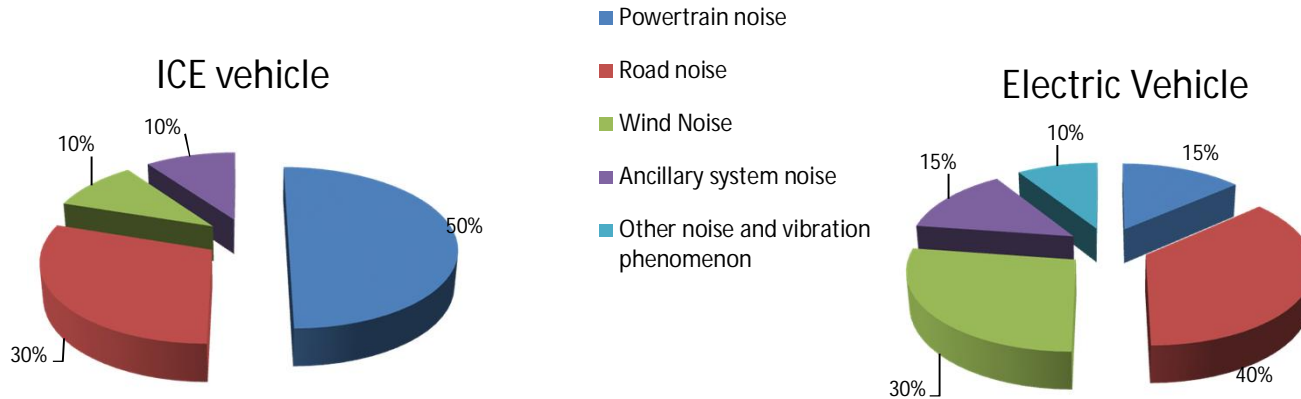


# Essentials of vehicle aero-acoustics testing

# Why?



Source: *Leading the Charge – The Future of Electric Vehicle Noise Control*, Greg Goetchius, *Sound & Vibration*, April 2011

**Shift engineering efforts to road and wind noise reduction**

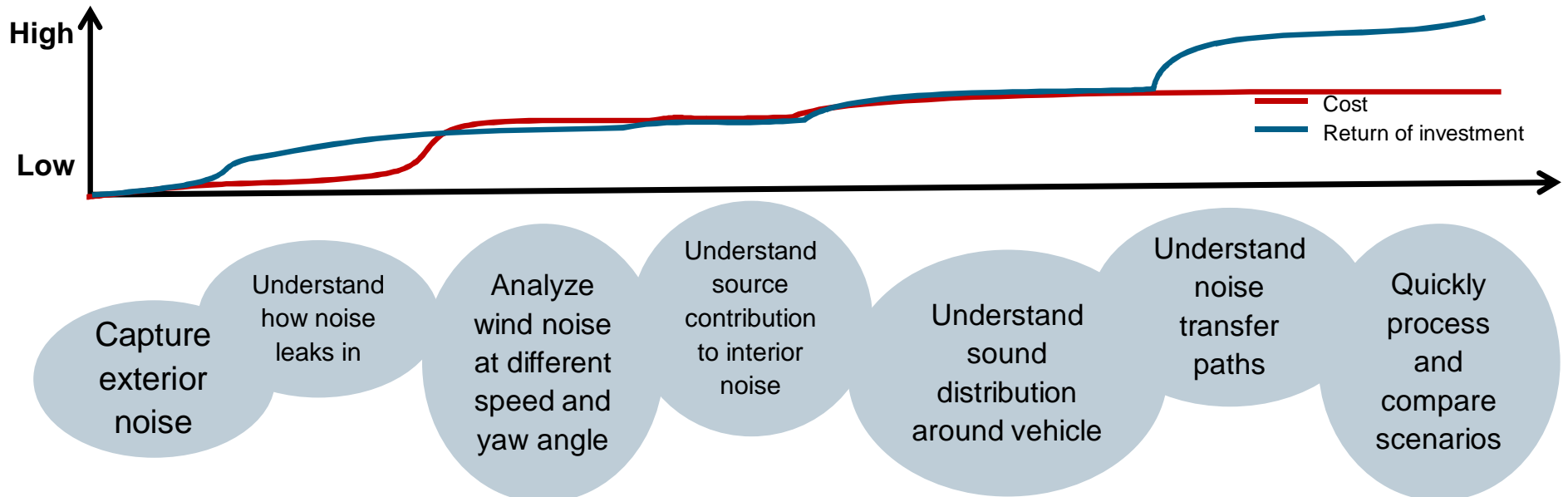
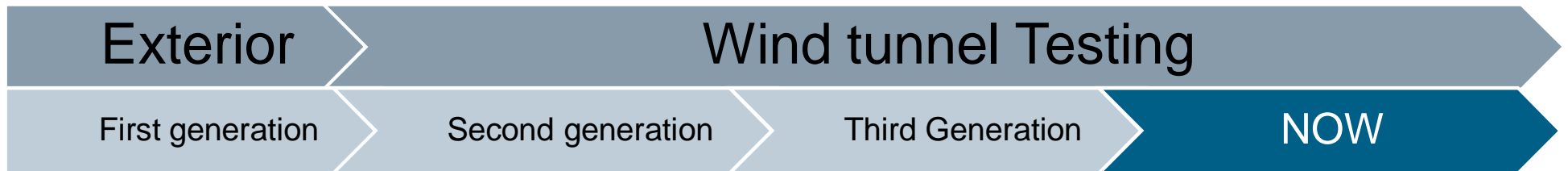
## New investments in aero-acoustic testing

