

NVH DEVELOPMENT OF THE NEW FORD PUMA GEN E® UTILIZING THE VI-GRADE DESKTOP SIMULATOR

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- At **Ford's Development Center** in Cologne, the **VI-Grade NVH Desktop Simulator** has been utilized to refine several aspects of the sound quality for the **new electrified Ford Puma Gen E®**.
- This presentation demonstrates **how** the **VI-Grade NVH Desktop Simulator** has been **employed** for auralization and subjective evaluation of analytical data, thereby **reducing the need for physical prototype vehicles**.



- The **VI-Grade NVH Desktop NVH Simulator** has been **set up in 2020** in Germany.
- Several **VI-Grade Compact Simulators** are operational at **various Ford facilities**, allowing **easy sharing** of **simulator models** between different **locations**.
- A self-built **vehicle buck**, featuring a vehicle seat and the dimensions of a **Ford Kuga**, enhances immersion.
- A **multiple-headphones** playback system is utilized for group evaluations.
- **Several ICEVs** and **BEVs** have been modelled as level 1, 2 and 3 **simulator projects**.
- In recent years, the **simulator** has become a **standard tool** for virtual vehicle evaluations.



The new electrified Ford Puma:

- Front Wheel Drive with e-Motor
- Max. Power / Torque: 124kW / 290Nm
- 0-100kph: 8s
- Usable Battery Capacity: 43kWh
- WLTP-Range: 347-376 km
- WLTP-Consumption: 13,1-14,5 kWh/100 km
- 10-80% DC fast charge in 23 min
- 145l Gigabox in trunc
- Tailored active interior propulsion sound



Source: Ford.de

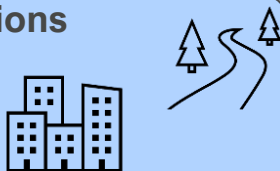


- **EVs** show **sound phenomena** which are significantly **different** to the sound of **ICEVs** and which have mostly **tonal character**, this requires special **target setting** approaches under individual operating conditions.
- For the **assessment of tonal sound** components, aspects like road/wind noise, auxiliary system noises, vehicle speed and load need to be taken into consideration as they are driving the **masking level** which is an **essential contributor** for the level of acoustic annoyance.
- The **masking level** can be derived from the **current vehicle model** while **coasting** with engine switched off.
- **Loudness, Articulation Index, Tonality, Sharpness etc.** are basic descriptions for **sound quality targets** and to define the position among the **competition**.
- However, **objective targets** are not easy to handle since the background algorithm is complex and they seem to appear “**abstract**” **sometimes**.
- The **NVH Simulator** is a useful facility to close the gap between the sound quality target development in terms of objective numbers and their **meaning** with regard to **subjective perception**.



Operating Conditions

- City Traffic
- Rural Roads
- High Speed
- ...



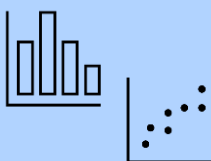
Competitor Performance

- OEM1
- OEM2
- OEM3
- ...



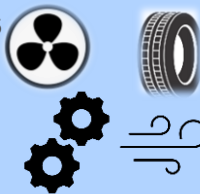
System Level Data

- Propulsion System
- Transfer Functions
- Eigenmodes
- ...



Other Sound Sources

- Road Noise
- Wind Noise
- Auxiliary Noises
- ...



Sound Quality Metrics

- Loudness
- Articulation Index
- Sharpness
- ...



