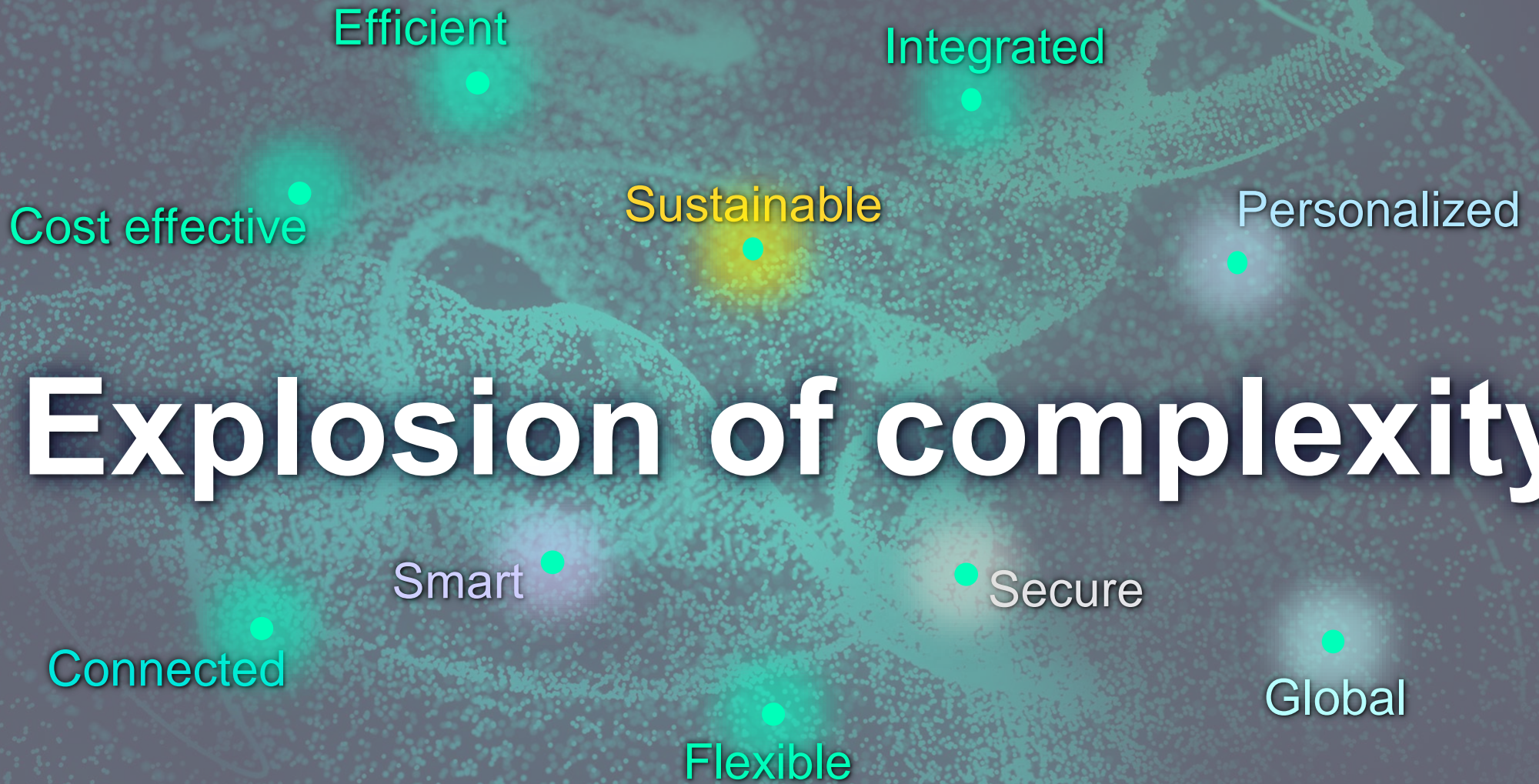


# NVH prediction without physical vehicle prototypes, by creating virtual assemblies combining test & CAE models

Bart Verrecas

Global Business Development lead – Automotive Testing







**30-70%**  
of scheduling and resources  
are consumed by  
**integration issues**



**Digitalization**  
across product lifecycle is key

*Source: Data captured by Siemens in the field.*

# How does these impact NVH development?

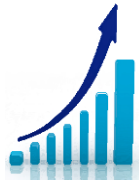


# Need for new process for managing Vehicle NVH performance

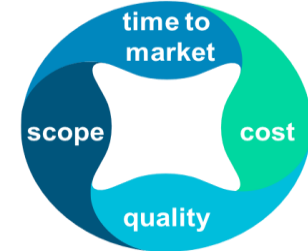
## Electrification



## # of vehicle variants & increasing software



## Status Quo no option



**More noise sources** to be integrated and controlled, going electric  
**More vehicle variants**, increasing combinations and **large driving/controls conditions**  
While overall need to develop in less time at lower costs

**Need for process that allows NVH prediction for a virtually assembled vehicle**  
this at any stage during development  
Fitting into company process and addressing needs of all stakeholders

# A complex assembly of sources, components and software

Systems & building blocks that influence NVH performance of assembled vehicle

## Subsystems

Structural & Acoustic Sources

EPS



Steering rack



Drive line



Engine



Transmission



HVAC



Exhaust



EDU



Tires



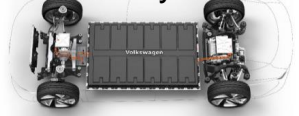
Reduction gearbox



Compressor



Battery



Vehicle NVH  
performance



Interior NVH?  
Exterior Noise?  
Sound Perception?

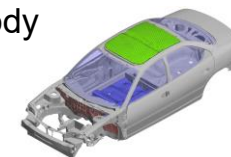
## Passive components

Structural characteristics

Mounts



Body



Suspension



Subframe, ...