**SIEMENS**  
*Ingenuity for life*



Picture: courtesy of Daimler

# Evolution towards the next generation aero-acoustic testing



## Essentials of aero-acoustic testing

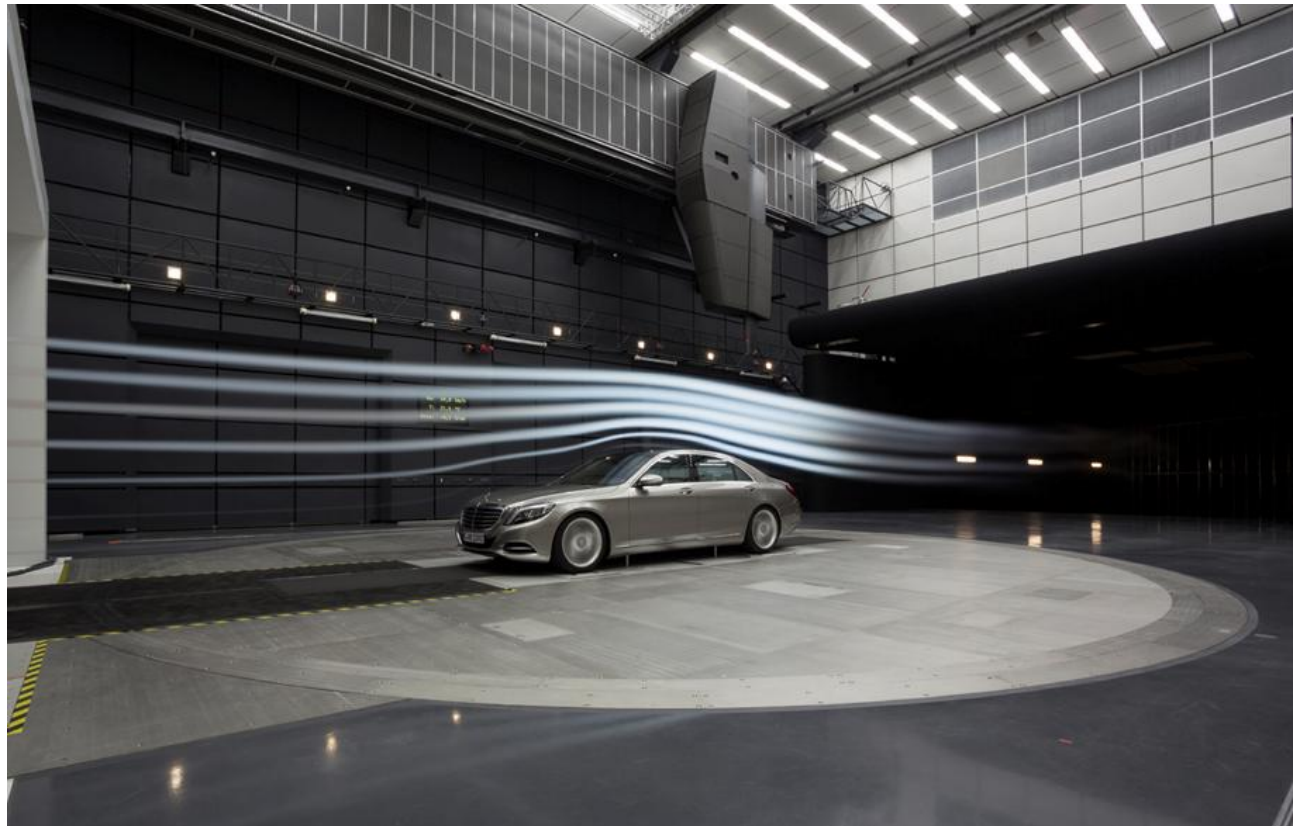
**SIEMENS**  
*Ingenuity for life*

**Understand aero-acoustic testing technologies**

**Combine all into one integrated solution**

**Get the maximum out of your test campaign**

**Work with a trusted partner**



# Essentials of aero-acoustic testing

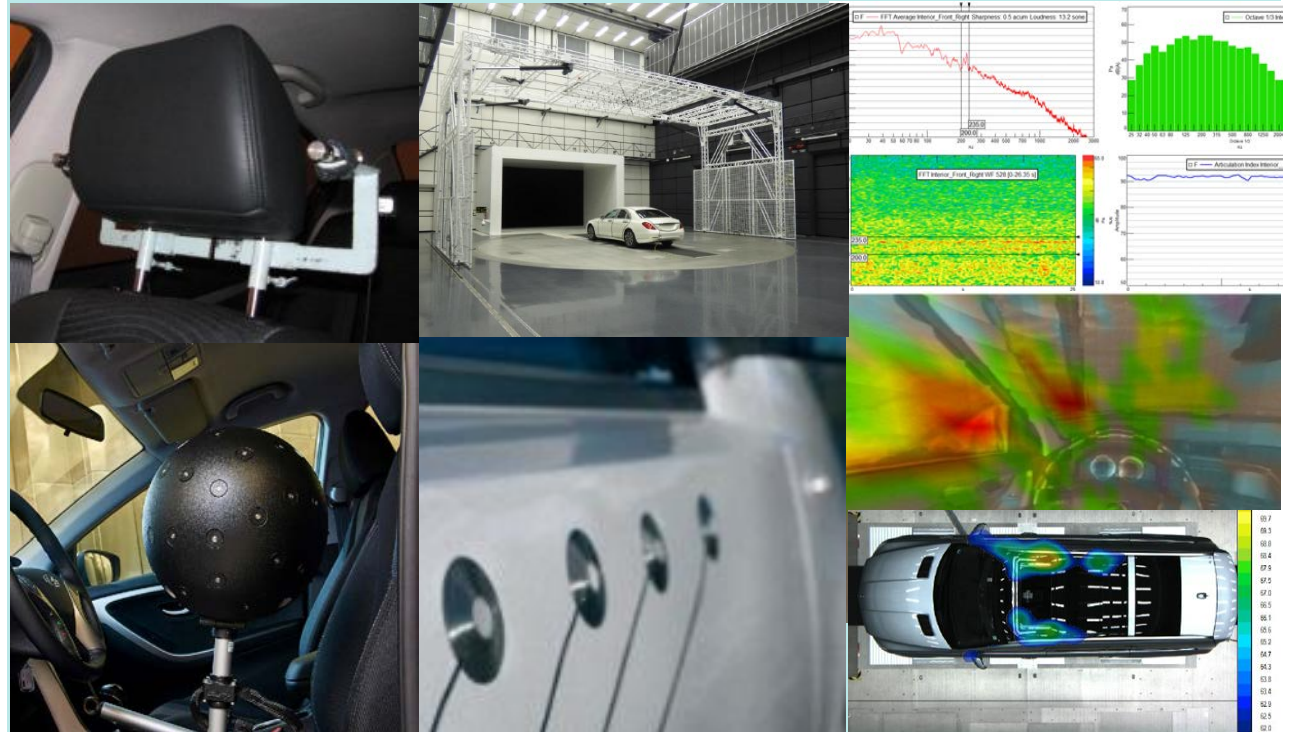
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# Overview of aero-acoustic testing technologies

## Interior wind noise measurements

### Direct interior measurements

This section illustrates direct interior measurements. It includes two photographs showing microphone placement inside a car cabin. Accompanying graphs include: an FFT Average Intensity plot (Frequency [Hz] vs. Intensity [dB]), an Octave 1/3 octave bar chart (Frequency [Hz] vs. Intensity [dB]), an FFT Intensity spectrogram (Frequency [Hz] vs. Time [s]), and an Articulation Index Interior plot (Frequency [Hz] vs. Articulation Index).

### Interior sound source localization

This section illustrates interior sound source localization. It features a photograph of a microphone array and several 3D visualizations of sound field localization within a car interior, showing intensity distributions on the seats and dashboard.

S  
C  
A  
L  
A  
B  
L  
E

## Exterior source identification

### Direct exterior measurements

This section illustrates direct exterior measurements. It includes photographs of microphones and air vents. A 3D visualization shows a car with a sound field distribution, highlighting areas of high intensity around the vehicle.

### Acoustic arrays for source estimation

This section illustrates acoustic arrays for source estimation. It features a photograph of a car in a wind tunnel and several 3D visualizations of acoustic arrays and source estimation results, showing intensity distributions on the car's exterior.

# Overview of aero-acoustic testing technologies

## Interior wind noise measurements

### Direct interior measurements

This section illustrates direct interior measurements. It includes two photographs showing microphone placement in a car's front and rear seats. Accompanying graphs include: a line graph titled 'FFT Average Intensity, Front, Right Sharpness: 0.5 acam Loudness: 13.2 sone' showing intensity vs. frequency; a bar chart titled 'Octave 1/3 Hz' showing intensity across frequency bands; a spectrogram titled 'FFT Intensity, Front, Right Wt: 120 (0-20, 20-)' showing intensity over time and frequency; and a line graph titled 'Articulation Index Interior' showing the articulation index vs. frequency.

