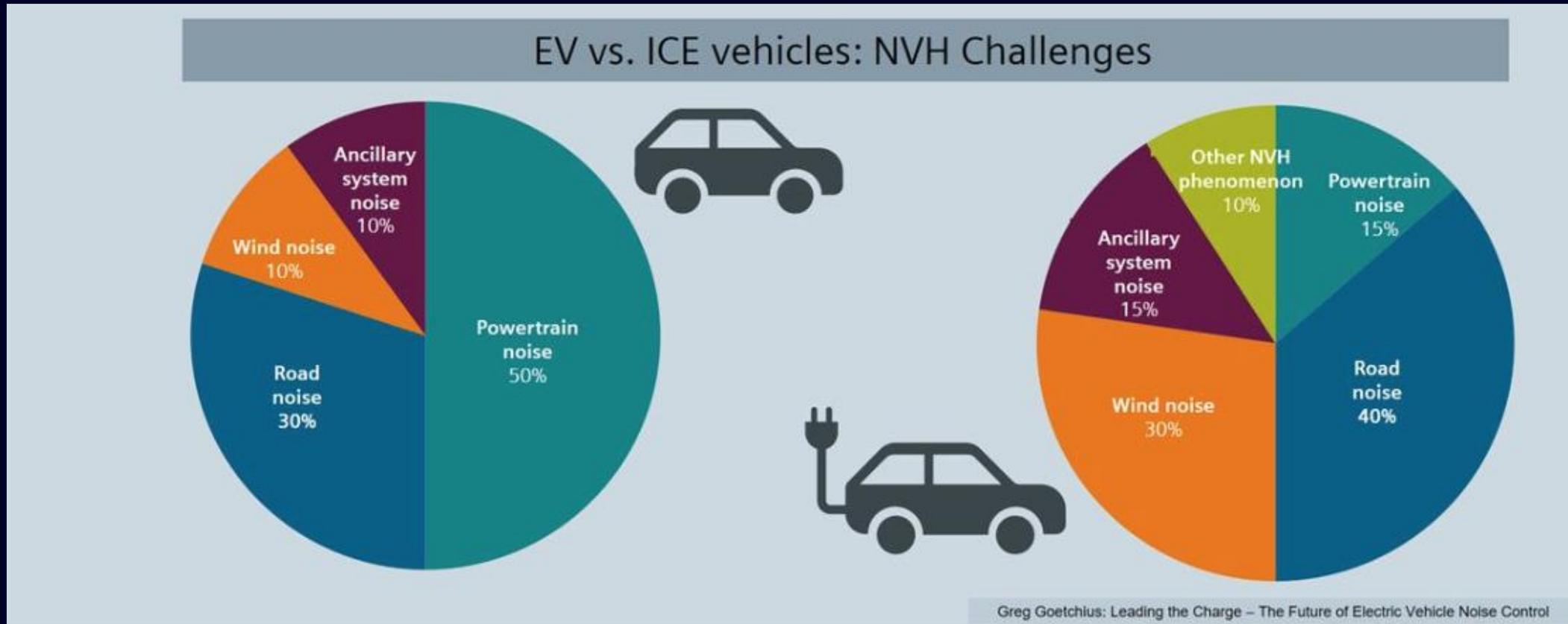


# Siemens Acoustic Wind Tunnel Testing

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Simulation and Test Division

## Shift towards increased effort to reduce wind noise

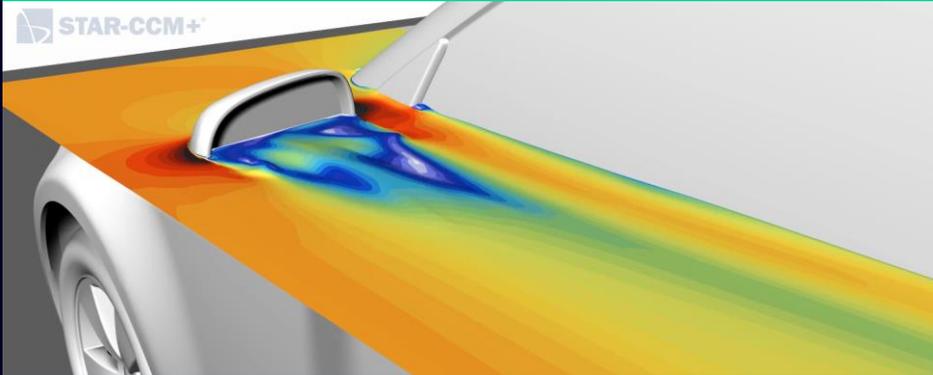


Reduction of wind noise is highly increasing in importance with new cars  
Leading to increased need of wind noise testing & simulation