## Software

Controls

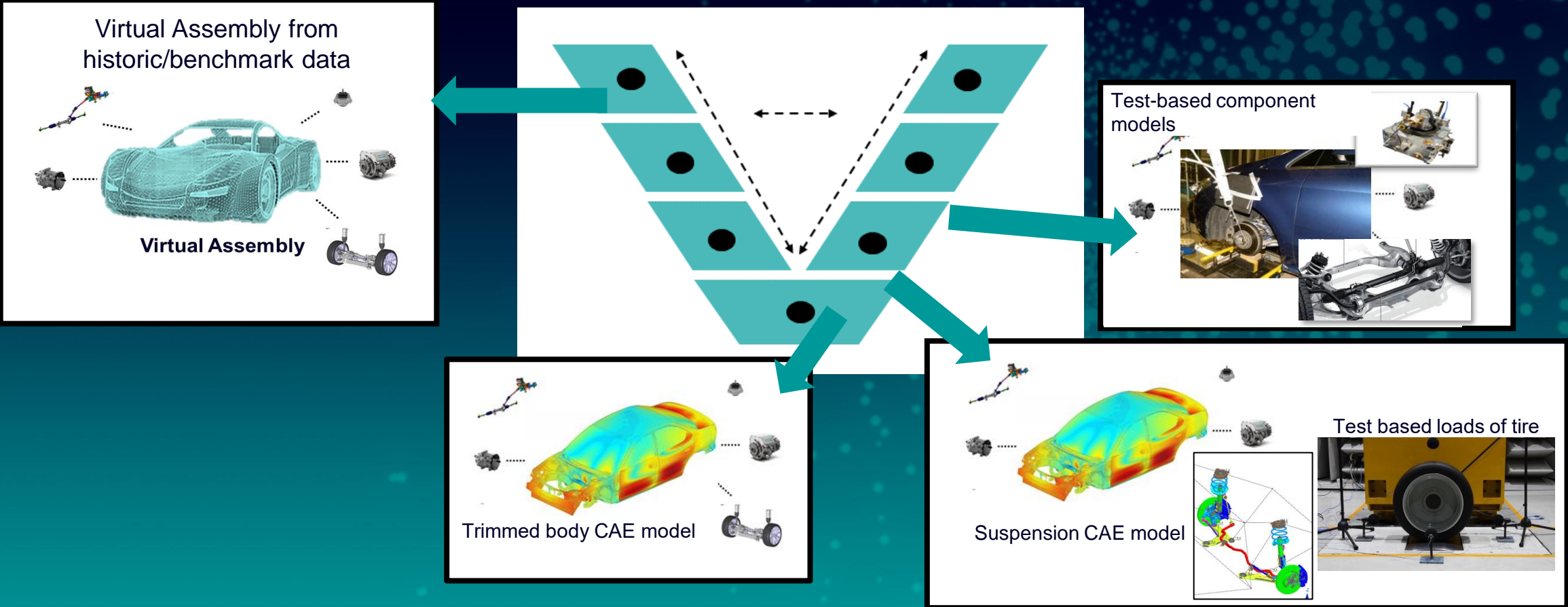
ECUs



# Requirements for NVH prediction process & tool

Technology that allows to work modular or system driven:

Replace/update one component/subsystem by more recent or alternative version





# Requirements for NVH prediction process & tool

Technology that allows to work modular or system driven:

Replace/update one component/subsystem by more recent or alternative version

Ability to integrate sources that are strongly coupled with the vehicle (e.g. tires)

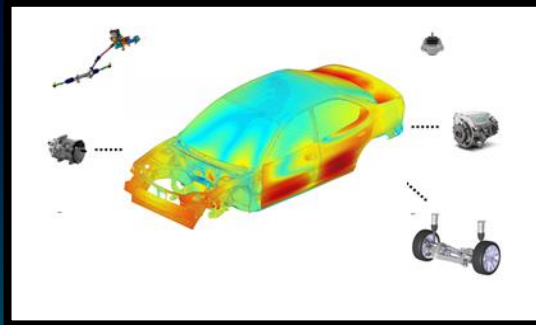


Be able to couple sources with direct connection (no soft mounts)

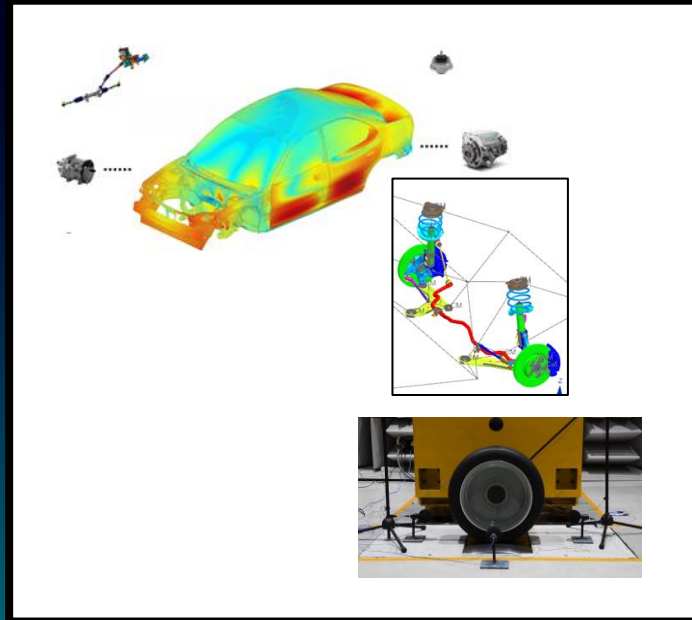


# Requirements for NVH prediction process & tool

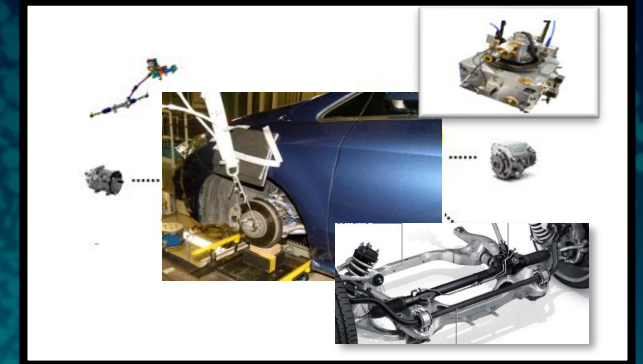
Mix and match CAE & Test based components