### Interior sound source localization

This section illustrates interior sound source localization. It features a photograph of a microphone and a photograph of a car interior with heatmaps overlaid on the seats and dashboard, indicating sound source locations. To the right, four small 3D car models show localized sound sources in different areas of the interior.

S  
C  
A  
L  
A  
B  
L  
E

## Exterior source identification

### Direct exterior measurements

This section illustrates direct exterior measurements. It includes a photograph of microphones mounted on a car's exterior, a photograph of a circular grille, and a photograph of a car with heatmaps overlaid on its exterior, indicating sound source locations. A 3D model of a car's exterior is also shown with a color-coded sound intensity map.

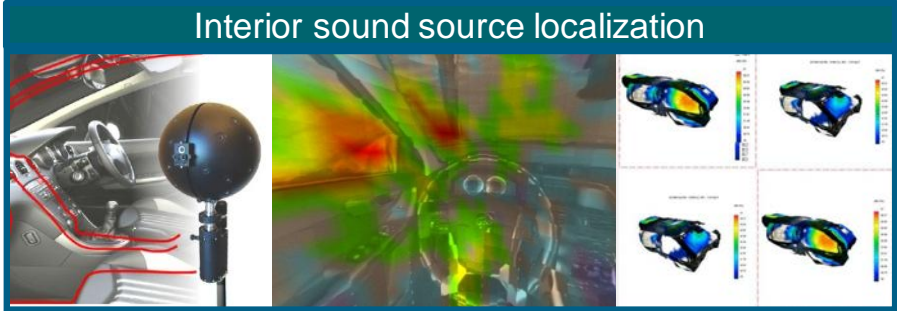
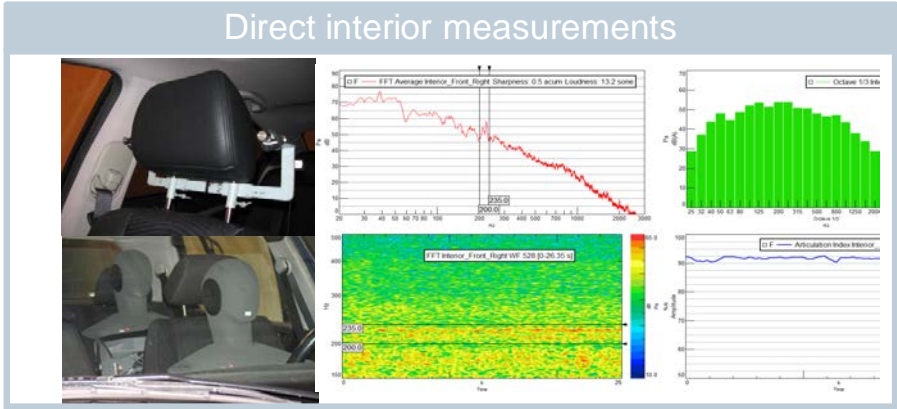
### Acoustic arrays for source estimation

This section illustrates acoustic arrays for source estimation. It features a photograph of a car in a wind tunnel with an acoustic array positioned around it. To the right, a 3D model of a car shows heatmaps overlaid on its exterior, indicating sound source locations.



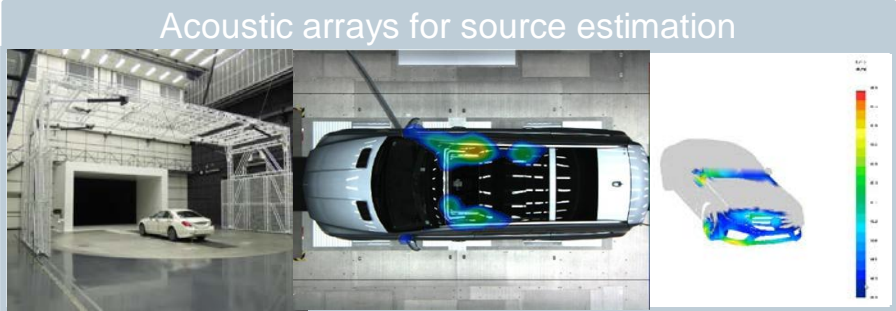
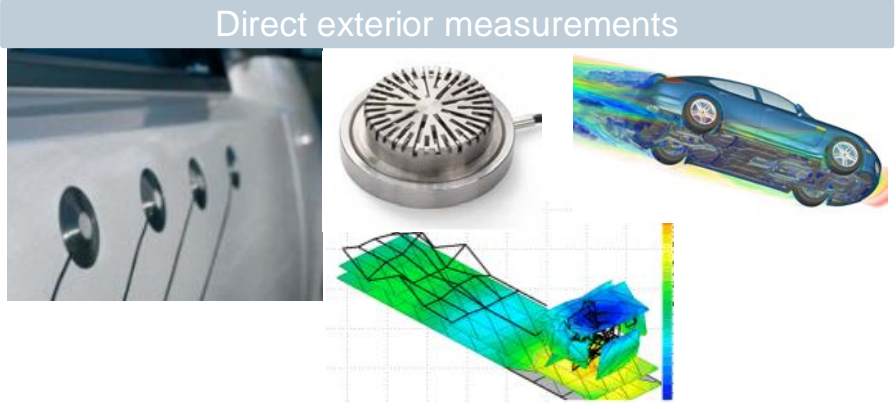
# Overview of aero-acoustic testing technologies