# How to reduce wind noise? Use Simcenter Test & Simulation

Concept validation & iteration through  
**simulation before** prototypes

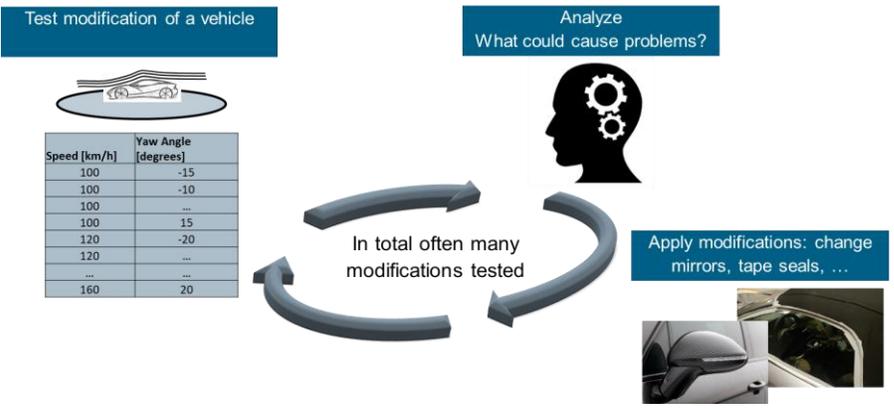
- ✓ CFD simulation (STAR CCM+)
- ✓ Vibro-Acoustic Simulations (Simcenter 3D)



- ✓ **Calculation intensive**  
(> 1 week for 1 case)
- ✓ Limited in **max frequencies**, no leak identifications

Perform most wind noise optimizations through  
**efficient wind tunnel testing** once prototype available

- ✓ View interior & exterior aero-acoustic pressure through acoustic arrays
- ✓ Implemented in automated way showing real-time results



8 hours of testing  
> 200-300 measurement iterations

Siemens testing solution enables:

- ✓ **Immediate comparisons** (immediate results)
- ✓ **Interactive** optimizations/solving on the spot