=

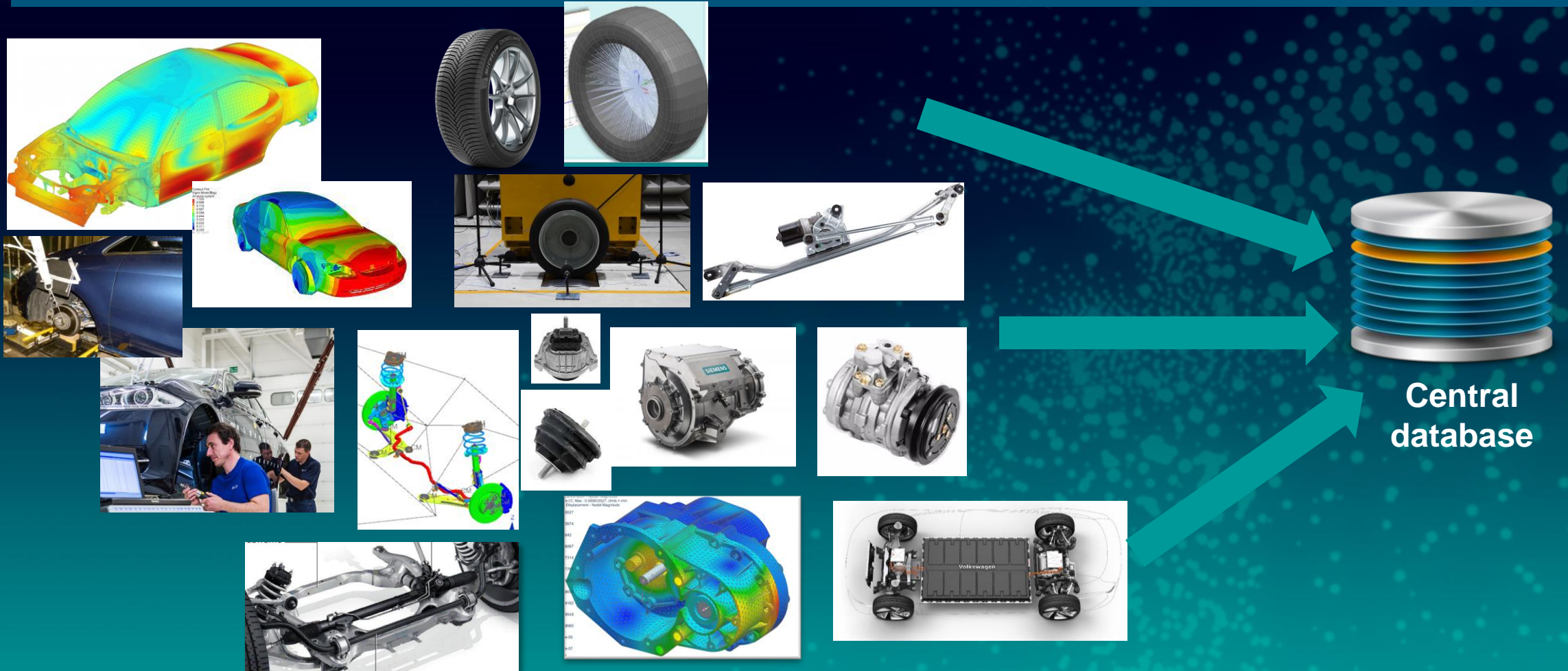


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## Requirements for NVH prediction process & tool

## Search & manage available component models in a central database



# Requirements for NVH prediction process & tool

Bridge between OEM & suppliers

Make suppliers contribute to this process  
Enable vehicle integration/evaluation for suppliers



Supplier



OEM

Exchange ONLY the absolute essentials without losing prediction accuracy  
No need for exchanging CAE models and confidential data



# Requirements for NVH prediction process & tool

Bridge between NVH and energy management (controls development)



Enable impact assessment of controls development on NVH by control engineers

# Requirements for NVH prediction process & tool

Bridge between NVH and energy management (controls development)



Enable impact assessment of controls development on NVH by control engineers

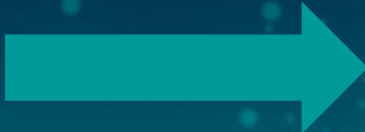
# Requirements for NVH prediction process & tool

**BUT above all, a fail-safe process that covers the need of all stakeholders**  
**Enabling strong collaboration between teams, sites and companies**

Provide confidence to experts that provide data  
that their data can only be used correctly

Focus on the explicit need of the analysts that use  
the virtual assembly

**TEMPLATES**  
 **DOCUMENTED**  
**EASE to PUBLISH**



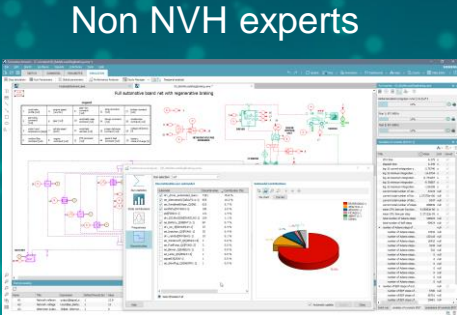
Road noise



Pass-by noise



Sound Quality

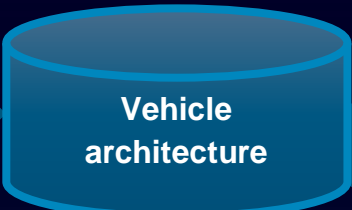


Non NVH experts



# Vehicle NVH prediction

## Predict vehicle NVH performance using a virtual prototype assembly



Populate assembly  
&  
perform calculation

### Analysts

#### Contribution analysis

Contribution analysis charts showing frequency response and a close-up of a car wheel.

#### Sound synthesis

Sound synthesis waveform and a person working on a computer.

#### Pass-by-noise synthesis

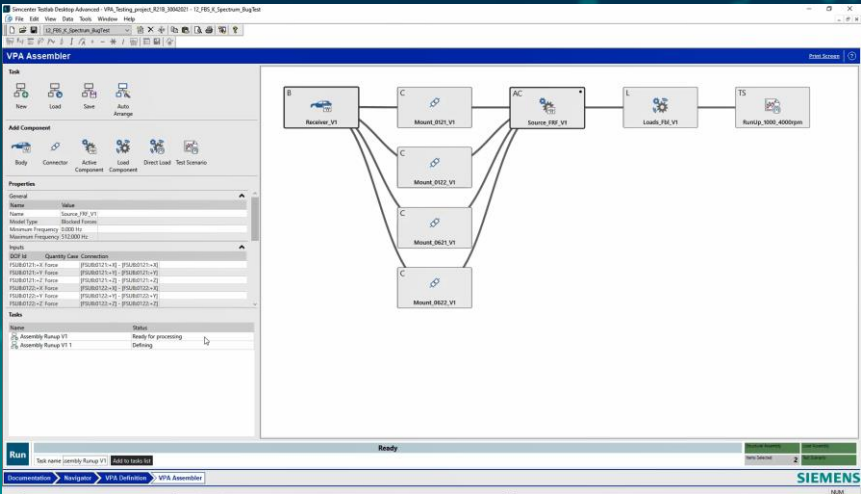
Pass-by-noise synthesis graph showing frequency response and a car on a road.

#### NVH driving simulator

NVH driving simulator setup with a person at a steering wheel and a computer monitor.

#### Link impact of controls to NVH

Link impact of controls to NVH diagram showing the flow from Gasoline Engine, Battery, Electric Machine, CVT, Clutch, and Vehicle.



# Data created by the experts

## But published in full confidence for fail-safe reuse



1D specialist

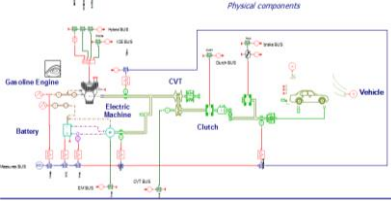


Test specialist

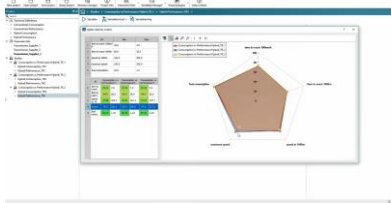


CAE specialist

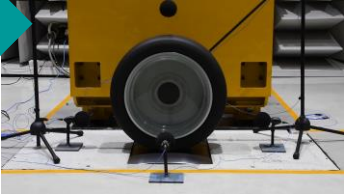
### Driveline simulation to simulate drive profiles