## Interior wind noise measurements



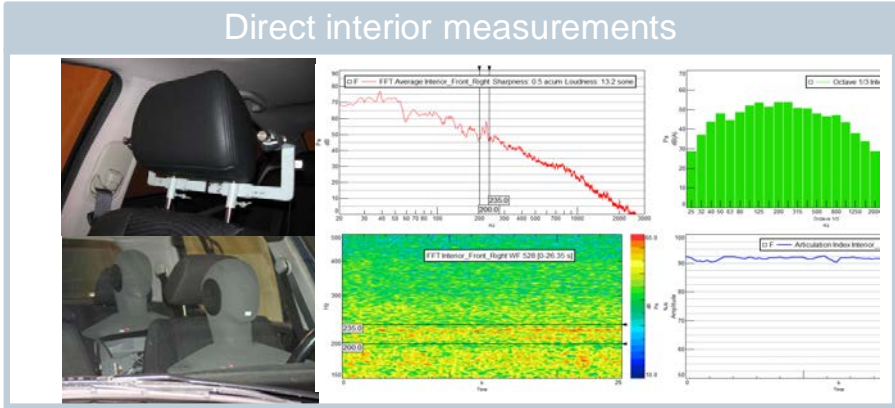
S  
C  
A  
L  
A  
B  
L  
E

## Exterior source identification



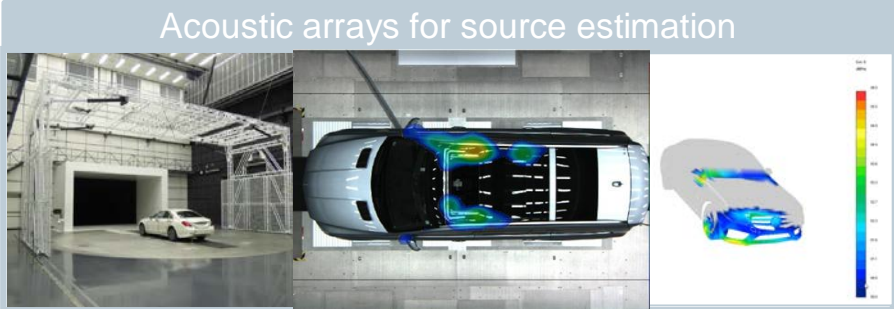
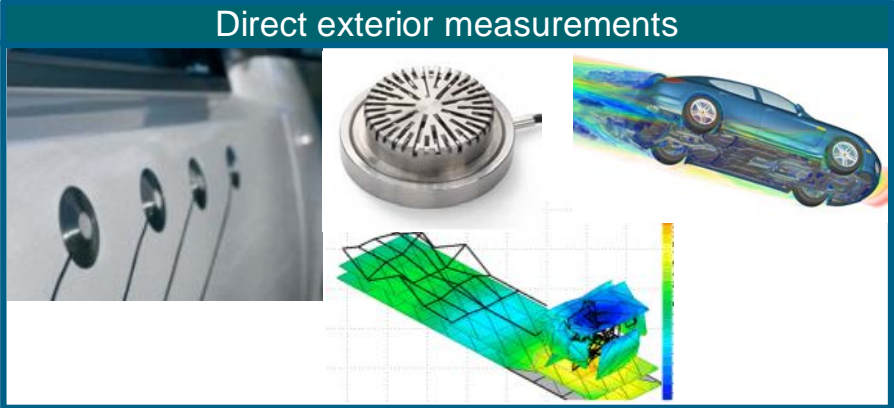
# Overview of aero-acoustic testing technologies

## Interior wind noise measurements



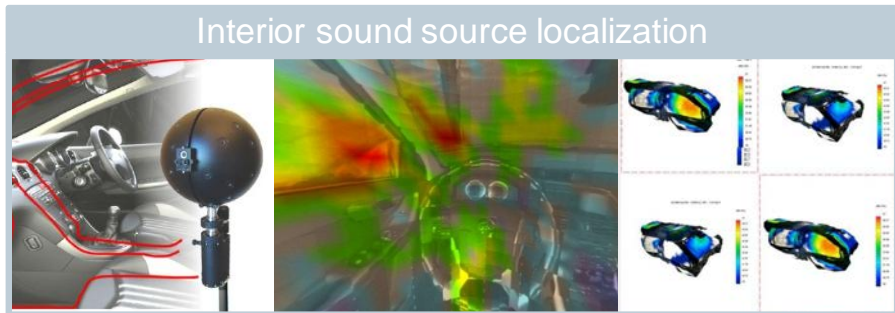
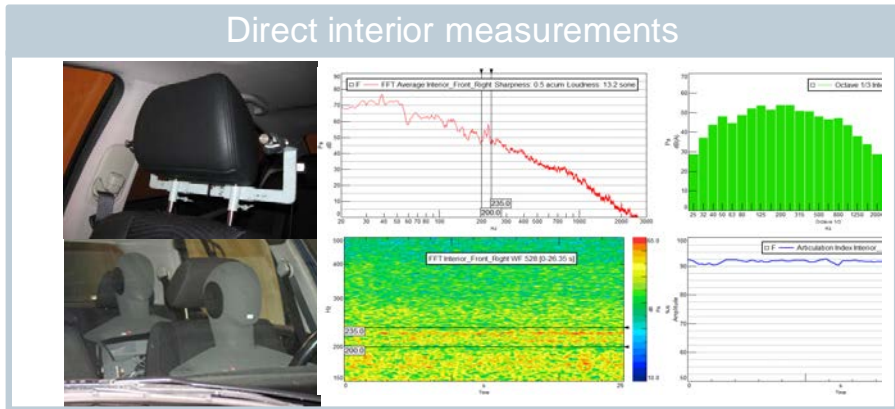
S  
C  
A  
L  
A  
B  
L  
E

## Exterior source identification



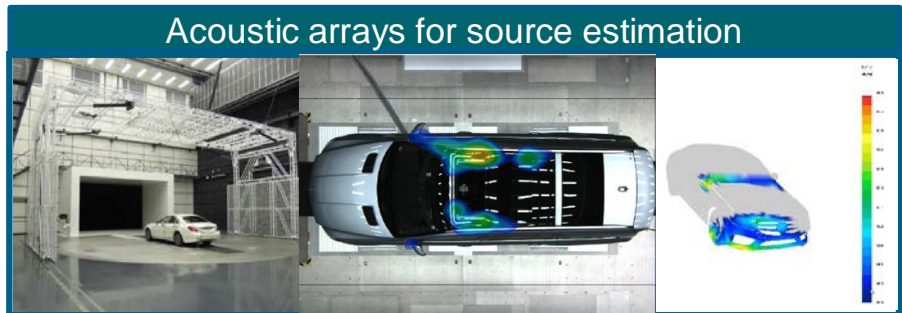
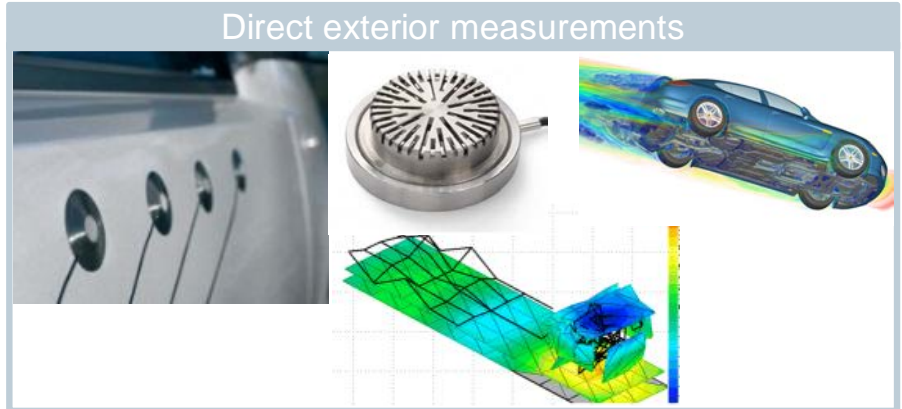
# Overview of aero-acoustic testing technologies