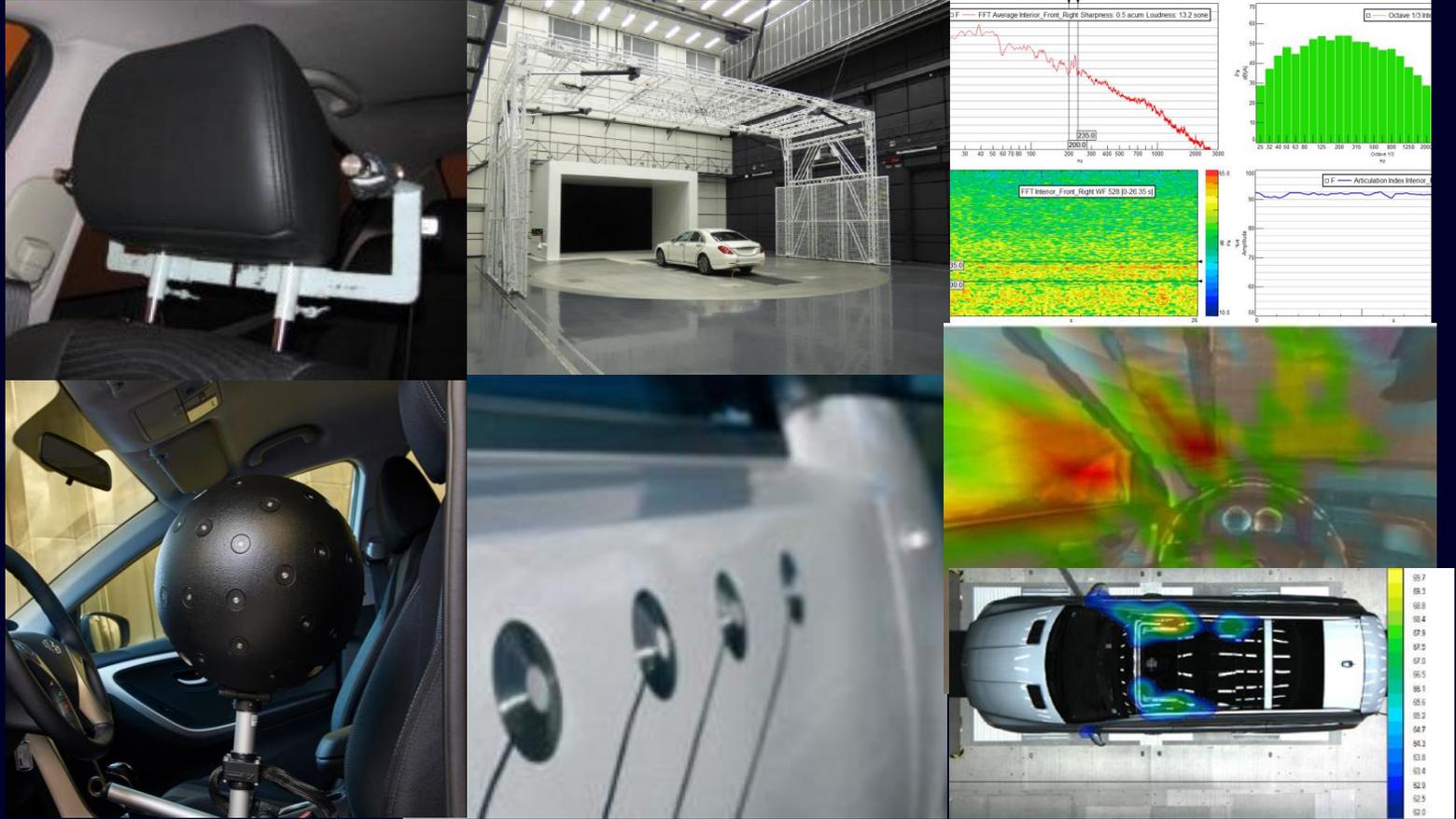
# Goals of the campaign

Driver and passenger comfort

Ventilation noise

External noise

Downforce/Drag values

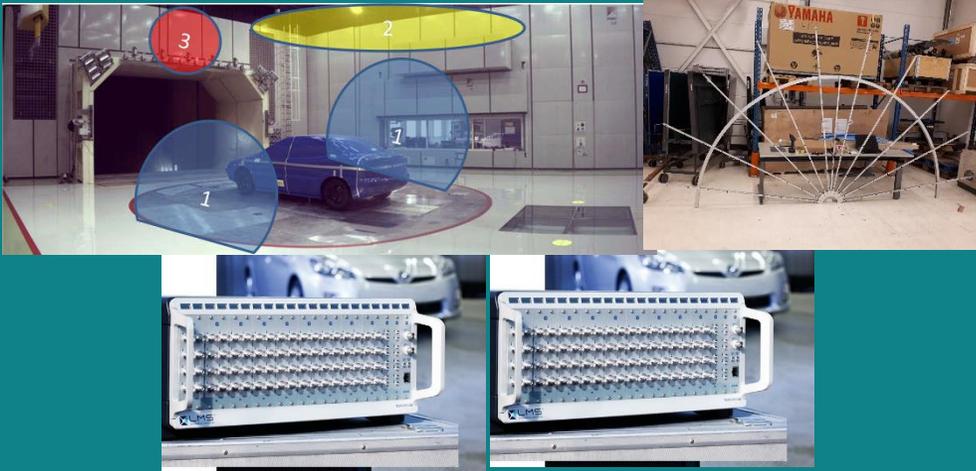


# Siemens Experimental setup

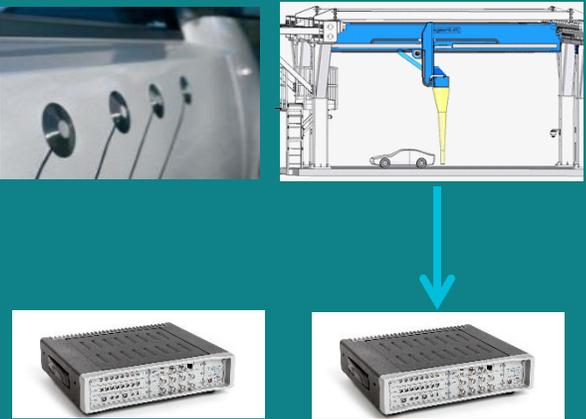
In vehicle



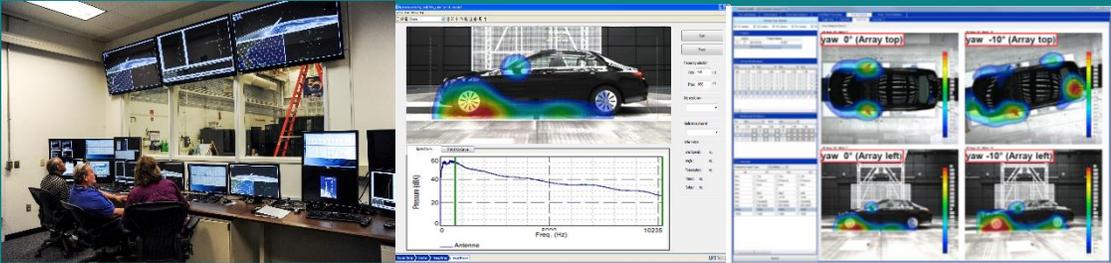
4 exterior Arrays



Turntable & Traverse



Wind tunnel control room



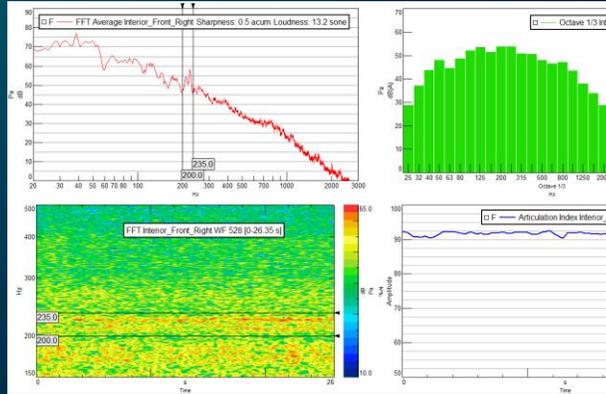
Online and offline Analysis system

- Integrated with wind tunnel controller
- Automatic processing
- View & analyze processed results in 10 seconds
- Data management

