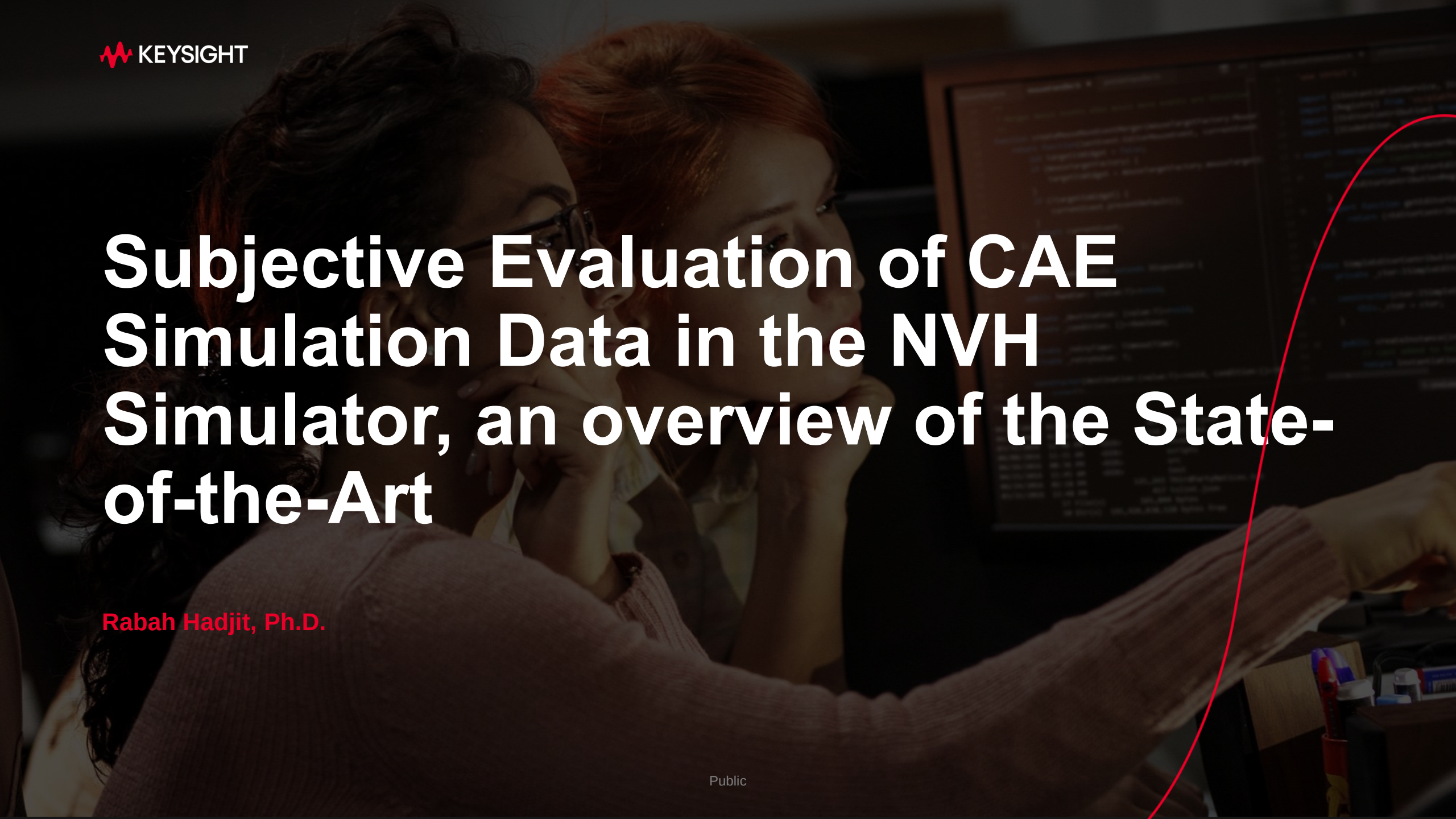


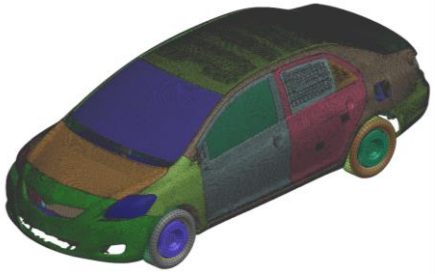
Subjective Evaluation of CAE Simulation Data in the NVH Simulator, an overview of the State-of-the-Art

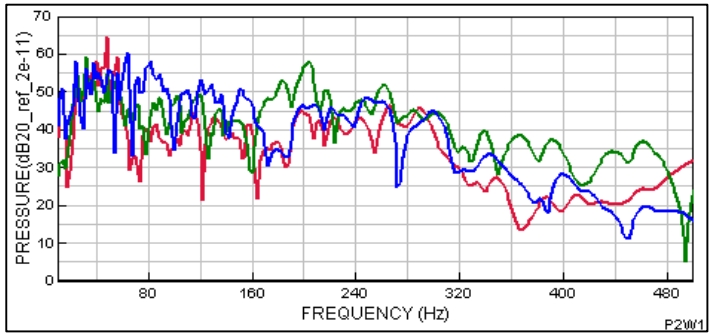
Rabah Hadjit, Ph.D.

On the Road to Zero Prototypes: Vibro-Acoustic Simulations

Deterministic or mesh-based methods

Finite-element modeling for low frequency structure-borne and boundary element modeling for exterior noise propagation





Energy based methods

Statistical Energy Analysis for high frequency airborne noise.