## Interior wind noise measurements



S  
C  
A  
L  
A  
B  
L  
E

## Exterior source identification



## Essentials of aero-acoustic testing

**SIEMENS**  
*Ingenuity for life*

**Understand aero-acoustic testing technologies**

**Combine all into one integrated solution**

**Get maximum out of your test campaign**

**Work with a trusted partner**

**Getting maximum out of all used methods by having access to best technology**

## Essentials of aero-acoustic testing

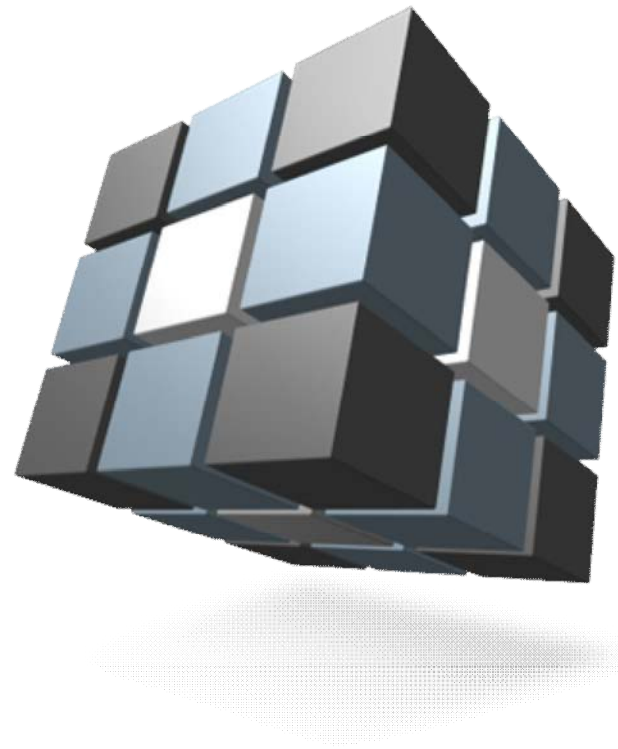
**SIEMENS**  
*Ingenuity for life*

Understand aero-acoustic testing technologies

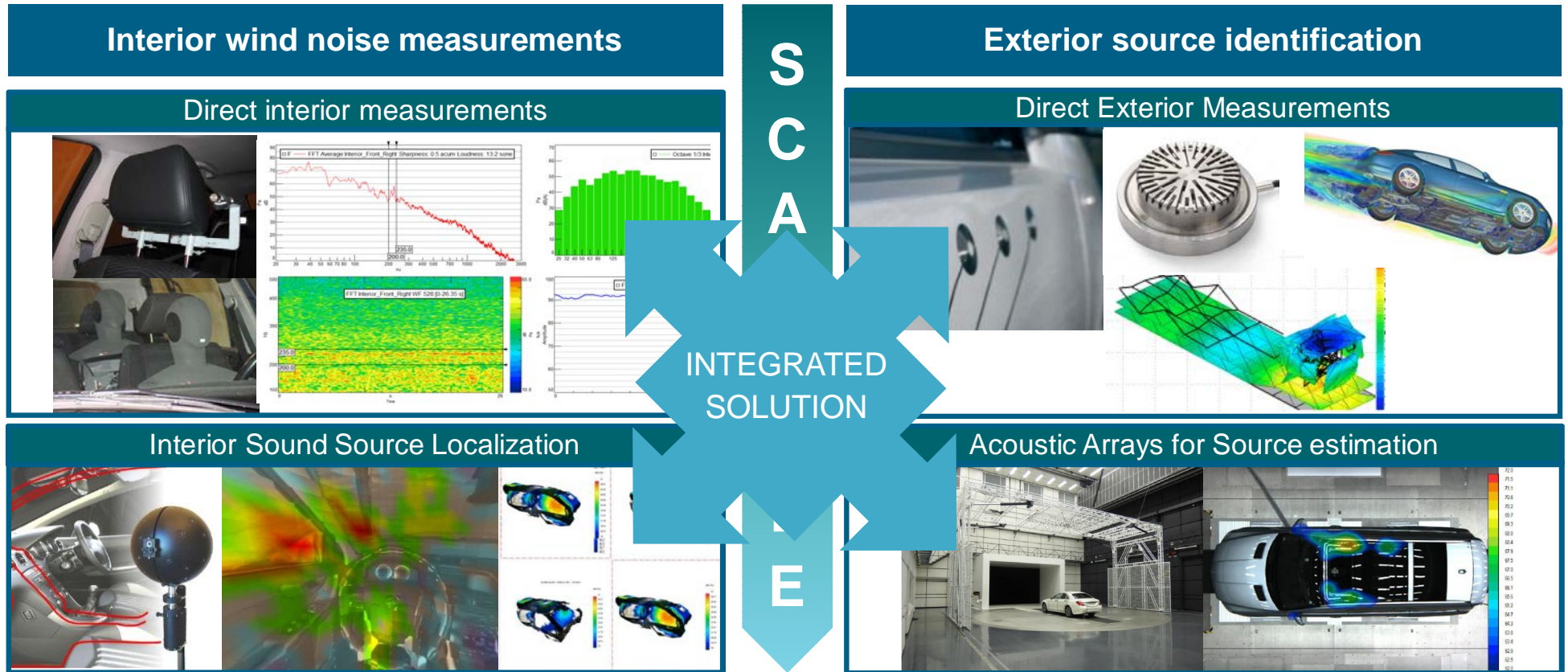
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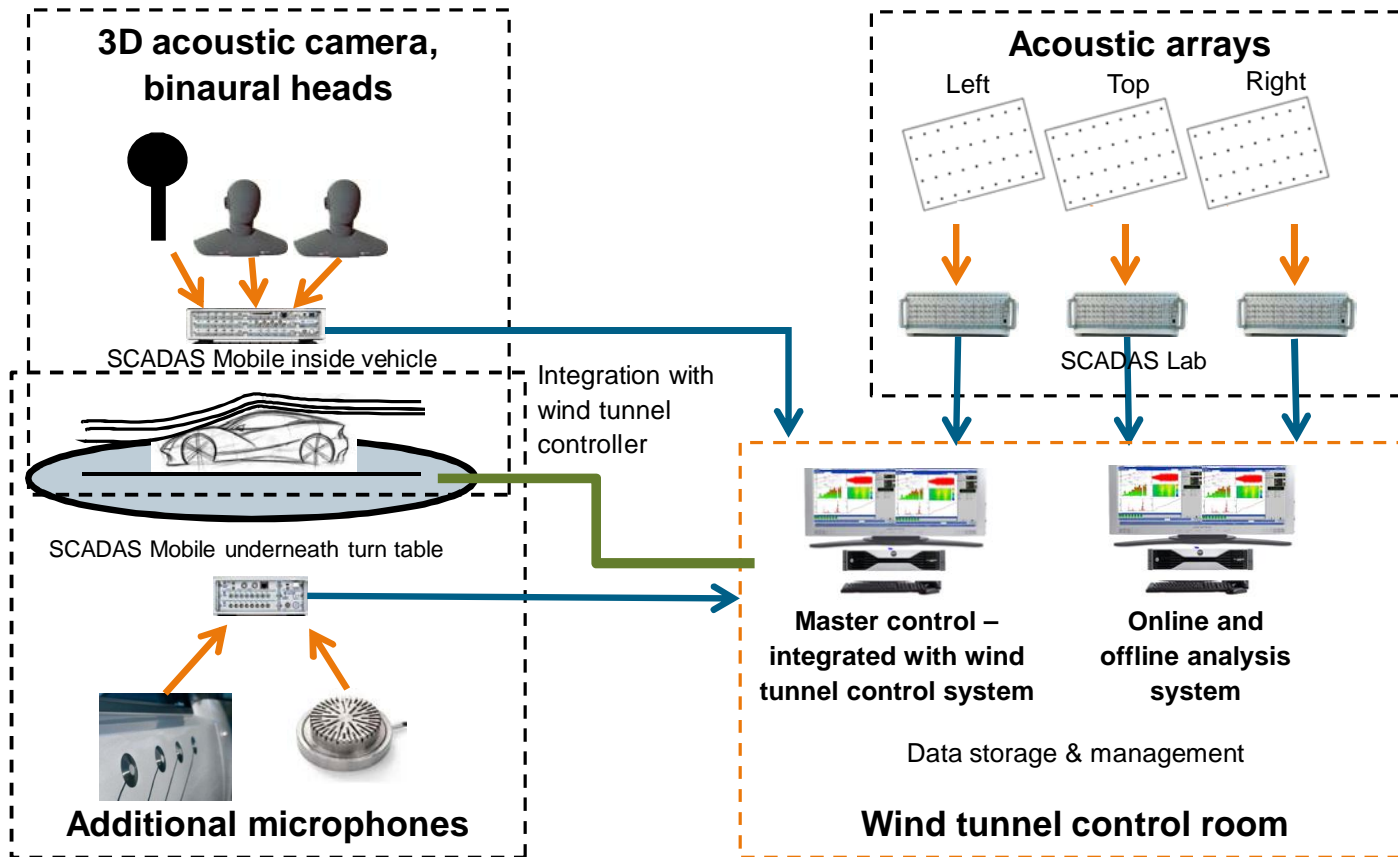