### Drive scenario simulation for different control scenarios




### Invariant loads




### Blocked forces

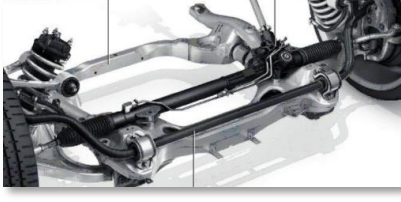
### FRFs on sources




### NTFs of body



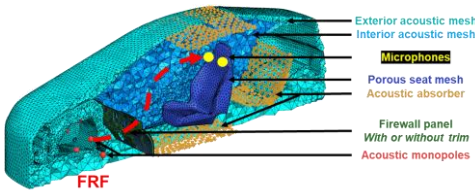
### FRFs of components



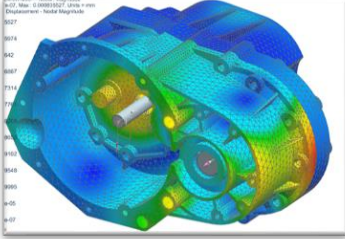
### Mount characterization



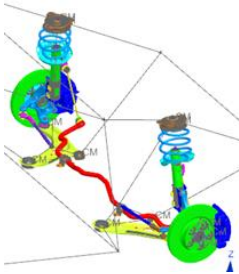
### Trimmed body NTFs



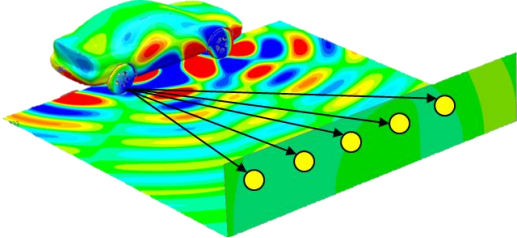
### Impedance of a source



### FRFs of suspension



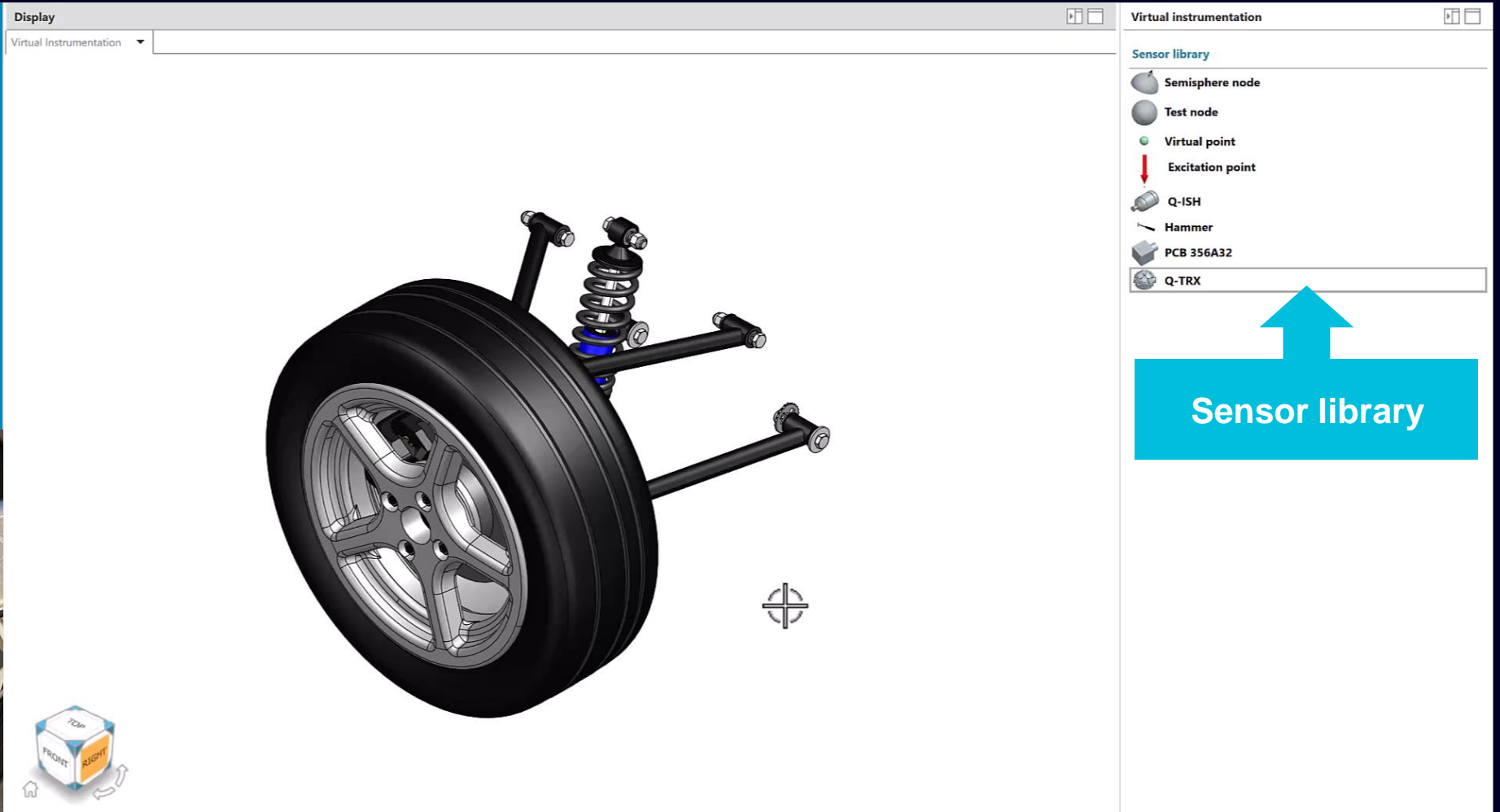
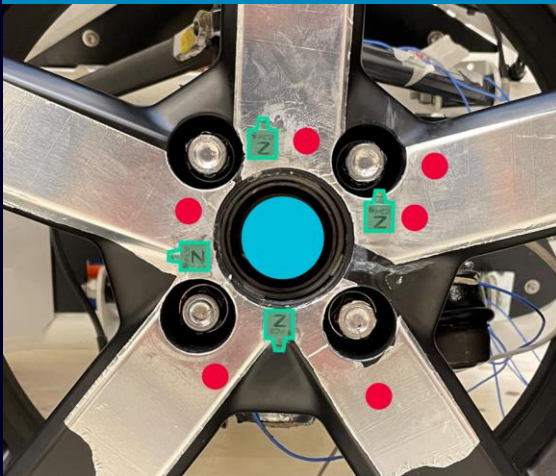
### NTF for exterior acoustics



# Road noise case study

## CAD-centric data acquisition in Testlab Neo

- ✓ Convenience
- ✓ Accuracy
- ✓ Reliability







## Hyundai Motor Group

**uses MBSE to take new approach  
to virtual NVH development**

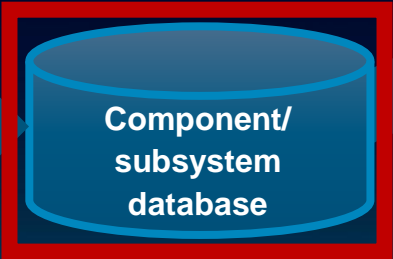
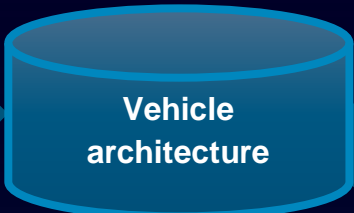
Hyundai Motor Group integrates test and simulation models to achieve highly accurate road noise prediction.