Image Source: VI-Grade

Vehicle & System SQ Targets Set

- City Traffic
- Rural Roads
- High Speed
- A/C on/off
- X"/Y"/Z" Tires
- Drive Mode Definition
- Electric Sound Enhancement
- ...
- ...
- Objective Metrics
- Subjective Alignment



Input Data & Sound Quality Metrics

Objective-Subjective Target Iterations

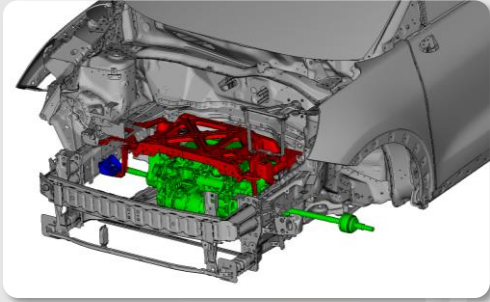
Sound Quality Targets Set

PREDICTING THE E-DRIVE ORDER LEVELS



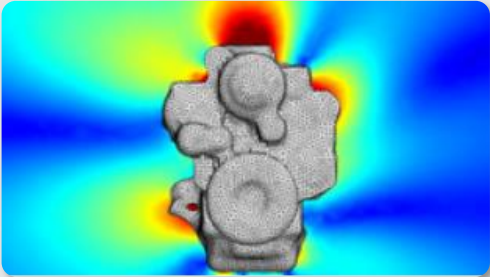
From traditional FE-based CAE model or measurements

S/B
Excitation



Radiated noise from BEM models or measurements

A/B
Excitation



Source: [Hexagon](#)

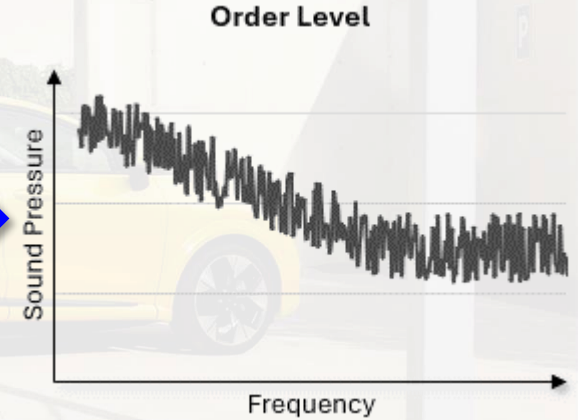
Set of transfer functions between excitation DOFs and Interior microphone position