# Overview of aero-acoustic testing technologies



**Integrated -**  
means that data is measured simultaneously, fully synchronized

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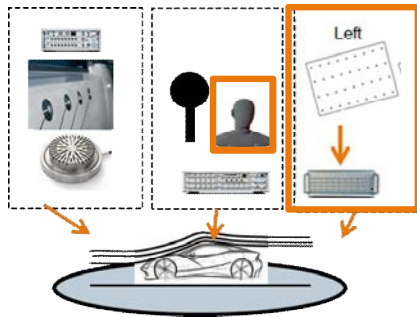
# What is the value of an integrated solution?



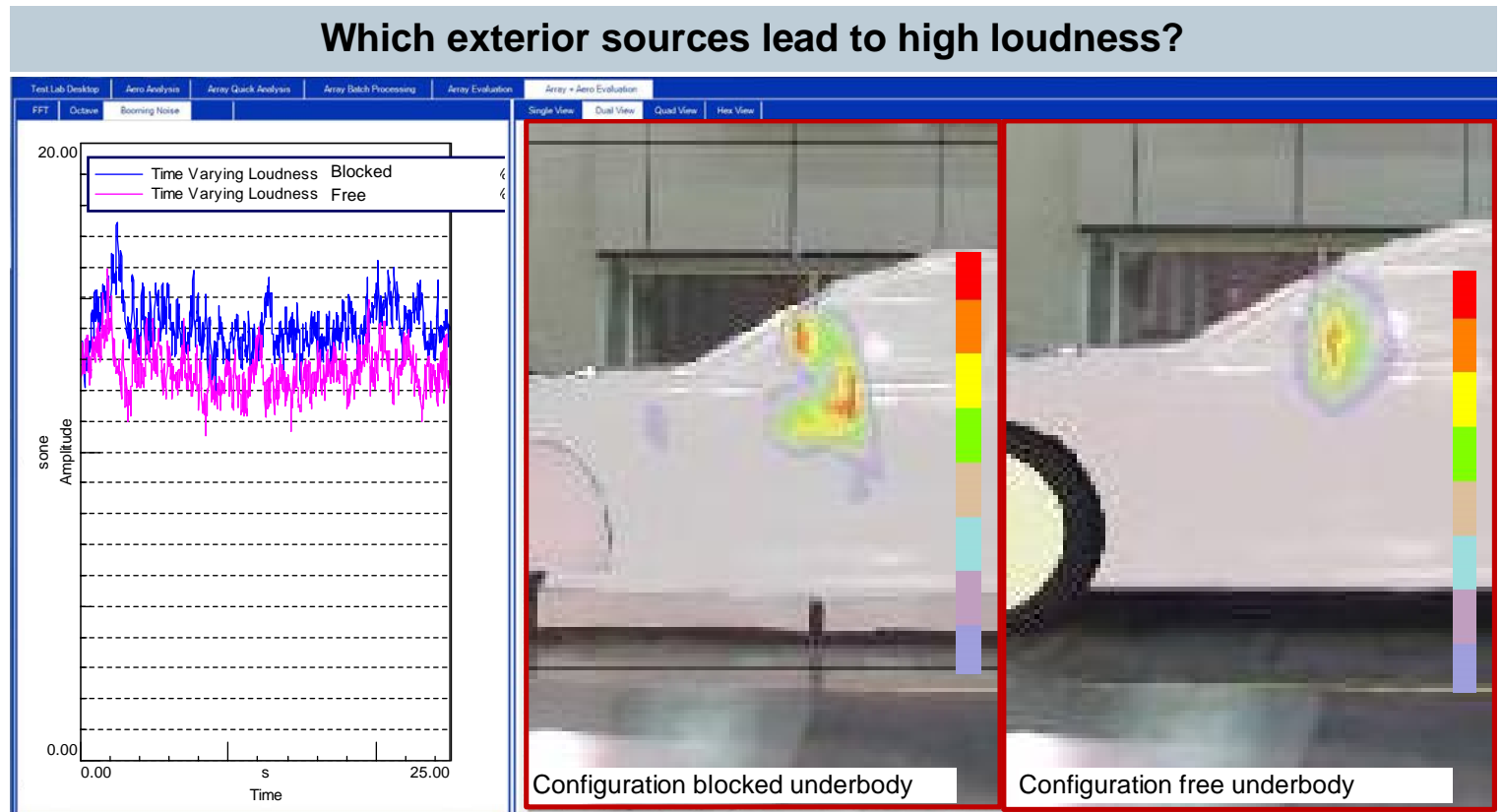


# Example 1

## Compare binaural head and exterior array results

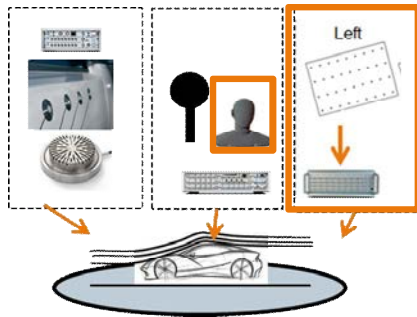


Viewing and comparing results from different techniques together on one screen gives additional insight



## Example 2

### Link binaural head with exterior array with coherence analysis

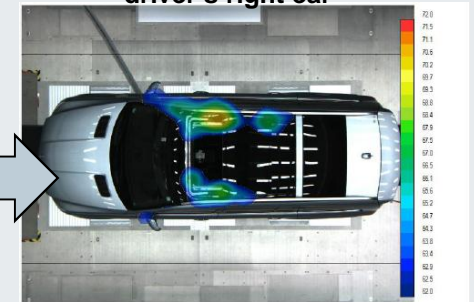
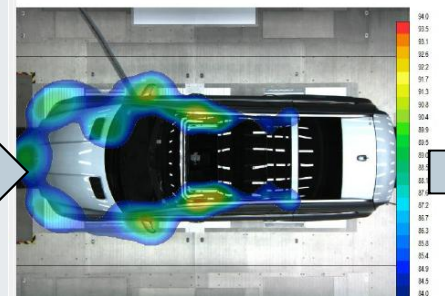


Which external source is important for driver's left ear?