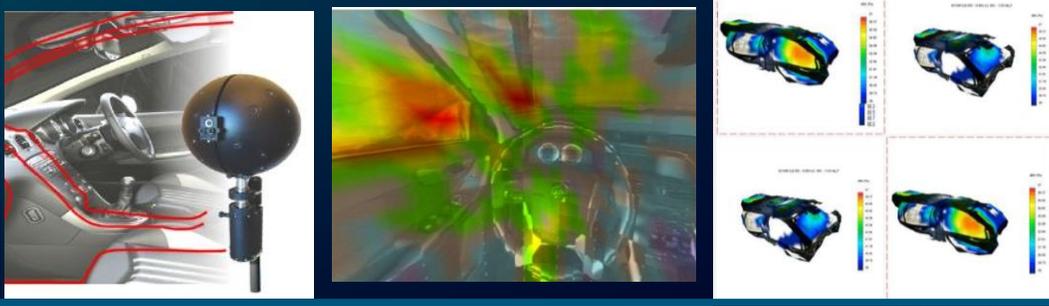
# Overview of aero-acoustic testing technologies

## Interior wind noise measurements

### Direct interior measurements



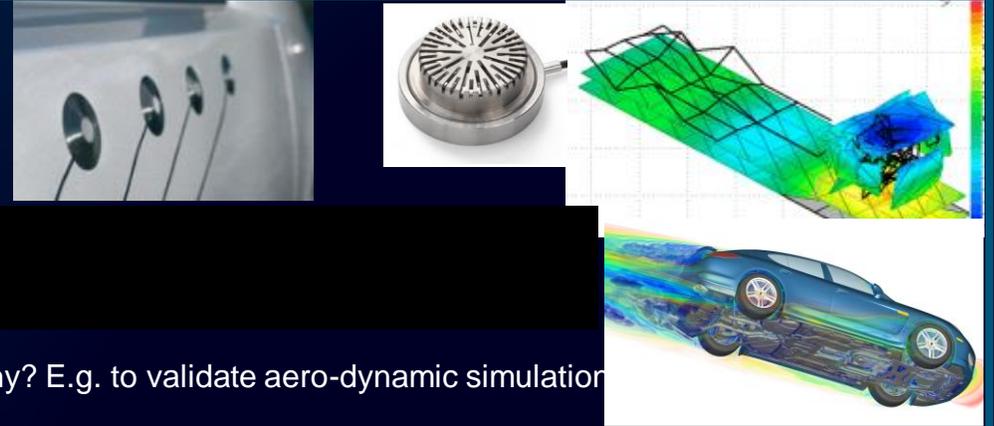
### Interior Sound Source Localization



S  
C  
A  
L  
A  
B  
L  
E

## Exterior source identification

### Direct Exterior Measurements



Why? E.g. to validate aero-dynamic simulation

### Acoustic Arrays for Source estimation



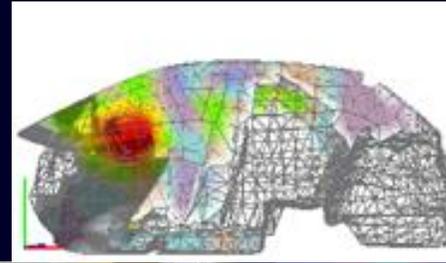
# Noise source localization and leak detection inside the vehicle

## Simcenter 3D Acoustic Camera



### Geometry scanning

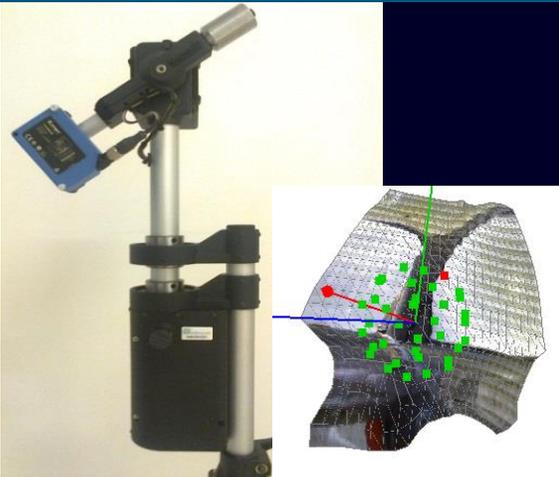
Locate and propagate sources on the **correct location**