Transfer
Functions

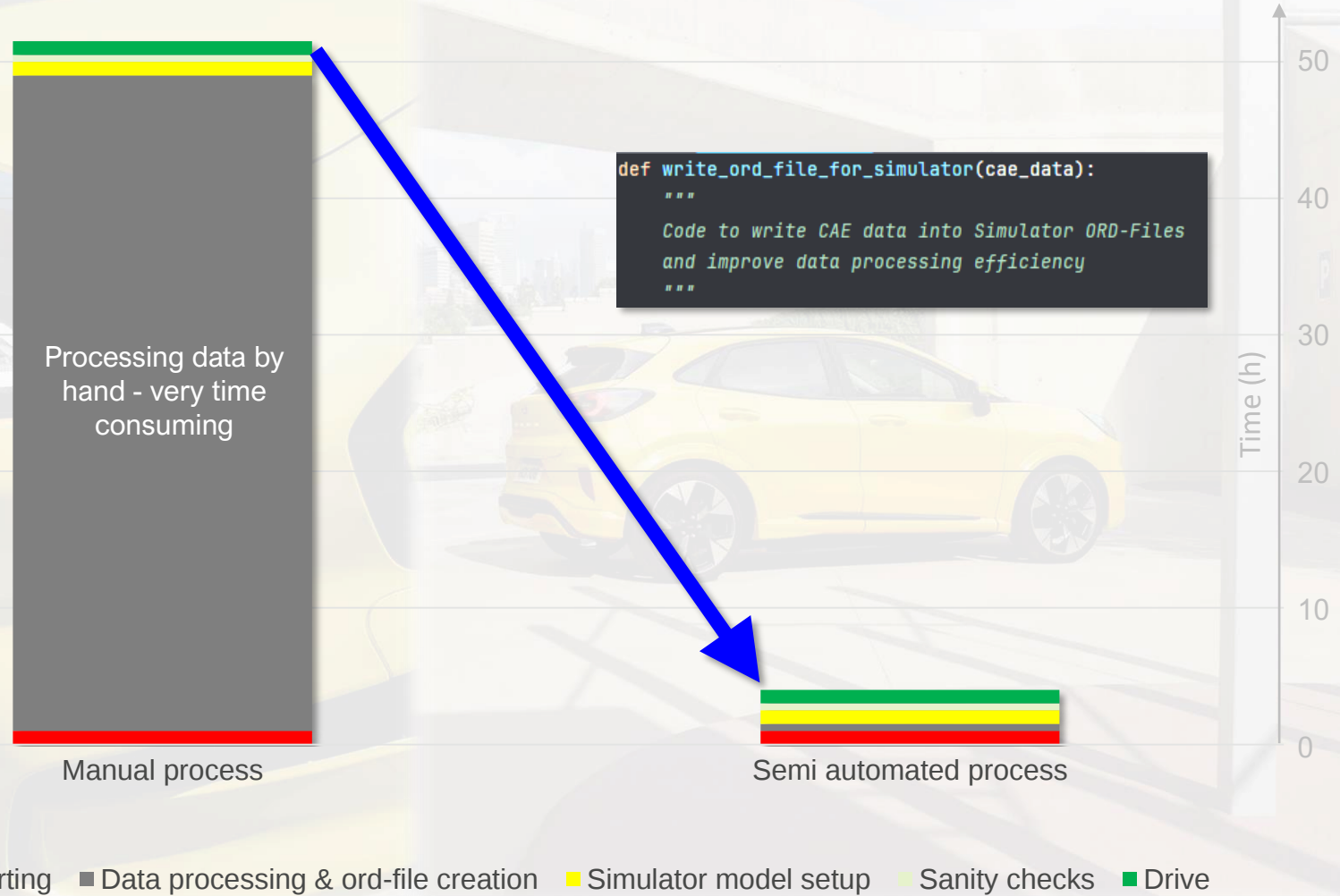
$$H(\omega)$$

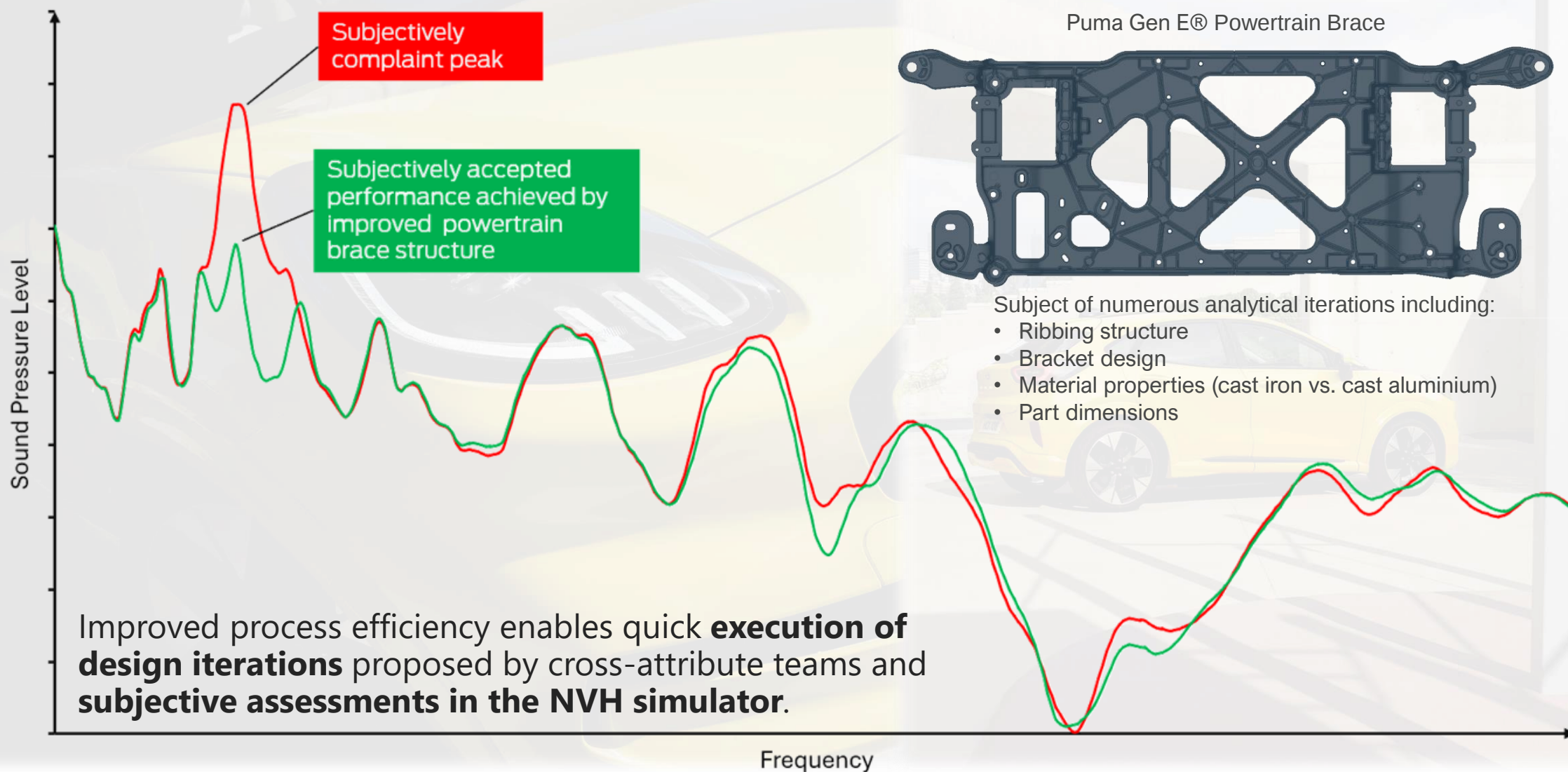
Prediction of e-drive order levels by setting up a Transfer Path Analysis (TPA) Model