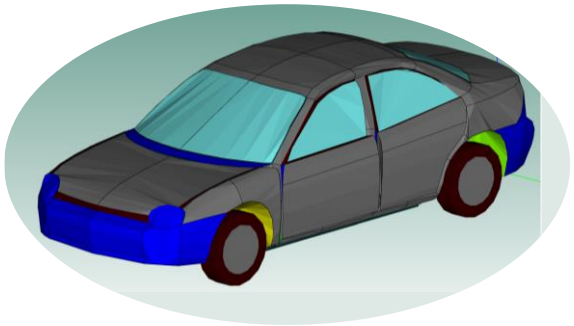
Which one of these curves "sound" better?
Are they worth the cost/weight addition?
How to convince program managers?

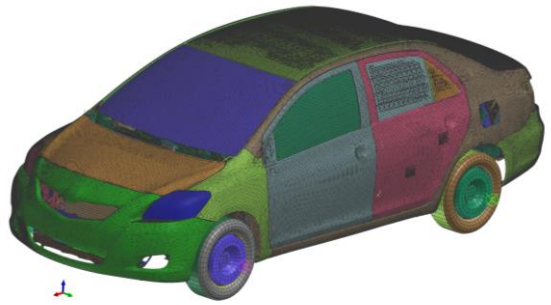
- Simulation with reference or unit loads or additional simulation required (e.g. CFD for wind noise, Electro-magnetic for motor noise, gear simulation for whine noise, multibody for structure-borne road noise, etc.)

Auralization in Driving Simulator for NVH

- Driving simulators provide calibrated audio and vibration feedback and replace physical prototypes in subjective evaluations.
- They also bring cost reduction and efficiency when making design decisions.

How to auralize CAE simulation results?





Road Noise Synthesis

Tire Test Stand

Source: www.hbk.com

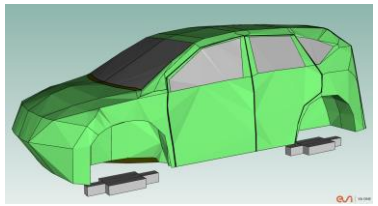
Airborne sources $Q_1, Q_2, \ldots$

Blocked forces $F_1, F_2, \ldots$

Vehicle Transfer Functions

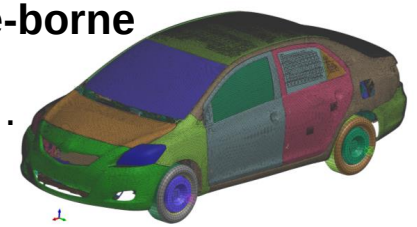
Airborne

$\frac{P}{Q_1}, \frac{P}{Q_2}, \ldots$



Structure-borne

$\frac{P}{F_1}, \frac{P}{F_2}, \ldots$



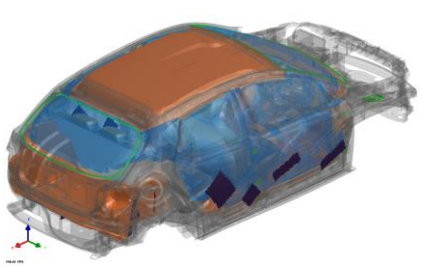
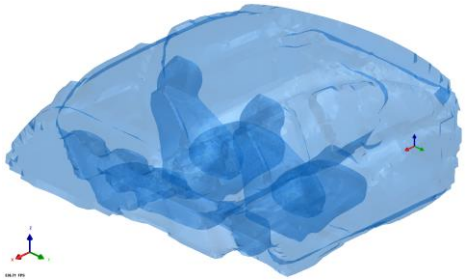
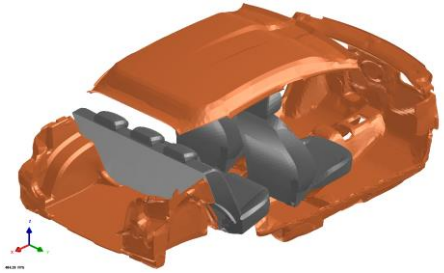
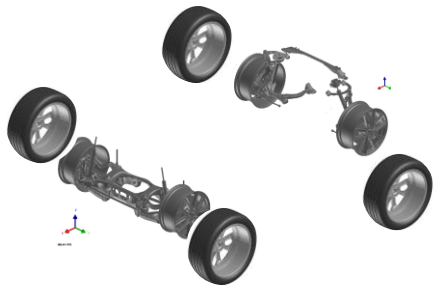
Virtual Prototype

Source: www.vigrade.com

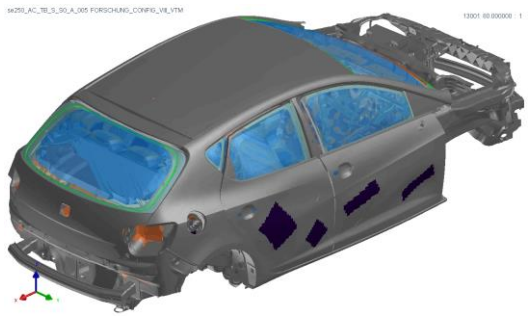
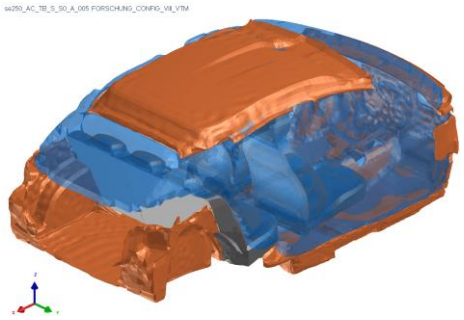
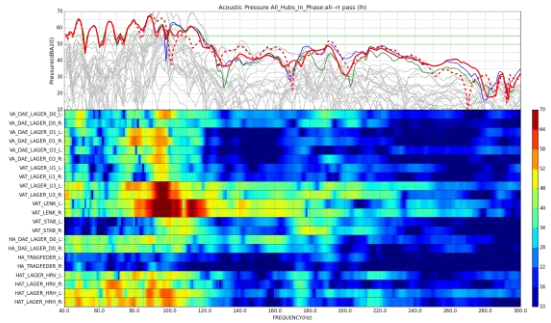
- The process is repeated for several speeds and the simulator environment interpolates between results to generate the road noise at any given speed.