Top array Result

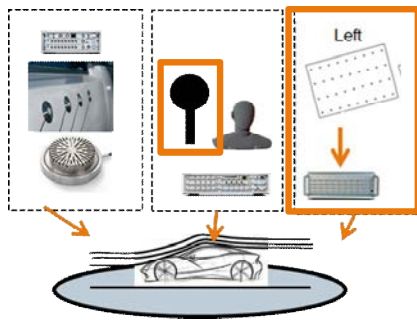
Top array result correlated to driver's right ear



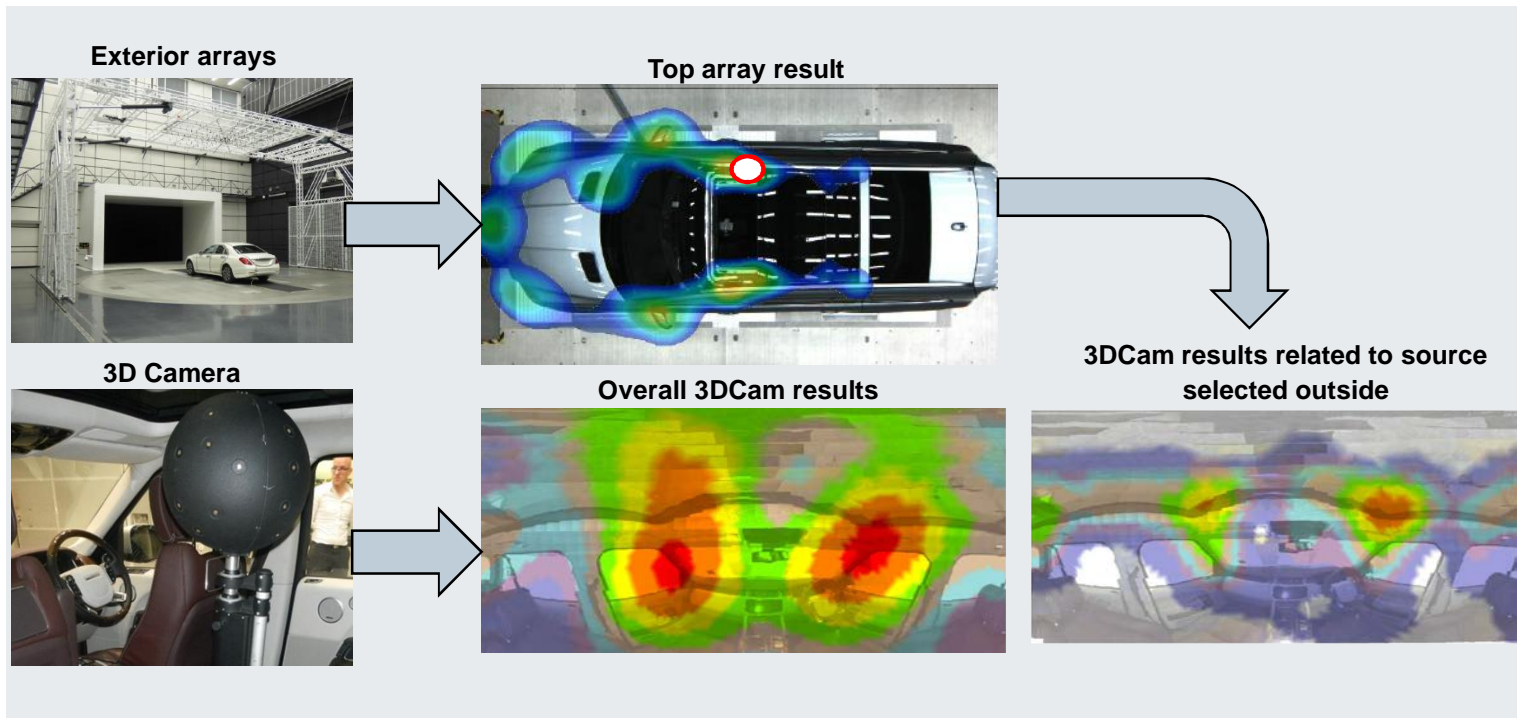
Coherence analysis allows to focus on sources for interior noise

# Example 3

## Link 3D Cam and exterior array with 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

## Essentials of aero-acoustic testing



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Getting new insights from combining technologies  
Increasing efficiency by having only one system

**Get maximum out of your test campaign**

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## Overview

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Amount of information

Efficiency

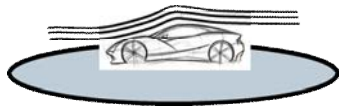
Effectiveness

ROI

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# How in practice does an aero-acoustic testing campaign look like?

Test modification of a vehicle



Speed [km/h]	Yaw Angle [degrees]
100	-15
100	-10
100	...
100	15
120	-20
120	...
...	...
160	20

Analyze  
What could cause problems?