**Efficient batch processing & comparison of datasets**, e.g. different frequencies, yaw angle, wind speed, ...

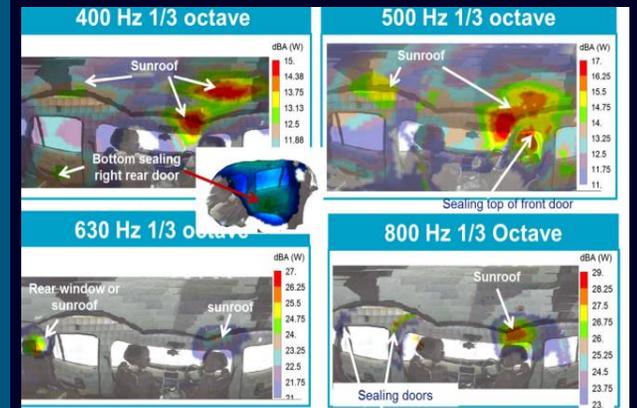
### Solid sphere with 54 microphones

Provides best-in-class results with **supreme directivity & dynamic range**

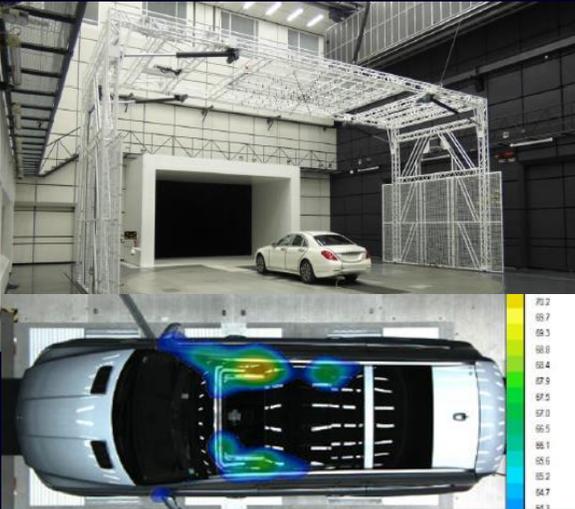


Additional post-processing with ESM & Bayesian Focalization for low frequency

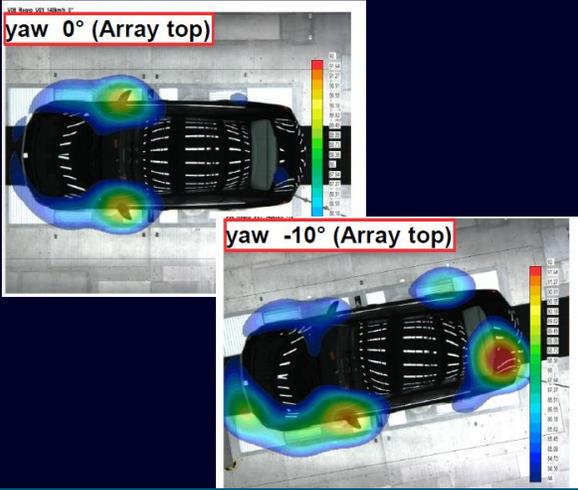
**Accurate results over wide frequency range**



# Exterior source localization by means of acoustic arrays



Standard & customized arrays



Enabled comparison of different side mirrors, splitters

Identification of pressure distribution around the vehicle by means of combination of multiple arrays



Wind speed & Yaw angle automatically taken into account

No Risks to make mistakes later



# Exterior source localization by means of acoustic arrays

Original



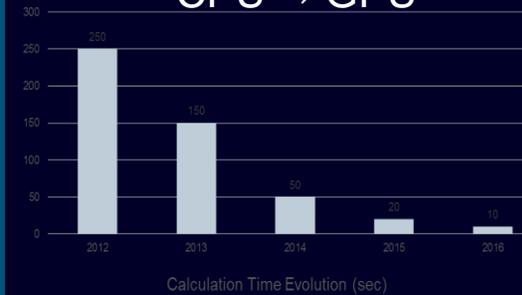
Coherence with left ear



Propagation on **plane surface** or **full 3D**

**Able to test multiple geometry configurations**

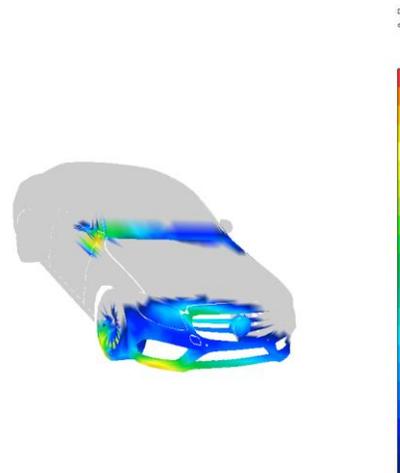
Evolution calculation speeds  
CPU → GPU