Structure-Borne Transfer Functions: Finite-Element Simulations

Body + **Acoustic cavity** + **Trim & Damping patches** + **Suspensions & Tires**

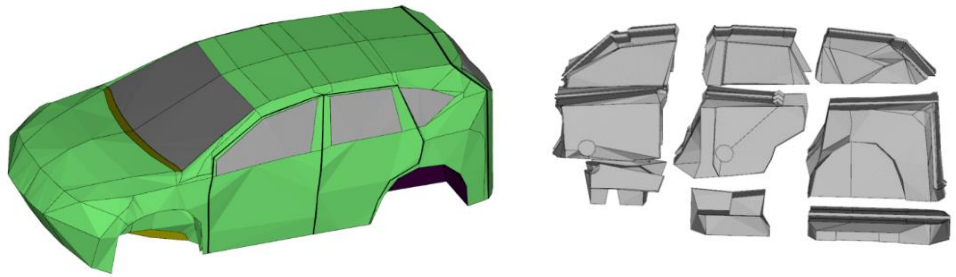





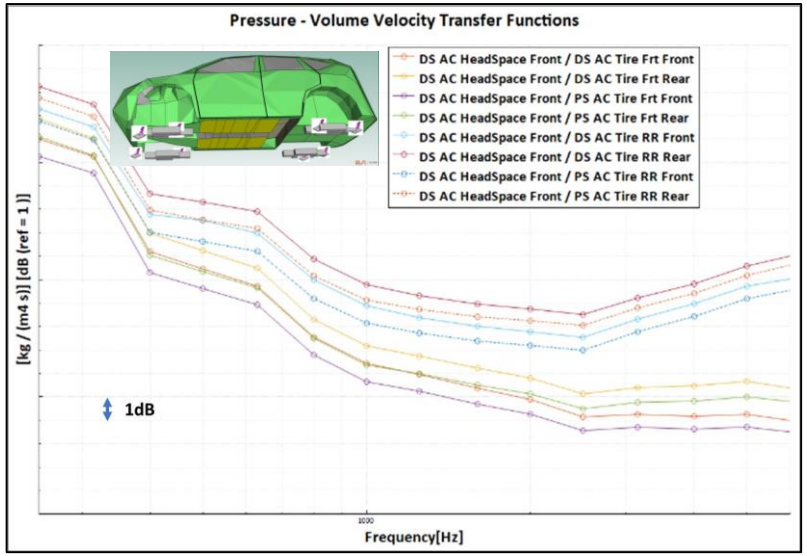
- State-of-the-art solver providing fast accurate results allowing engineers to understand the noise generation mechanism to optimize the vehicle design.

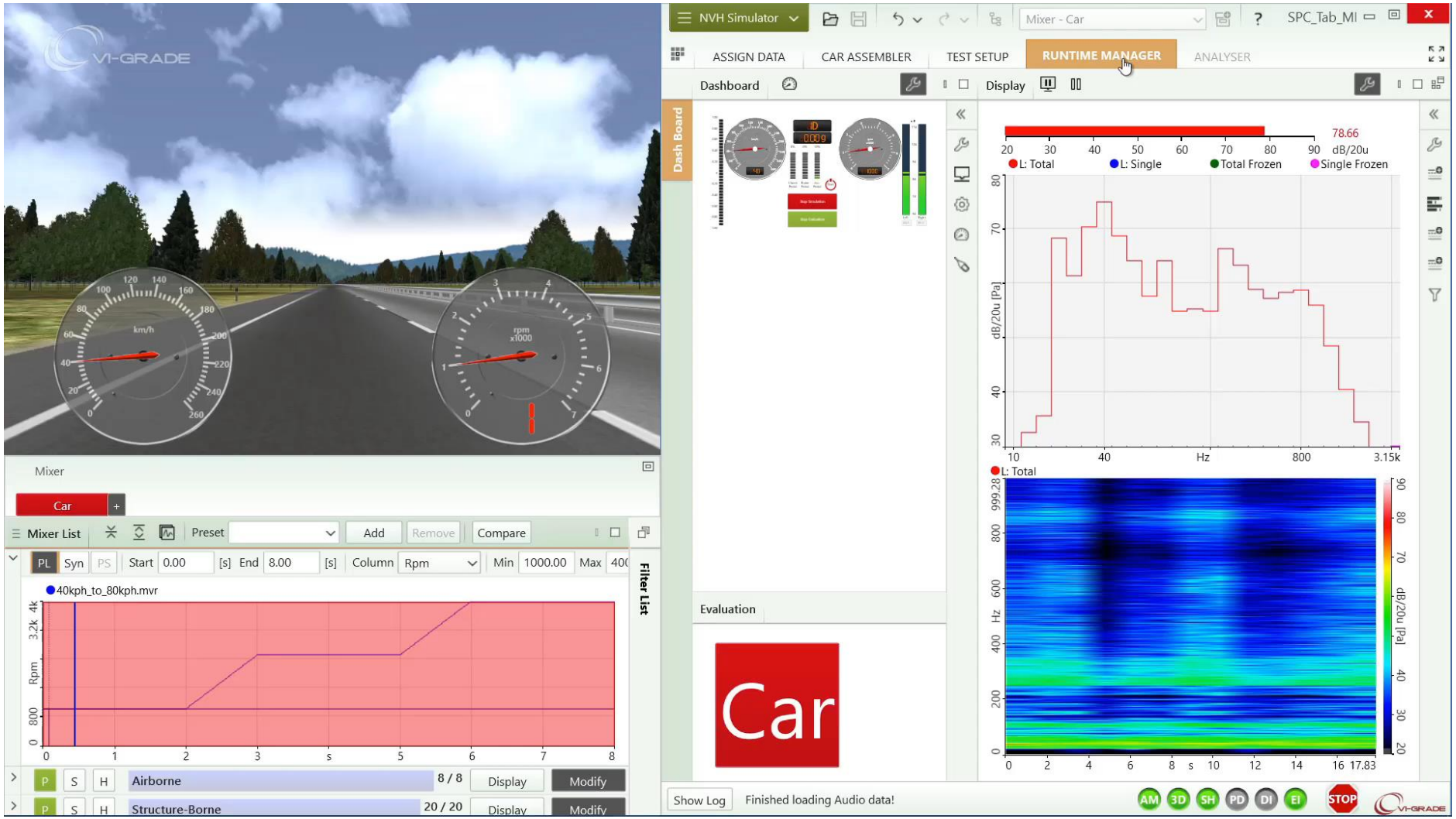
Airborne Transfer Functions: Statistical Energy Analysis