TPA-Model



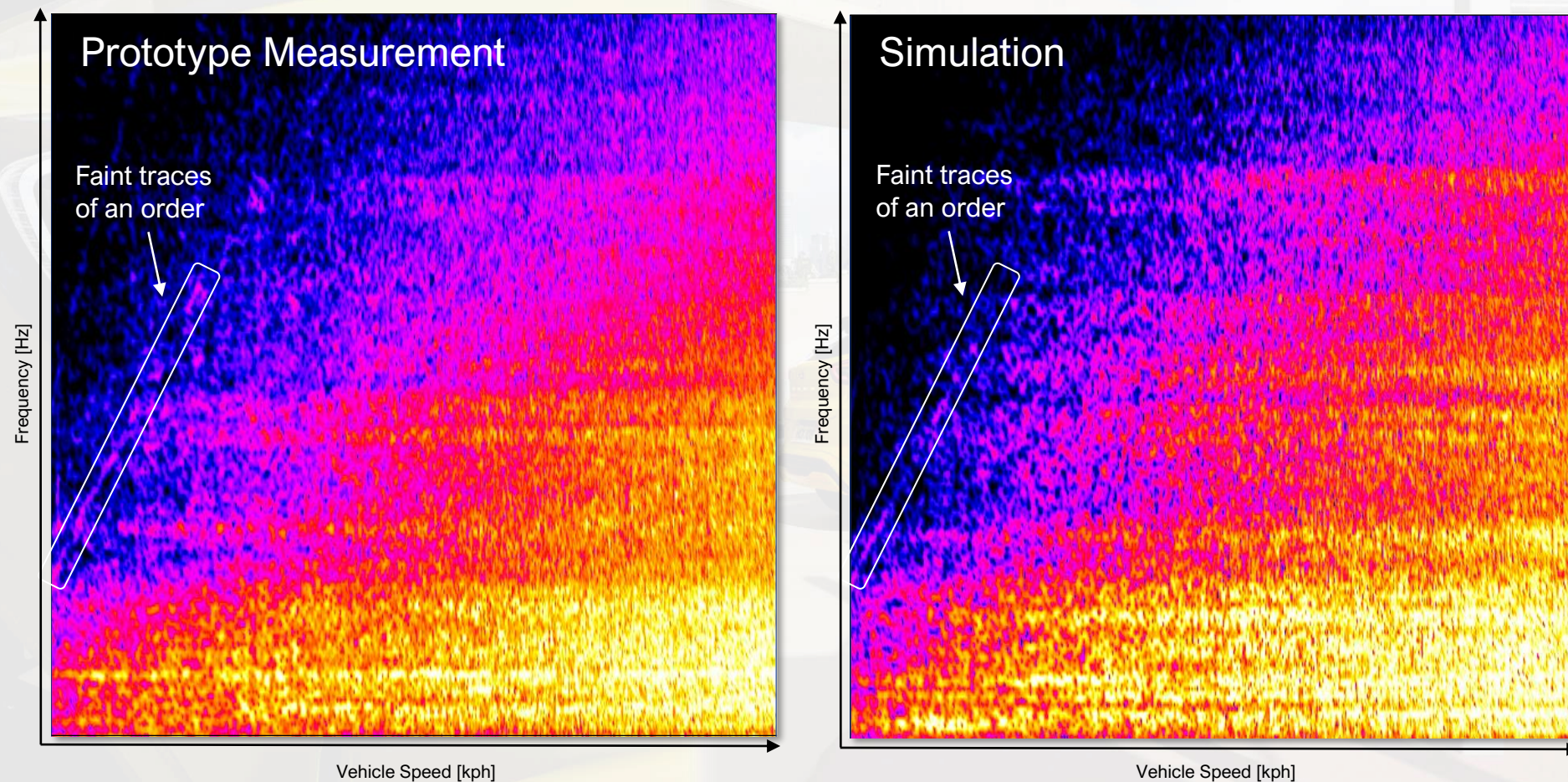
- Delivering significant **efficiency improvements** by partially **automating** the simulator model **data processing**.
- **Improved timing** enables same-day simulator drives and subjective assessments, supporting **quick management decisions**.





Spectrograms of a Wide Open Pedal Vehicle Acceleration

- **Motor-whine performance** finally **within targets**. Just slightly audible at low speeds and high vehicle accelerations.
- Overall **satisfying correlation** between prototype tests and simulator data. CAE-data matches overall trend very well