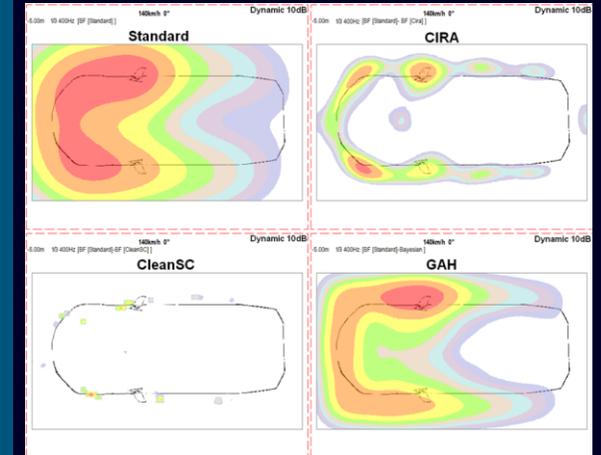
**Additional post-processing**

**Increased performance & wide frequencies**

**Coherence analysis with interior, e.g. drivers ear but also 3D Camera**

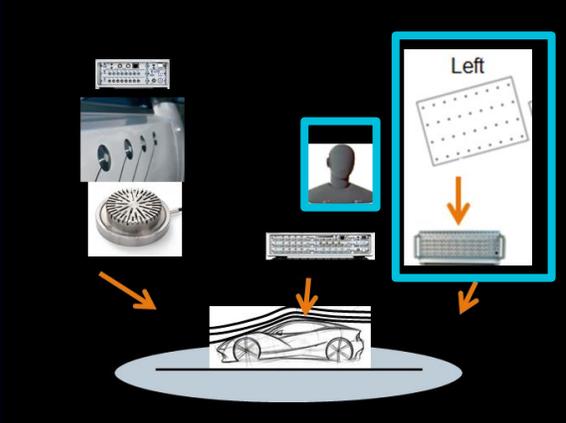


**Able to batch process locally or in cloud**

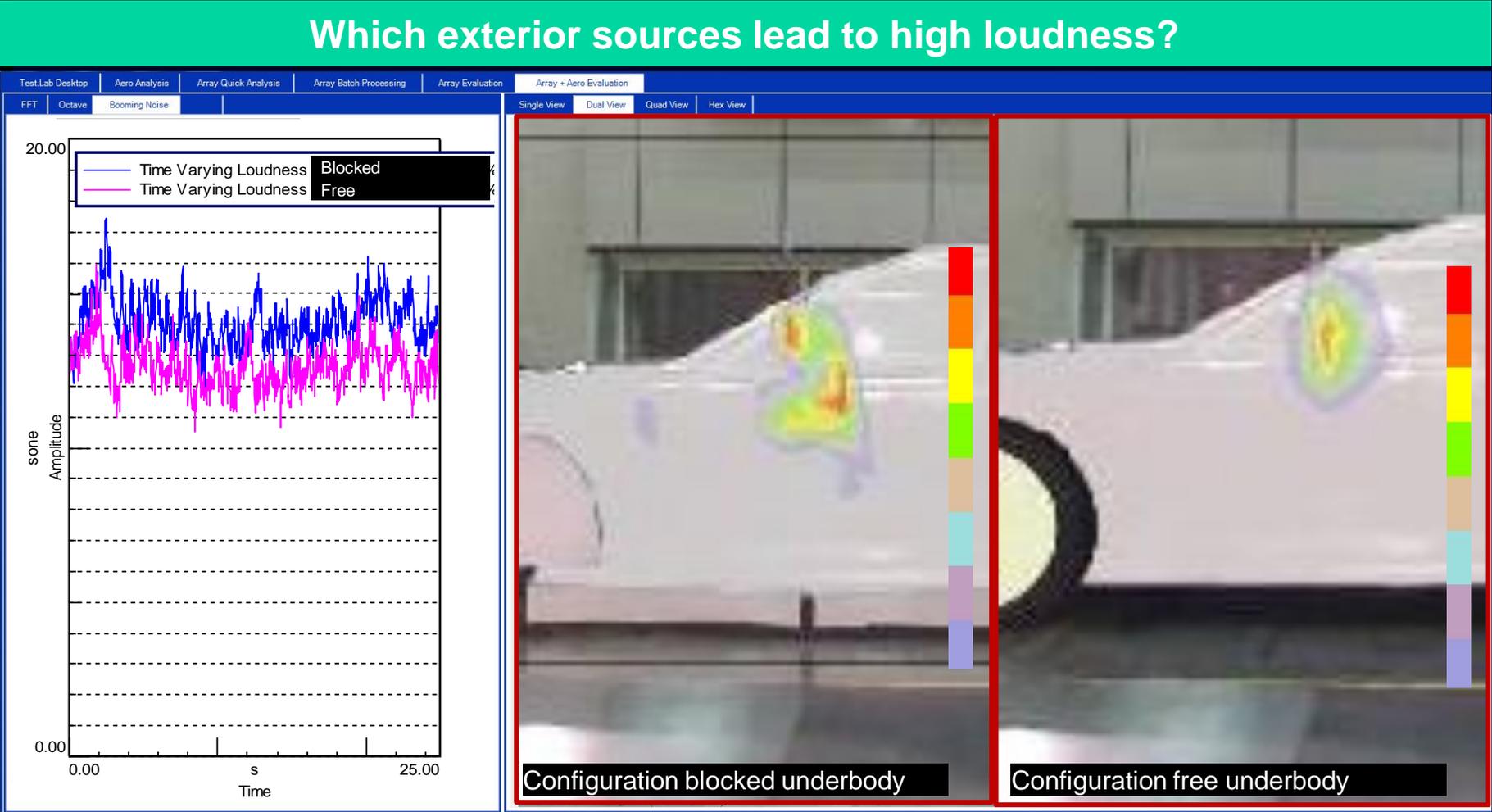


# Value of fully integrated solution – Example 1

## Link binaural head with exterior array by viewing together

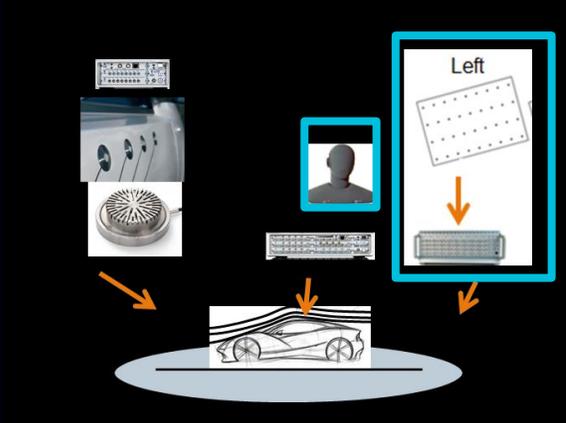