- Complement Finite-Element Analysis for high frequency simulation
- Reference simulation method for airborne noise sensitivity.
- Vehicle decomposed into subsystems, panels and acoustic cavities, that exchange, dissipate and store energy.
- Treatments add absorption, damping and insertion loss.
- SEA solves the power balance equation to estimate the average energy in each subsystem. The calculations are performed in frequency bands (third-octave bands)



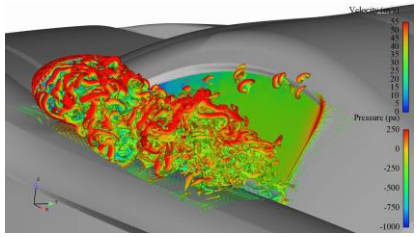


Road Noise Auralization: 40 to 80kph

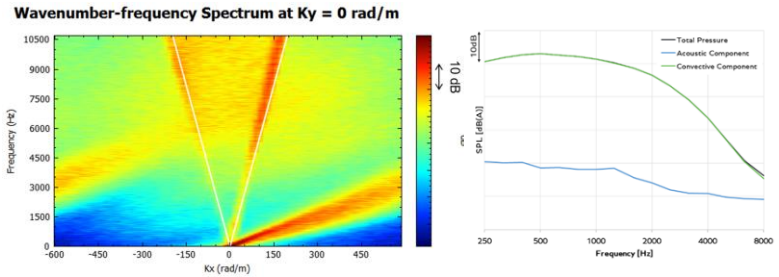


Wind Noise Simulation

CFD Simulation



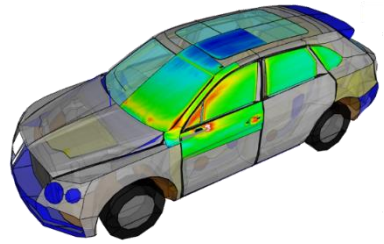
AVA Post-processing



Sources

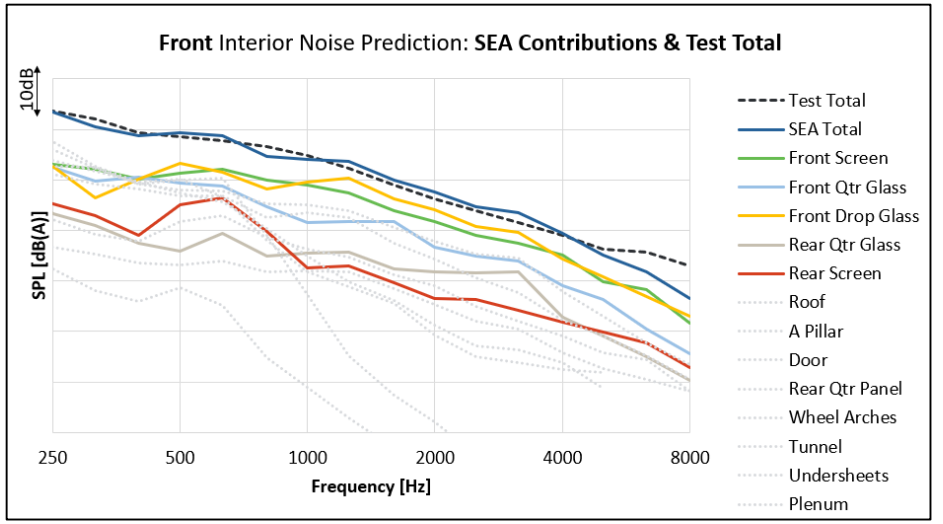
- Turbulent Boundary Layer
- Diffuse Acoustic Field
- General Surface Pressure