### Digital twin

of vehicle road noise achieved

# Vehicle NVH prediction

## Overview



Populate assembly  
&  
perform calculation



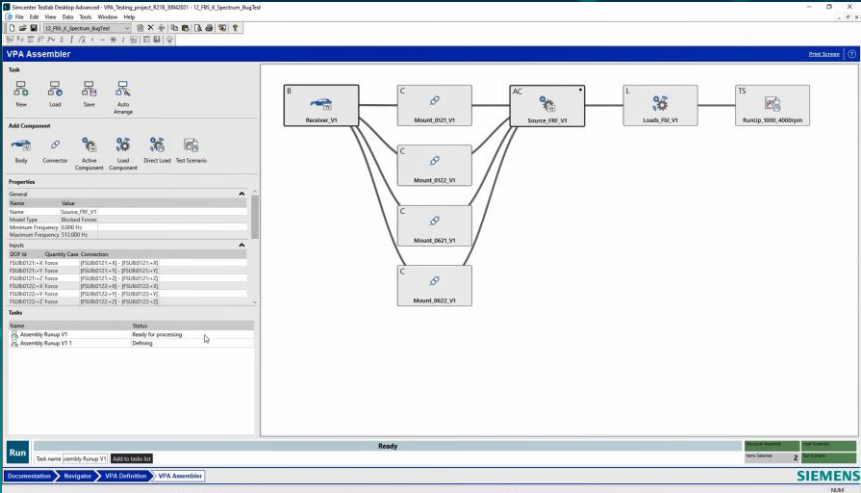
1D specialist



Test specialist



CAE specialist



### Analysts

#### Contribution analysis

Contribution analysis

#### Sound synthesis

Sound synthesis

#### Pass-by-noise synthesis

Pass-by-noise synthesis

#### NVH driving simulator

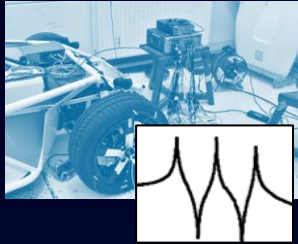
NVH driving simulator

#### Link impact of controls to NVH

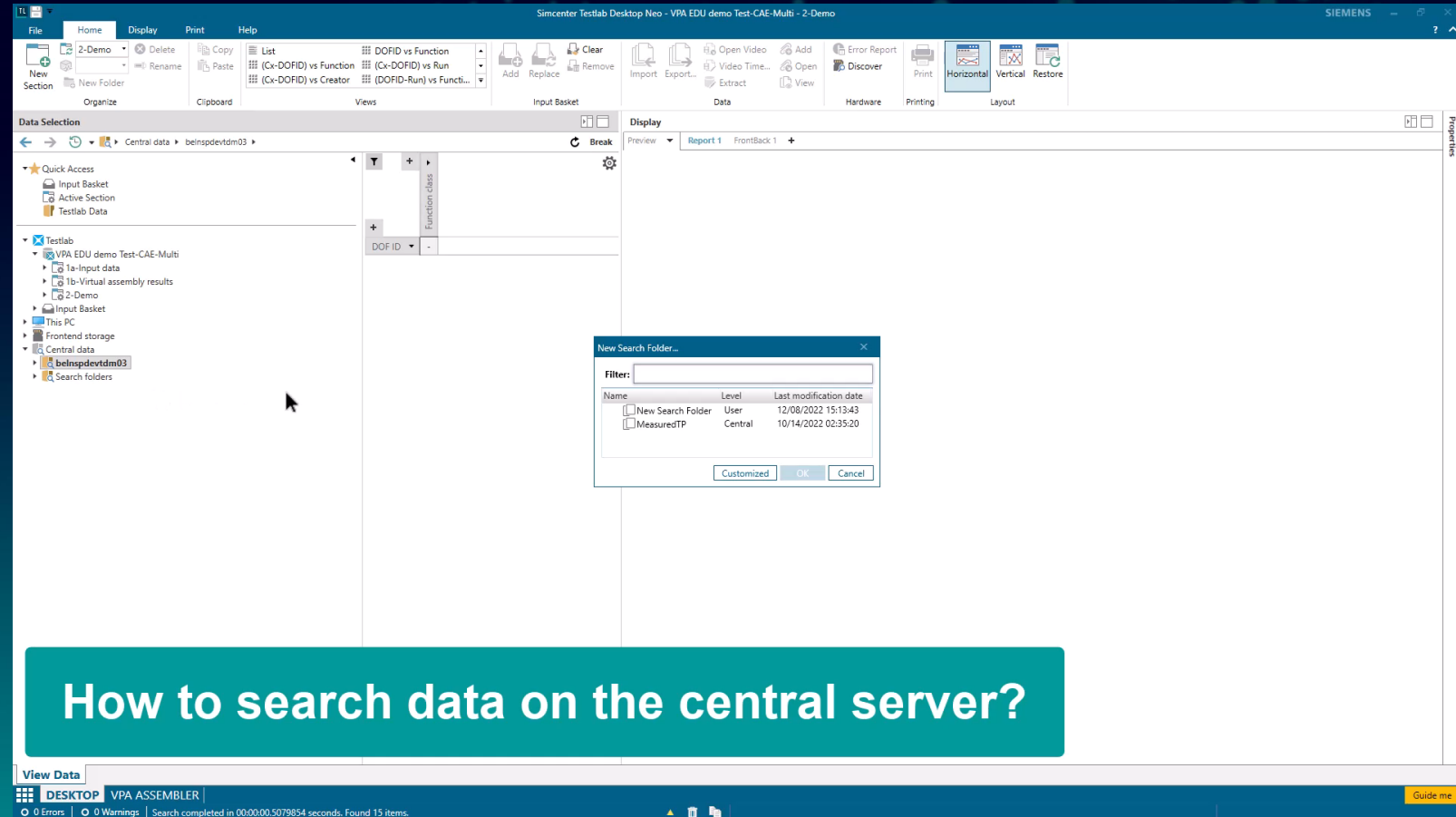
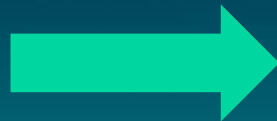
Link impact of controls to NVH



# Managing all components in a central database with Simcenter Testlab Data management



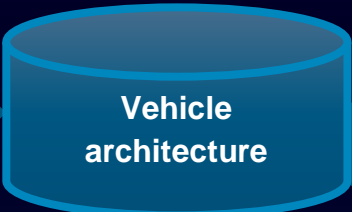
1. Annotate & Store
2. Search & Retrieve