Efficient viewing and comparing results from different techniques together on one screen gives additional insight

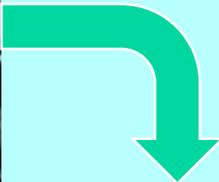


# Value of fully integrated solution – Example 2

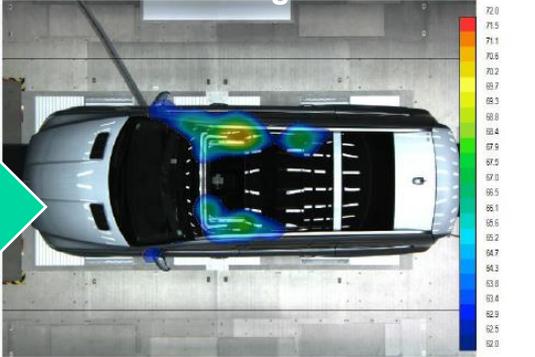
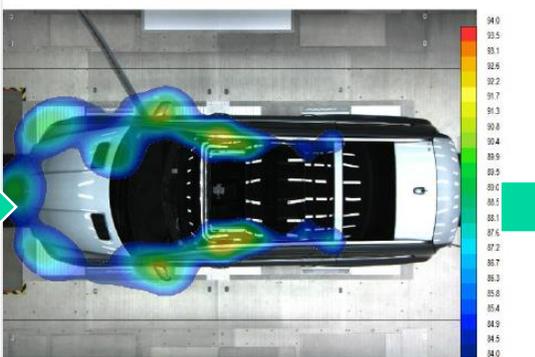
## Link binaural head with exterior array by coherence analysis



Which external source is important for driver's left ear?



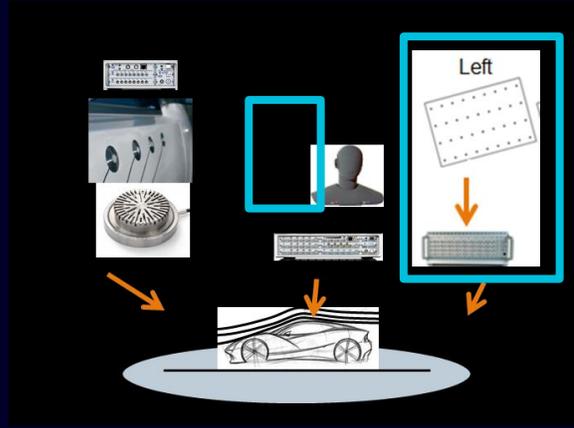
Coherence analysis allows to focus on sources for interior noise