Vibro-Acoustic Model

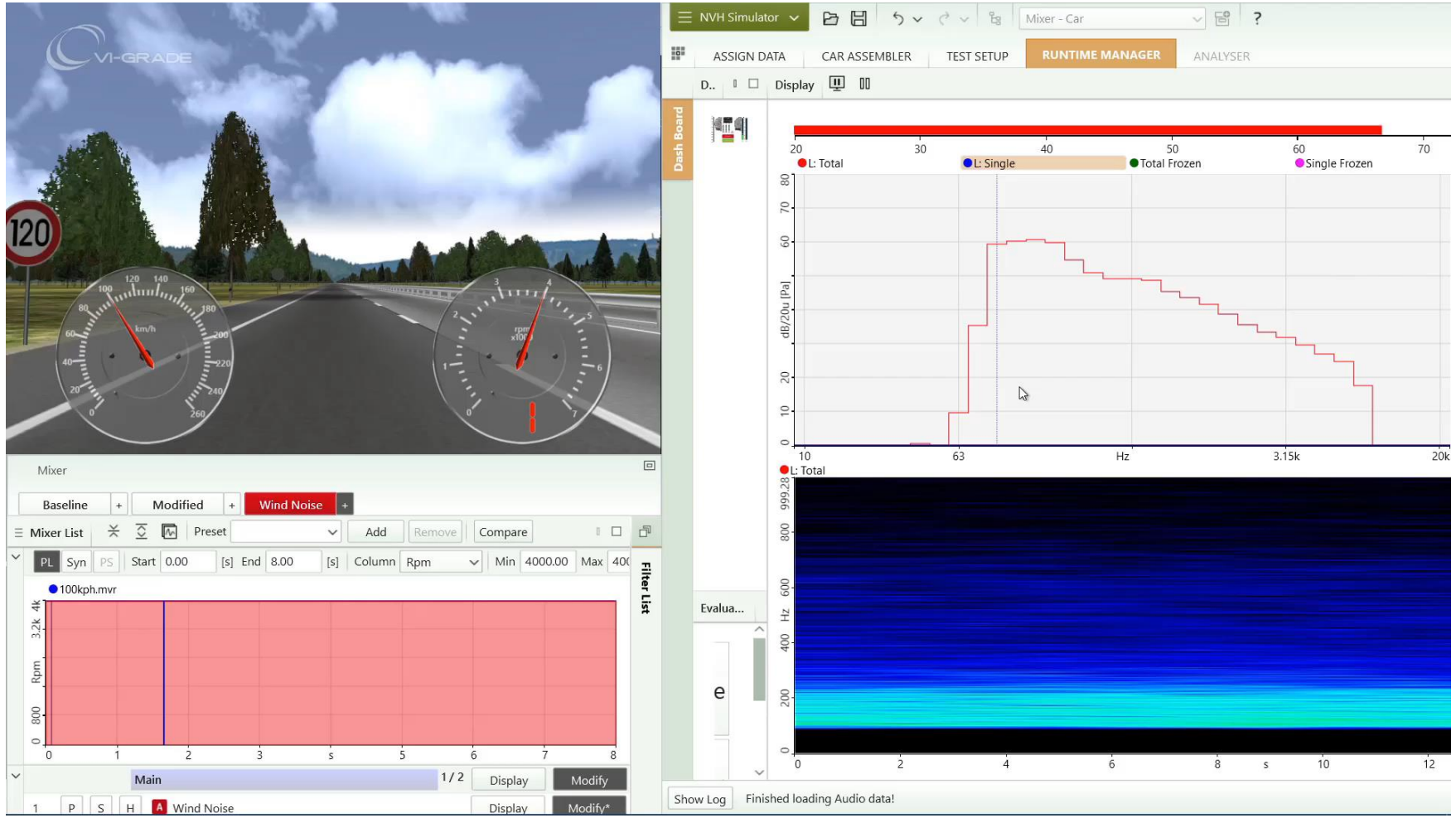


Validation of Combining Compressible CFD Results with Statistical Energy Analysis for Vehicle Interior Noise Simulation

Holly Daniels (Bentley), Joseph Venor & Simon Martin, Chad Musser (ESI Group) – ISNVH 2022