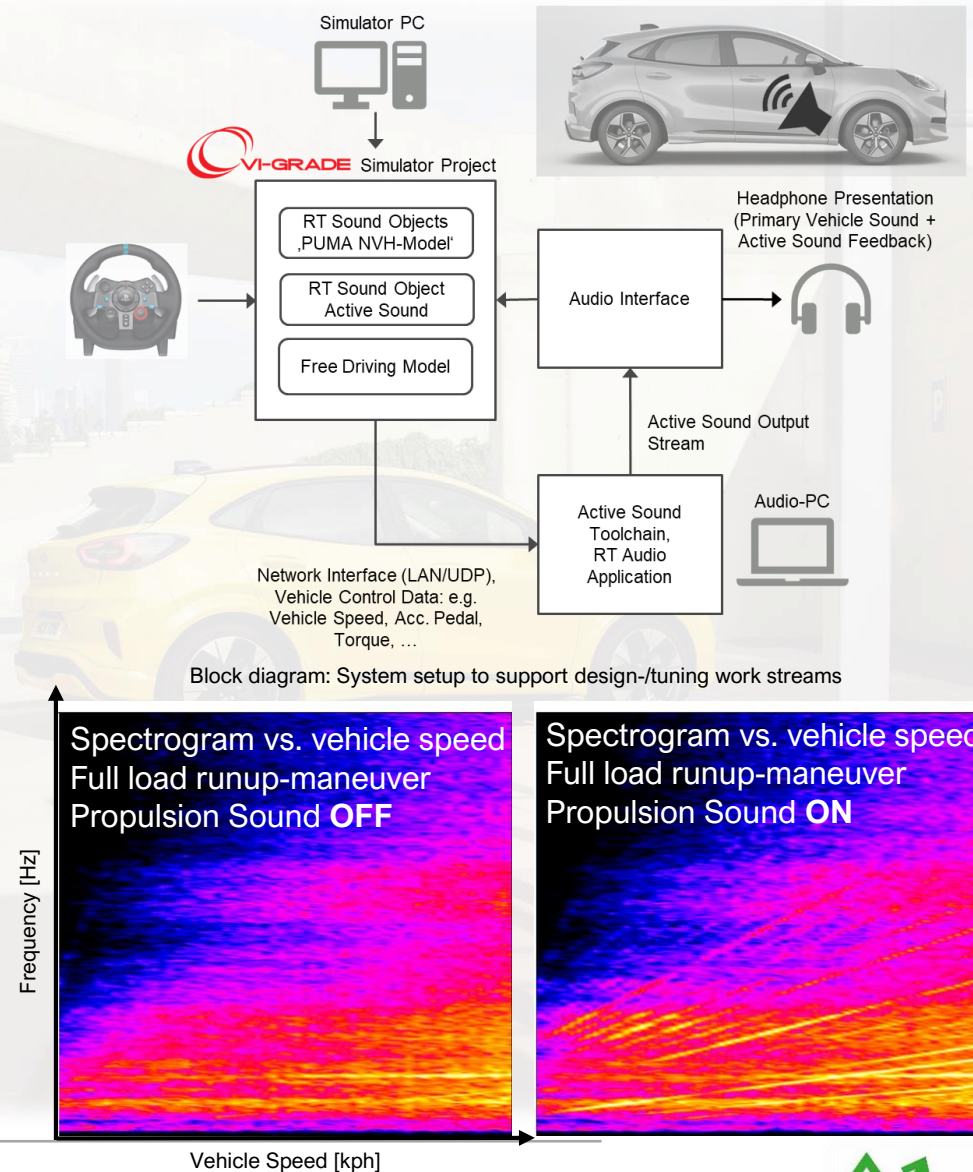


ACTIVE PROPULSION SOUND DESIGN WITH SIMULATOR MODEL



- Goal was to **develop** an **appealing target** sound to improve the driving experience by means of a sporty **‘fun to drive’ sound feedback** and to attract ICE-customers towards BEV products.
- In the early program phase, several **design proposals** with differing sound elements have been **evaluated by the Ford management-team and customers** to find the most preferable sound design. Here, the **simulator** environment was heavily **used for sound prototyping** and for **clinics** (cp. ‘Block diagram: System Setup...’).
- Rather **traditional sound elements** (PUMA ‘ICE-heritage’) and more **modern elements** have been selected and been **combined** in the final sound design.
- The preferred **sound design** was then further **refined** using the simulator setup; tuning robustness and vehicle complexity was further **verified on pre-production units** (‘production release’-calibration files).

→ 75% of the sound design has been developed in the simulator environment. The final tuning and verification work has been done on physical prototypes (pre-production vehicles).



- The **number of use cases** for the NVH Simulator is **increasing** over time, including:
 - ✓ ICE – Propulsion NVH
 - ✓ BEV – Propulsion NVH
 - ✓ Active Propulsion Sound Design (EVSE)
 - ✓ Acoustic Vehicle Alerting Systems (AVAS)
 - ✓ Accessory-NVH-Refinement
- This year, a **new VI-Grade Compact NVH Simulator** has been **established** at the Cologne Development Center to support even more use cases, **including calibrated vibration** playback.





Thank you for
your attention!