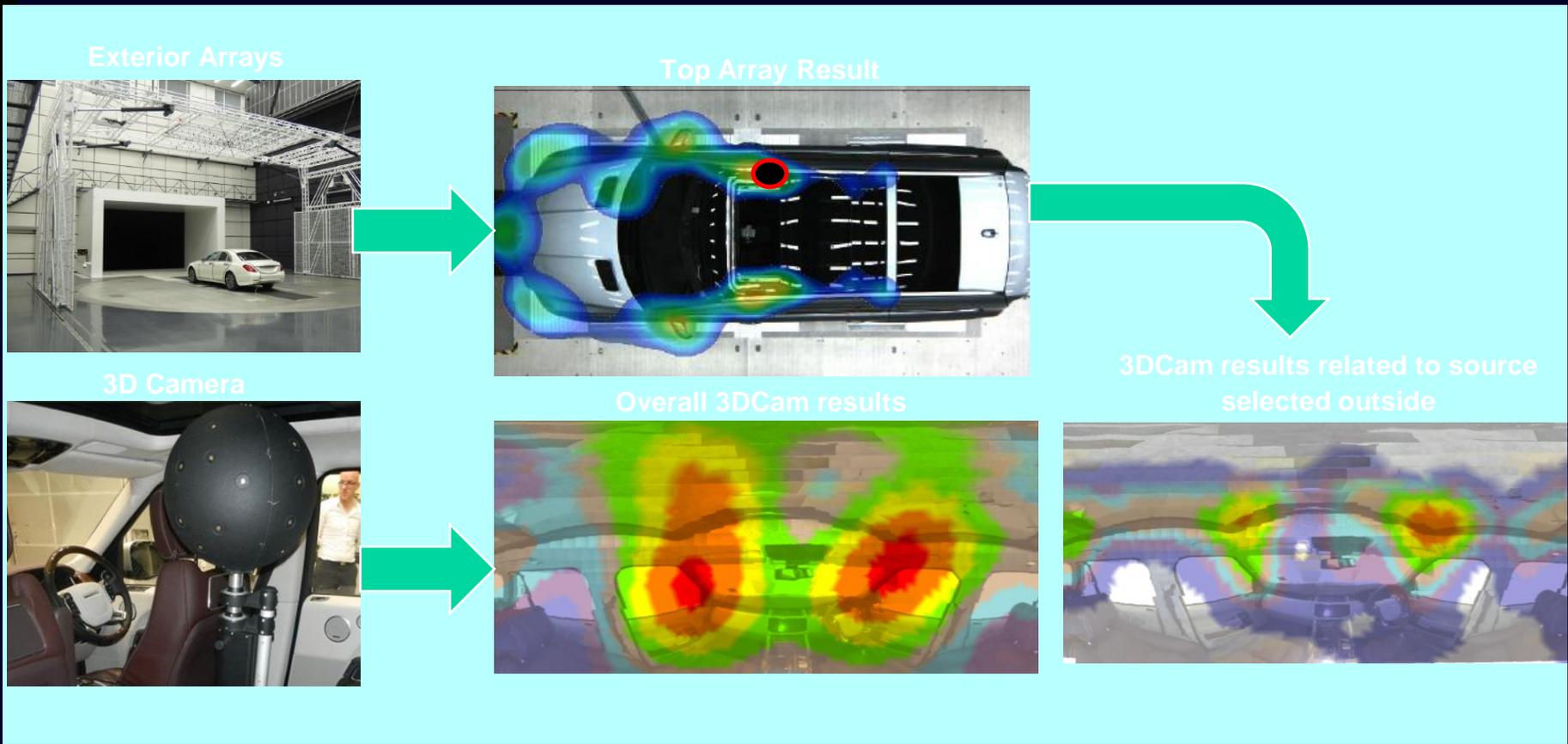
Top Array Result correlated to driver's right ear

# Value of fully integrated solution – Example 3

## Link 3D Cam with exterior array by coherence analysis



### Energy flow analysis - Where does an external source leak into the vehicle?



Coherence analysis between interior and exterior array allow energy flow analysis

# How to drastically increase testing efficiency?

## Allow easy comparison between processed datasets with only few clicks

Selection of data to be viewed with only few clicks & Easy comparison of results

The screenshot displays the Siemens AeroAcoustics software interface. On the left, there are four callout boxes pointing to specific UI elements: 'Projects / Vehicles' (pointing to the Project list), 'Vehicle Modifications' (pointing to the modification grid), 'Test conditions (windspeed, yaw angle)' (pointing to the Windtunnel Conditions section), and 'Processing: Array Method Reference ch Frequency band ...' (pointing to the Channels section). The main area shows four delta plots of a car model, each with a color scale. Callout boxes above the plots describe features: 'Delta plot', 'Up to 6 fully independent displays', 'Per display or common display settings', 'Spectrum point selection', and 'Data or image export for reporting'.

- Correlation and compare all channels
- Allows to decide what modifications to test next
- Enabled in-test configuration

## Campaign Summary

1

Partner company achieved noise reduction targets in a shorter time

2

Significantly reduced costs in the WT (€240k to €30k)

3

Reduced product development time