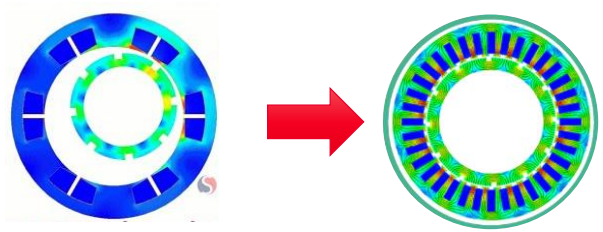


Wind Noise Auralization at 100kph

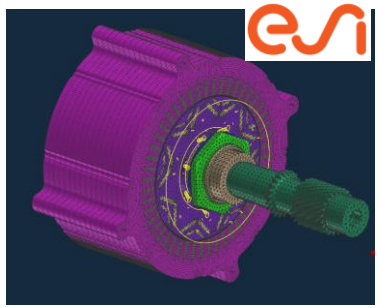


EV Powertrain Noise Simulation Process: Airborne Noise

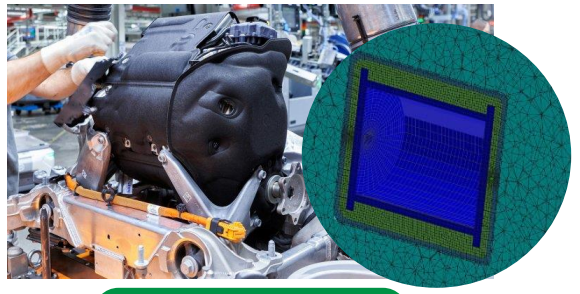
Forces: order domain



EM/Gear Simulation

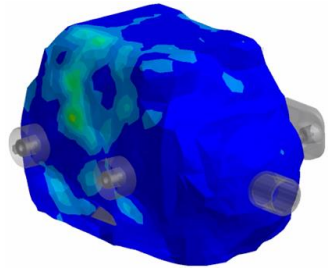


FE model



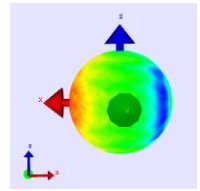
Poro-Elastic FE model

Noise Radiation

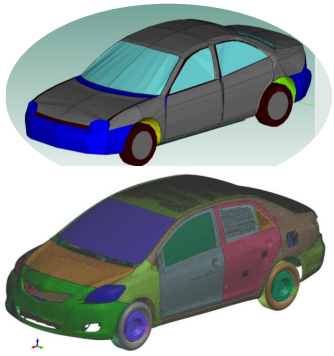


Vibro-Acoustic Simulation

Monopole/Compact Acoustic Source



Mount Forces

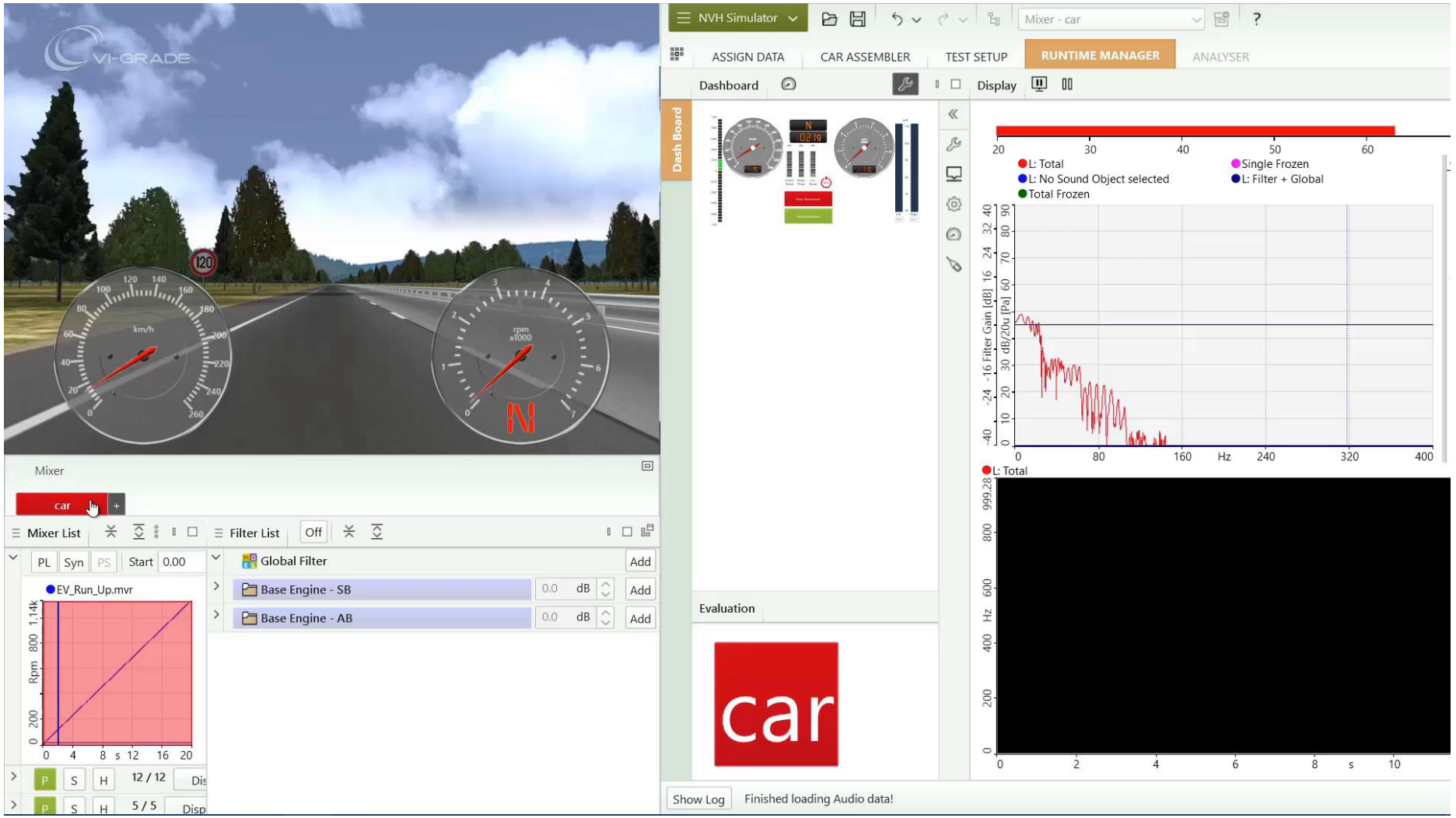