# Vehicle NVH prediction

## Overview



Populate assembly  
&  
perform calculation

**Analysts**

Contribution analysis

Analysts

Sound synthesis

Sound synthesis

Pass-by-noise synthesis

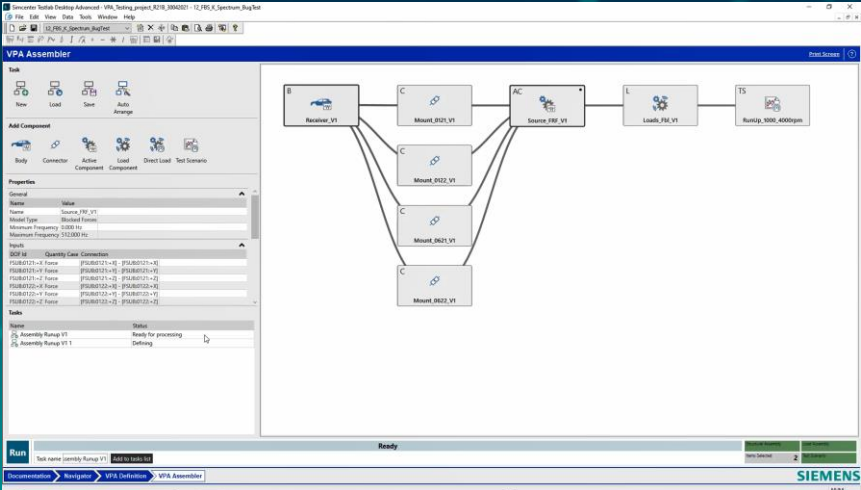
Pass-by-noise synthesis

NVH driving simulator

NVH driving simulator

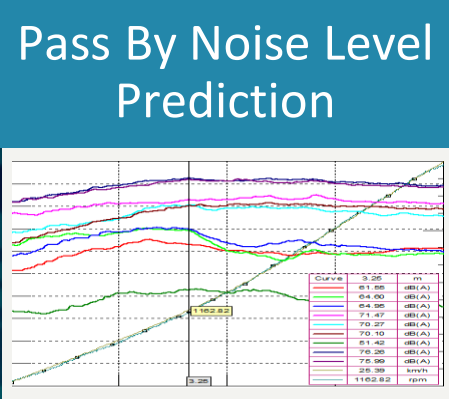
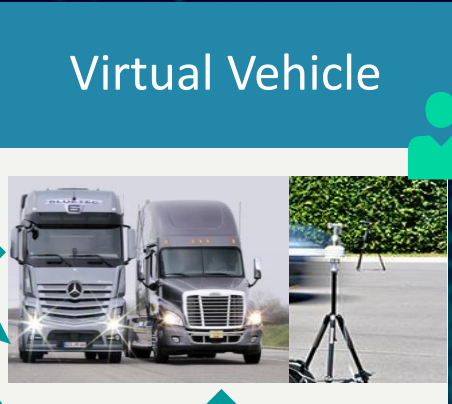
Link impact of controls to NVH

Link impact of controls to NVH



# Towards modeling for exterior noise

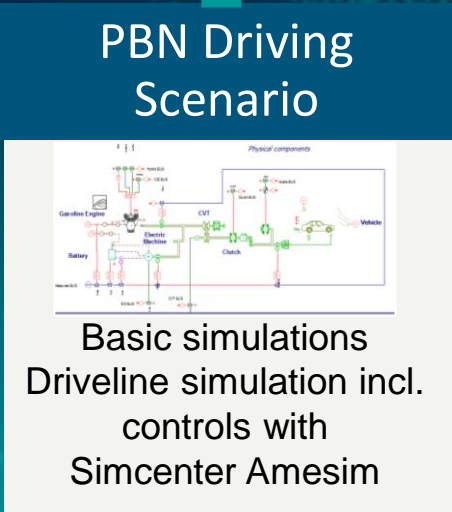
Pass-by noise Analyst



Early Prediction of Full PBN levels

Easily evaluate assembly alternatives

Evaluate impact of driveline/control alternatives



Vehicle Body A

**WHAT?**  
PBN microphone  
Noise Transfer functions

**HOW?**  
Measured if prototype available  
Simulated

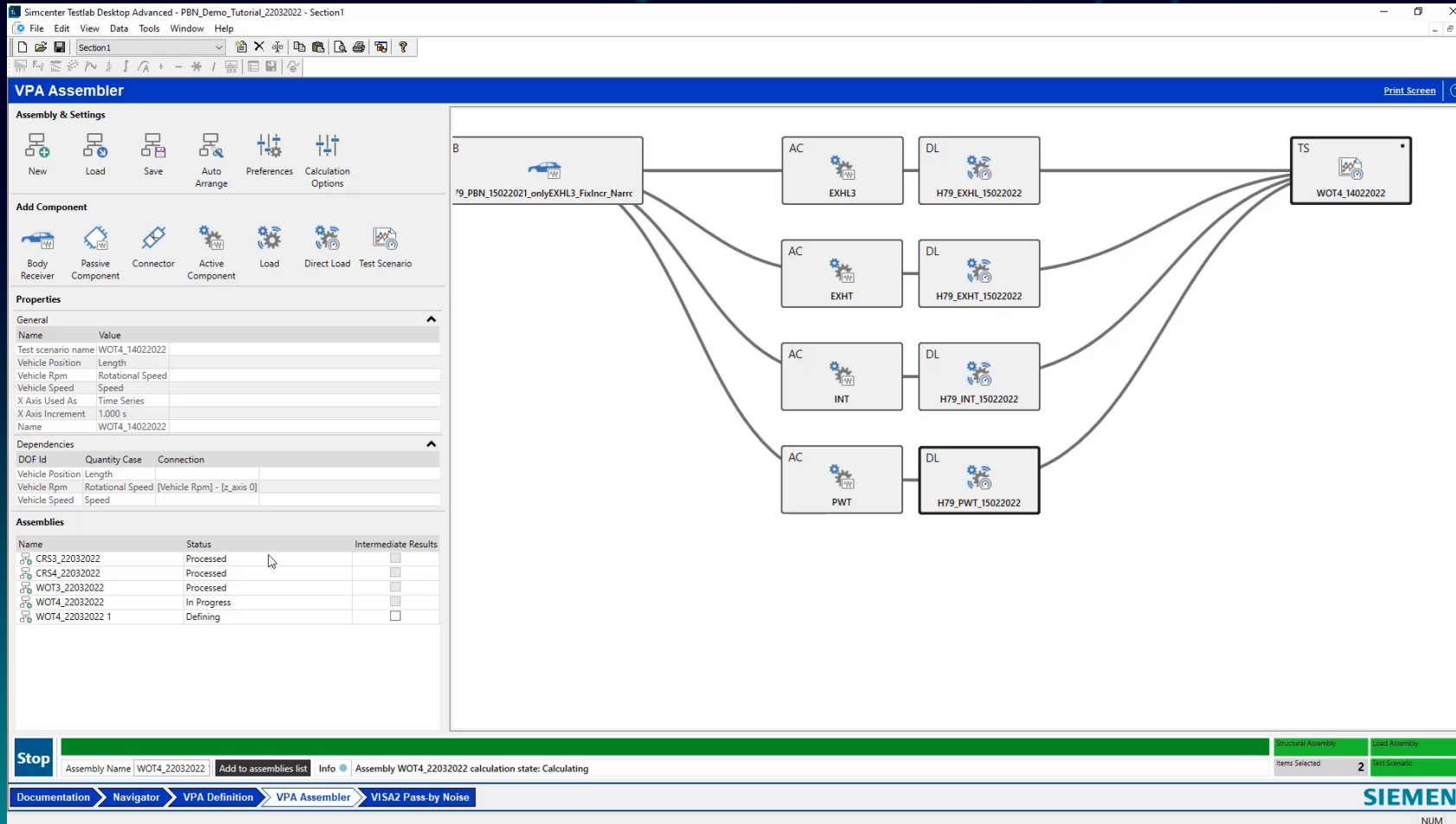
Component B

**WHAT?**  
Invariant (airborne) source description Qs

**HOW?**  
Measured on a bench or in-situ  
Simulated

Component C, D, ...

