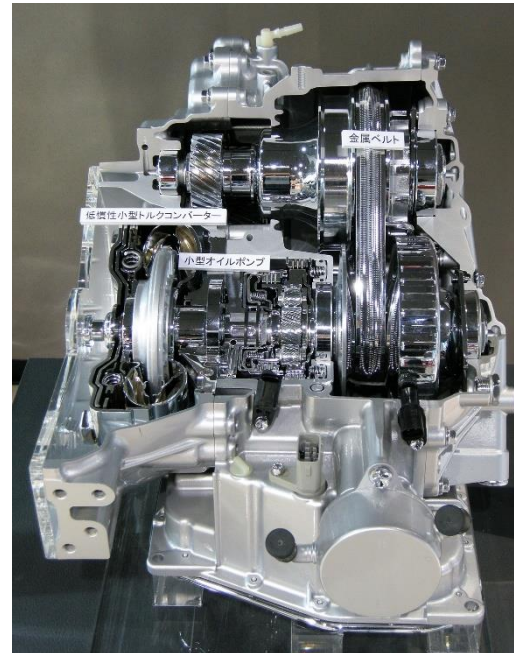
Shortly before Start of Production

- Powertrain, road and wind noise from late prototype
- Too late for hardware changes but TCU software still adaptable

CVT

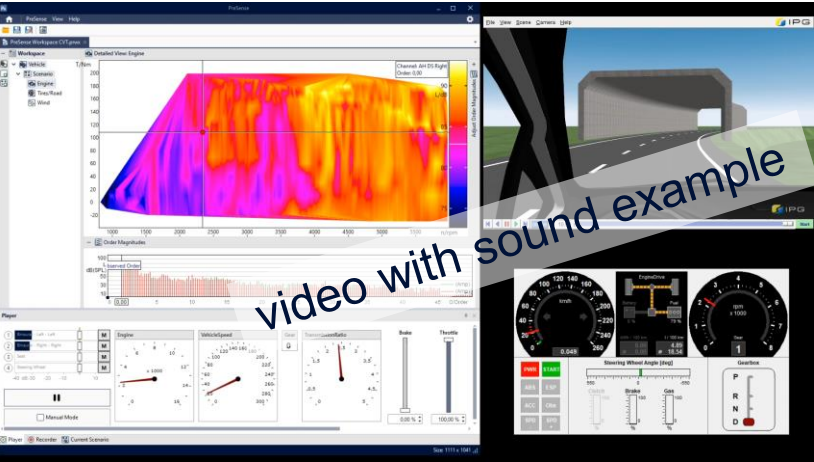
Continuously Variable Transmission

**No fixed gears:
What is the optimal strategy
for the transmission ratio?**



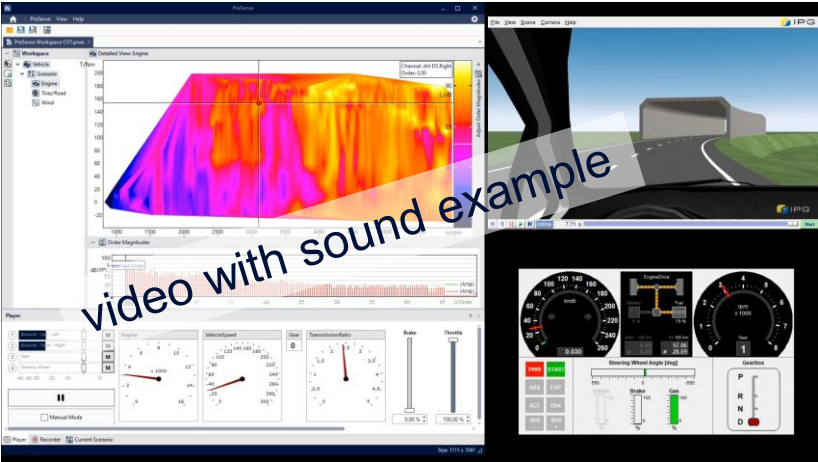
Example 2: Combustion Vehicle with CVT

CVT: Constant RPM with variable Ratio



vs.

CVT: Emulated fixed gears



Summary

- In a simulator engineers from all departments involved can tune the powertrain control strategy to find the optimum balance between for acoustics, drivability and fuel consumption.
- Different strategies can be compared in a simulator under safe and reproducible conditions. A driving simulator is particularly suitable for the evaluation of complex systems that involve a lot of human interaction.
- Engineers can use the same vehicle dynamic model for powertrain and NVH development.
- Experience a virtual prototype based on combination of test data, CAE data and test bench data.