Full Vehicle Model: FE, BEM and SEA

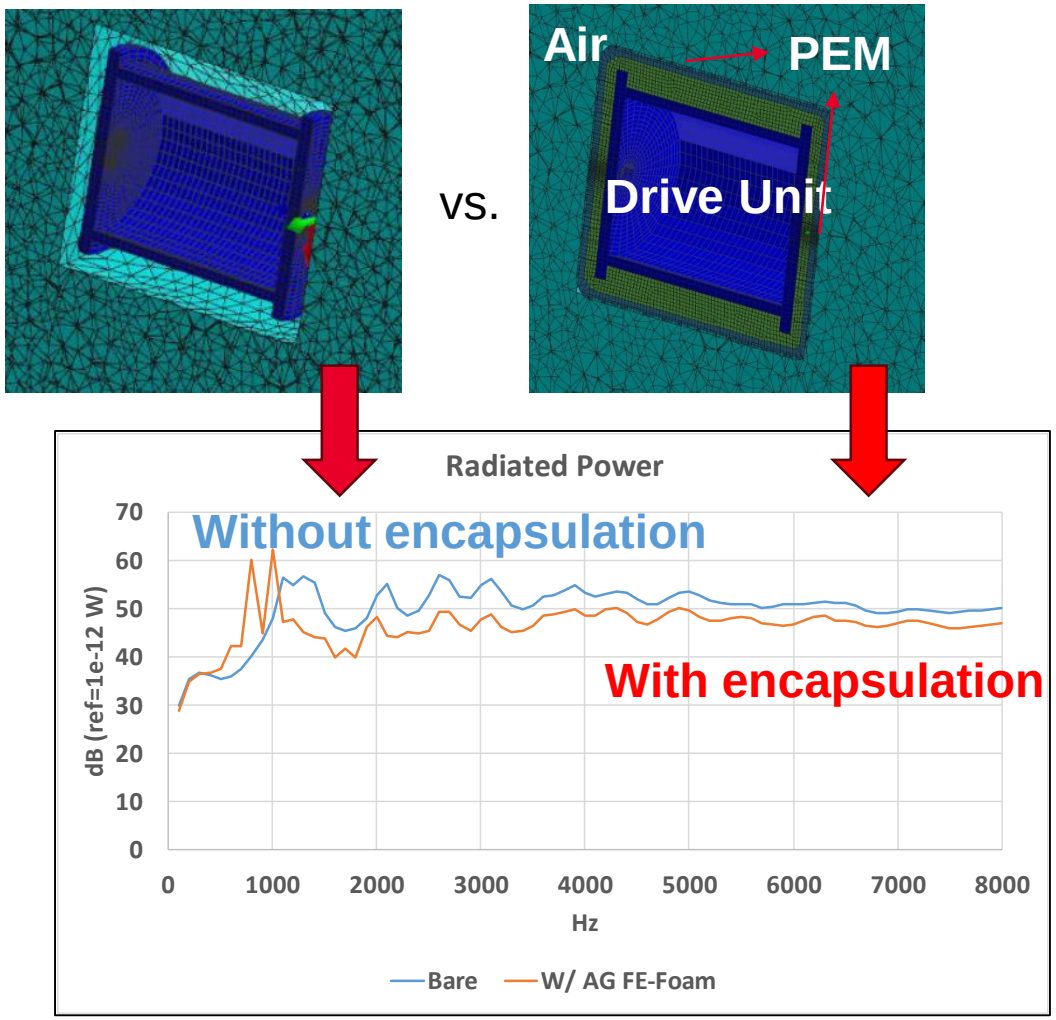
Interior SPL

Source: www.hbk.com

Powertrain Noise Auralization

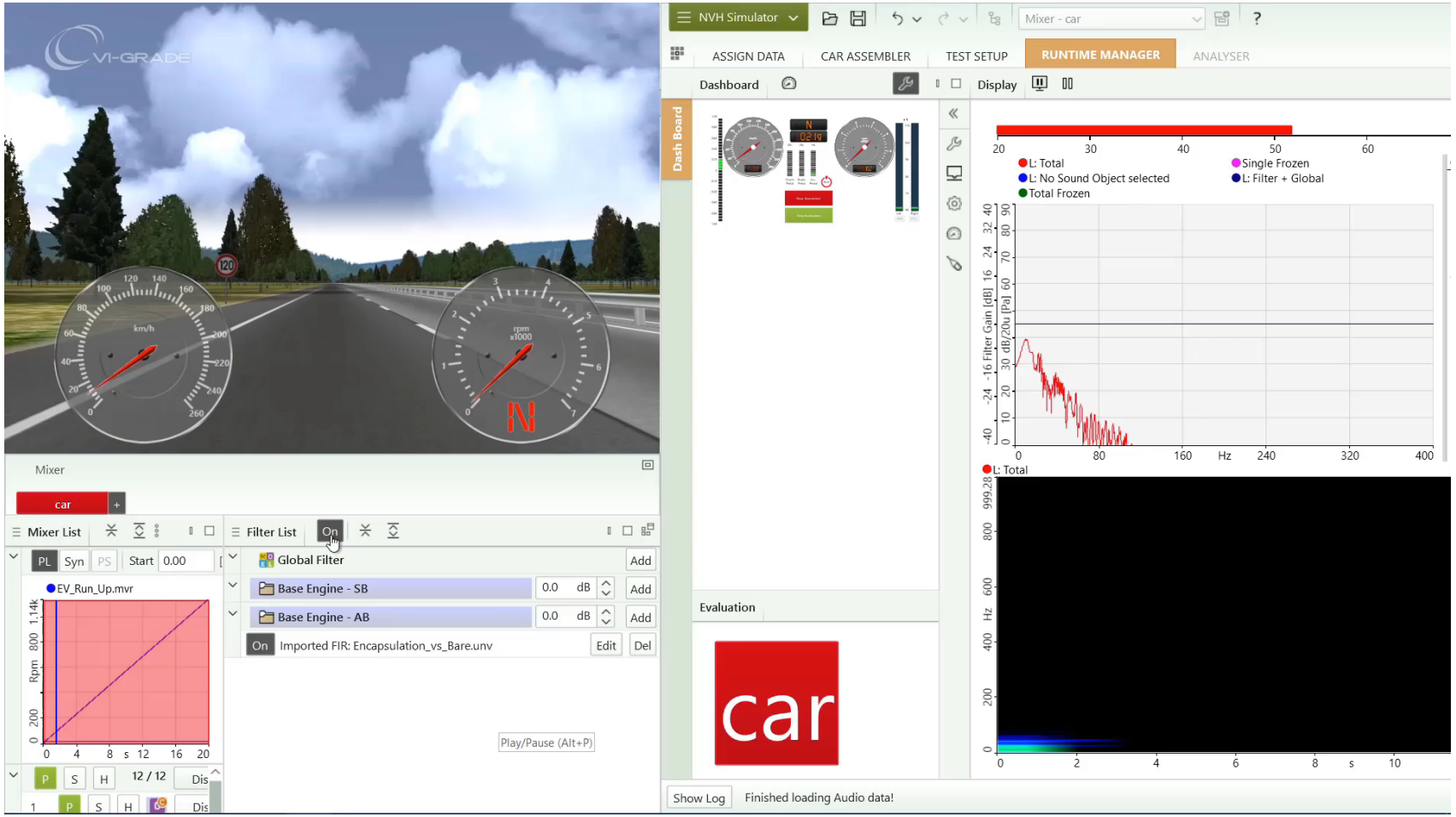


Encapsulation as a Frequency Dependent Filter

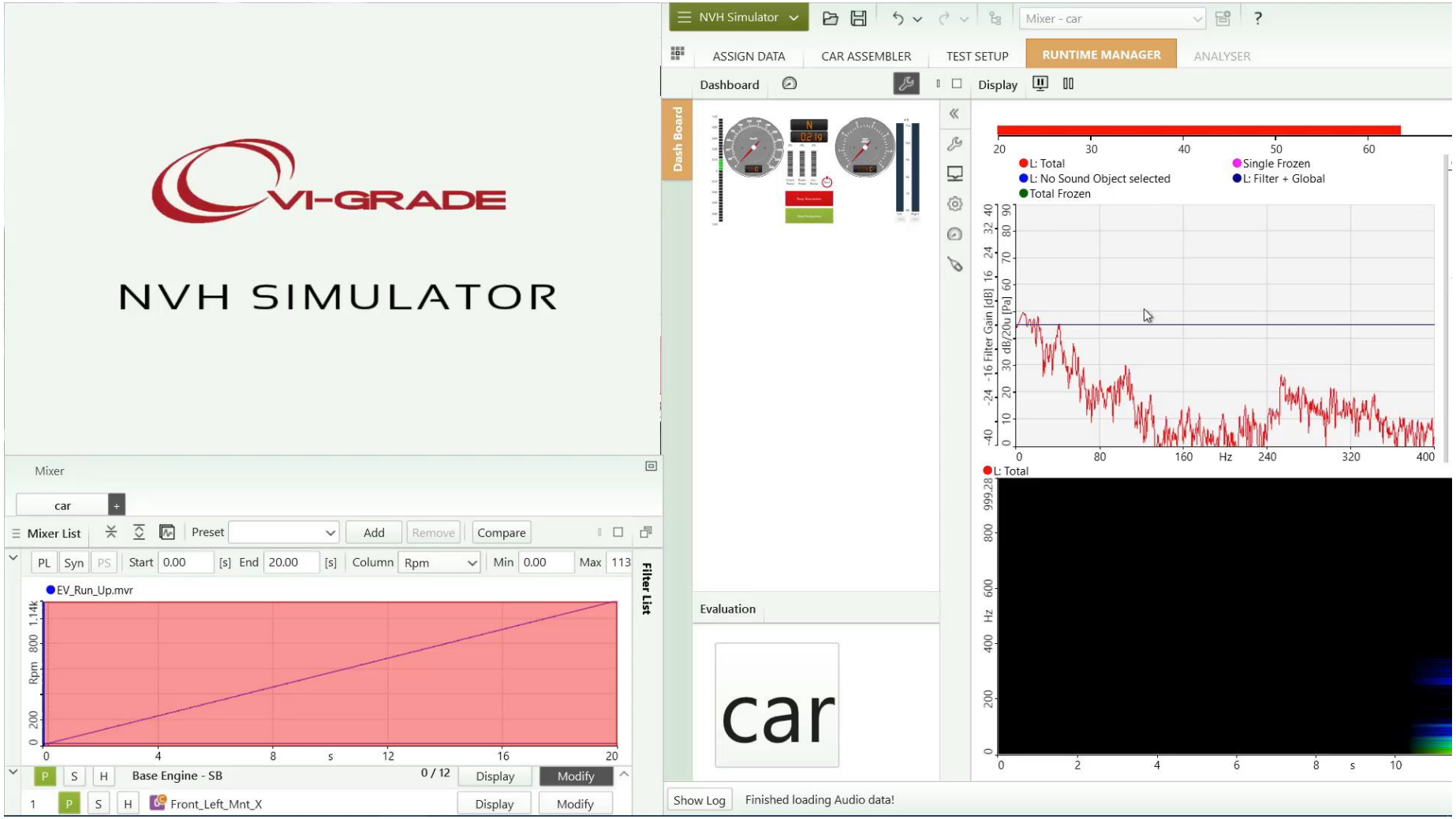


- The drive unit is excited with EM or generic forces at the stator attachments.
- A filter is created using the ratio of the sound power with encapsulation over the one without encapsulation.
- The filter is applied to Powertrain Sound Objects in the NVH Simulator

With vs. Without Encapsulation



All in All: Powertrain, Road and Wind



Conclusions

- We have presented the process we developed to simulate and auralize EV interior noise.
- With this process allowing realistic NVH evaluations early during vehicle development, OEMs are better positioned to identify the risks of NVH issue and when necessary, define and evaluate countermeasures.
- All of this is CAE-led, paving the roads towards “Zero Prototypes” vehicle development programs.

KEYSIGHT

Thank you


KEYSIGHT