# Speaking the language of the Pass-by Noise Analyst



Provide the data to the Pass-by noise Analystist with focus on their main task: meeting regulation

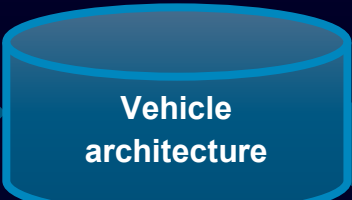
Get efficient guidelines:

- Troubleshooting
- Where to most effectively look for change



# Vehicle NVH prediction

## Overview



Populate assembly  
&  
perform calculation

### Analysts

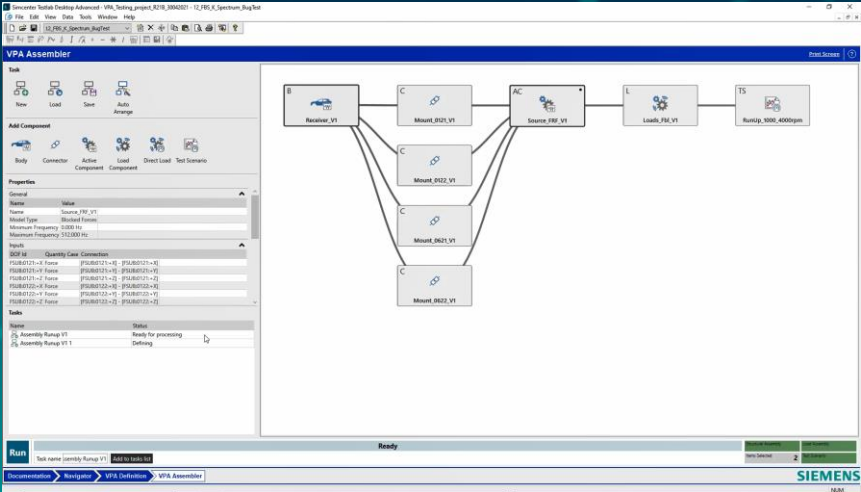
Contribution analysis

Sound synthesis

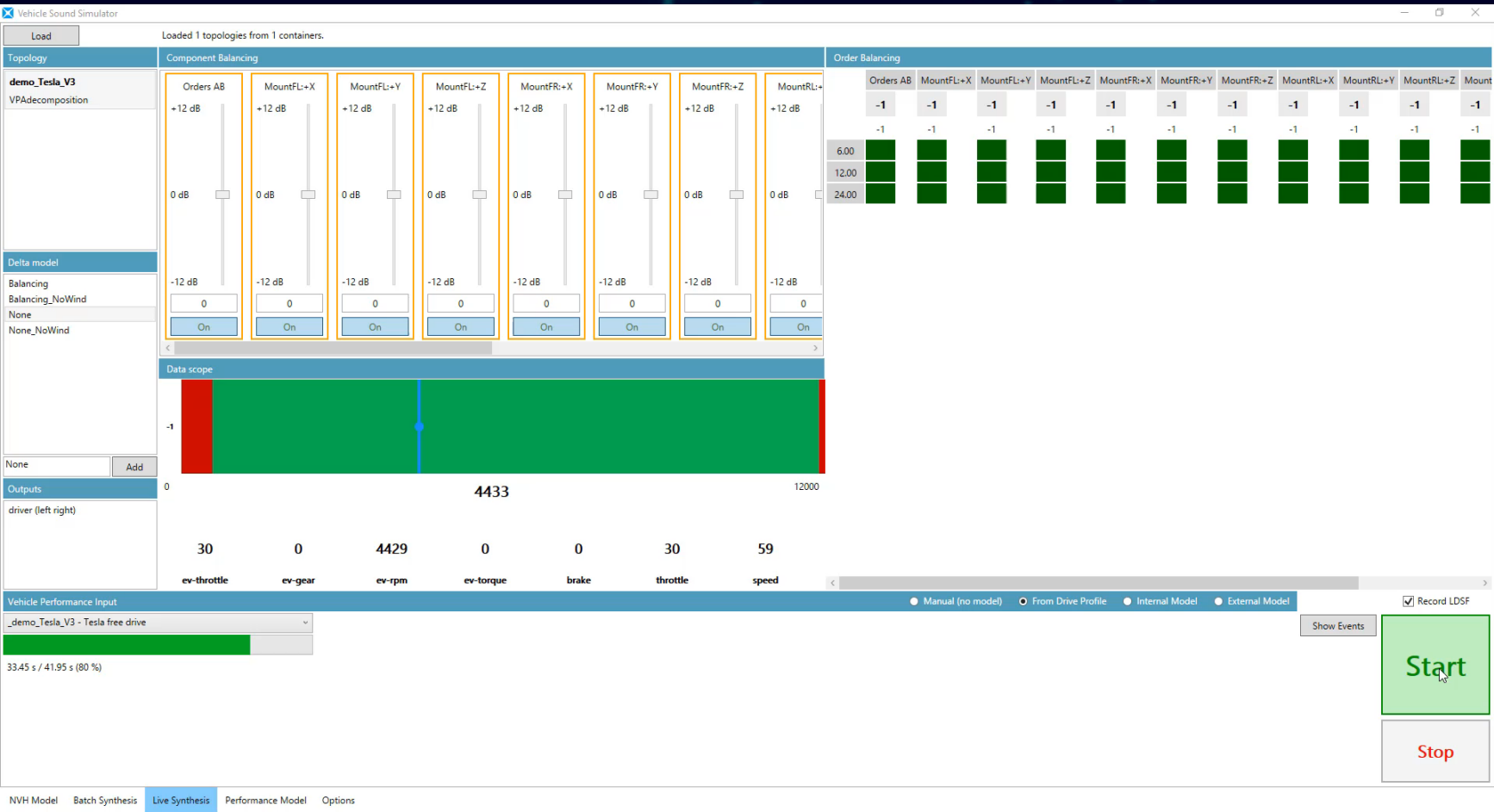
Pass-by-noise synthesis

NVH driving simulator

Link impact of controls to NVH



# Driving your virtual assembly on the Vehicle NVH simulator



Evaluate subjective NVH performance at any stage of development

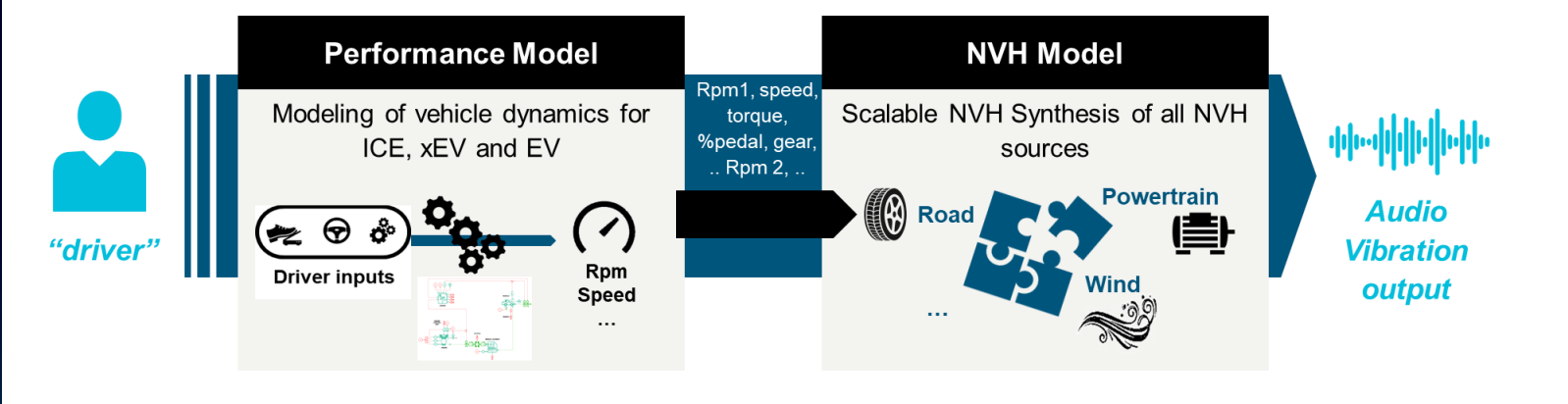
Example here:  
Tesla Model S road & wind noise  
& EDU of virtual assembly

Possibility to include Real-time performance models and controls



# Vehicle NVH simulator – Transforming your VPA models into KPI's

## Enabling powerful A-B comparison, making it a powerful engineering tool

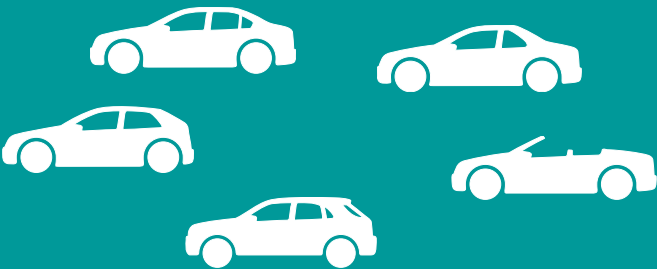


### NVH simulator in Batch Synthesis

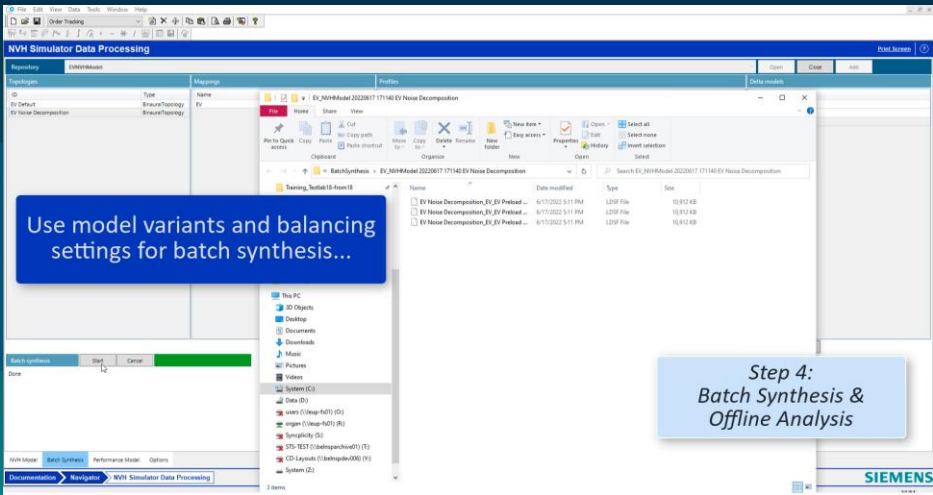
No human, but inputs from profiles:

- Throttle,
- Brake,
- ...
- RPM
- Speed

### Vehicle (VPA) Models



### Processing & A-B comparison in Neo







Renault

## How can I fix issues before building a physical prototype?

Development costs and time-to-market are reduced through a more accurate NVH virtual assessment earlier in design phase.

**5x**

expanded  
NVH prediction  
applications ↗

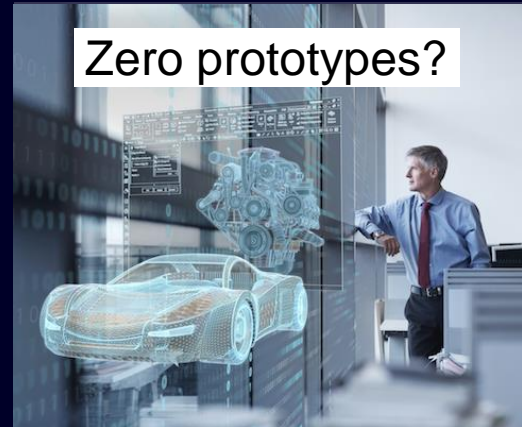
# Vehicle NVH prediction enabled with Simcenter Virtual Prototype Assembly



## Explore the possibilities



Reliable & fast exploration of vehicle assemblies with focused NVH results



## Stay integrated



End-to-end company process removing barriers & enabling collaboration

## Model the complexity



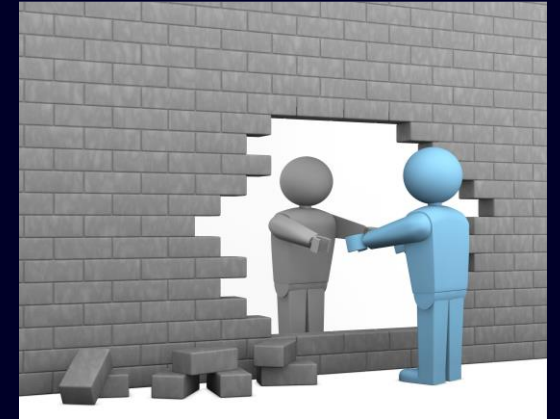
Access to Simcenter TEST & CAE portfolio to create accurate component data



## Go faster



Reduce physical prototypes & minimize risks of costly design change



## Comprehensive Digital Twin across the lifecycle



# Thank you!

## **Bart Verrecas**

Global Business Development lead – Automotive Testing  
Simulation & Test Solutions

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e-mail [bart.verrecas@siemens.com](mailto:bart.verrecas@siemens.com)