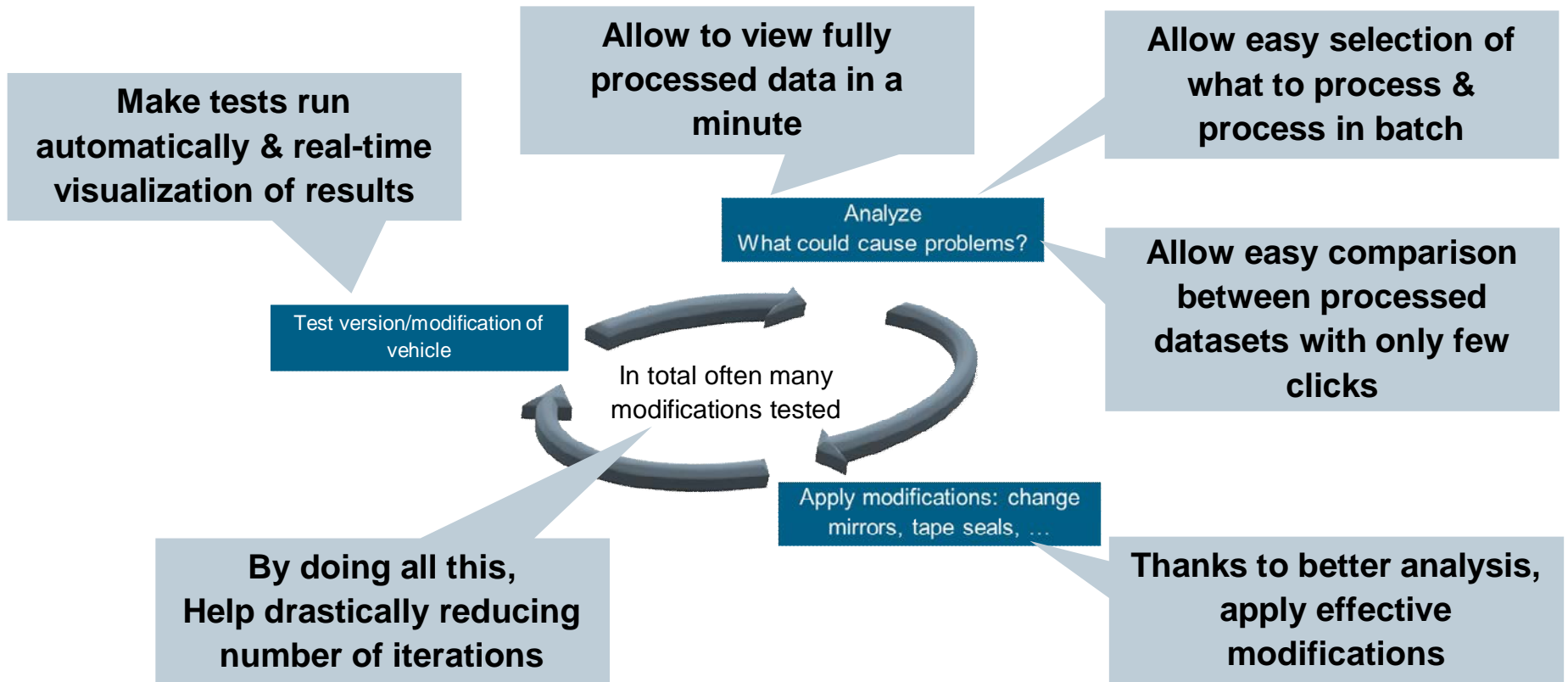


In total often many  
modifications tested

Apply modifications: change  
mirrors, tape seals, ...

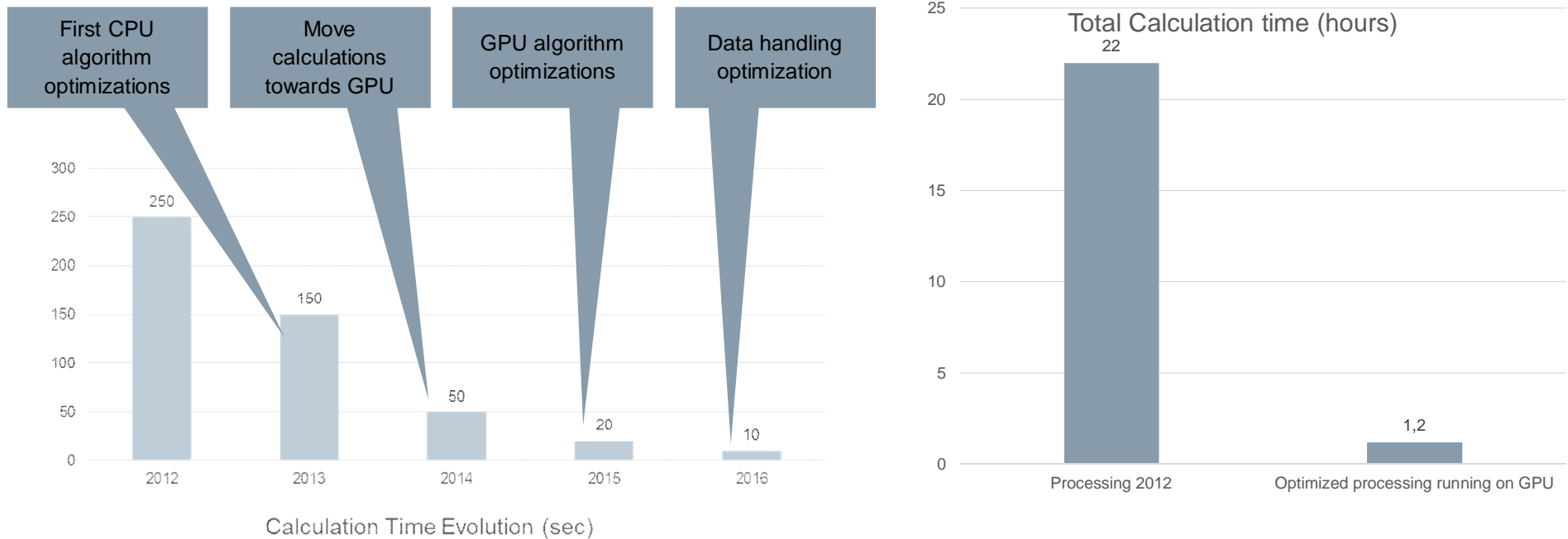


# How to drastically increase testing efficiency?



# How to drastically increase testing efficiency? Process and view array results in few seconds

## Drastic reduction in calculation time thanks to persistent optimizations and move towards GPU



**5 minutes versus 10 seconds ... So what?  
Calculation times add up!**



# How to drastically increase testing efficiency? Allow easy selection of what to process & process in batch

Easy selection of processing to be done: configuration, wind speed, yaw angle, frequency range, method, ...

Which data to process  
Configuration/yaw angle/speed

Which array

Which frequency/time

Processing list – color indication shows status

Config	Speed	Angle	Array	Reference	Group	Distance	Time range	Frequency range
Configuration2	125.3	-0.0	Right	No ref	FromSetup 12513	4.10	0:00 4:00	1000.00 1050.00 CSM
Configuration2	125.3	0.0	Right	No ref	3D mesh 11116	NA	0:00 4:00	1000.00 1050.00 CSM
Configuration2	125.3	0.0	Inside	No ref	3D mesh 11116	NA	0:00 4:00	1000.00 1050.00 CSM
Configuration2	138.0	0.0	Right	No ref	FromSetup 12513	8.10	0:00 4:00	1000.00 1050.00 CSM
Configuration2	138.0	0.0	Right	No ref	3D mesh 11116	NA	0:00 4:00	1000.00 1050.00 CSM
Configuration2	138.0	0.0	Inside	No ref	3D mesh 11116	NA	0:00 4:00	1000.00 1050.00 CSM
Configuration2	165.0	0.0	Right	No ref	FromSetup 12513	6.70	0:00 4:00	1000.00 1050.00 CSM
Configuration2	165.0	0.0	Right	No ref	3D mesh 11116	NA	0:00 4:00	1000.00 1050.00 CSM
Configuration2	165.0	0.0	Inside	No ref	3D mesh 11116	NA	0:00 4:00	1000.00 1050.00 CSM
Configuration2	80.1	0.0	Right	No ref	FromSetup 12513	4.10	0:00 4:00	1000.00 1050.00 CSM
Configuration2	80.1	0.0	Right	No ref	3D mesh 11116	NA	0:00 4:00	1000.00 1050.00 CSM
Configuration2	80.1	0.0	Inside	No ref	3D mesh 11116	NA	0:00 4:00	1000.00 1050.00 CSM

- Each calculation running fast on CPU
- Calculations running automatically in batch
- Status color indication
- Runs as background process – continue further analysis

# How to drastically increase testing efficiency? Easy comparison between processed datasets with only few clicks

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

Delta plot

Up to 6 fully independent displays

Per display or common display settings

Spectrum point selection

Data or image export for reporting

Projects / Vehicles

Vehicle Modifications

Test conditions (windspeed, yaw angle)

Processing: Array Method Reference ch Frequency band

- View & compare ANY result
- Allows to decide what modifications to test next
- drastically remove total test time or make test more effective

## Essentials of aero-acoustic testing



**Understand aero-acoustic testing technologies**

Getting maximum out of each used methods by having access to best technology

**Combine all into one integrated solution**

Getting new insights from combining technologies  
Increasing efficiency by having only one system

**Get maximum out of your test campaign**

Use all functionality ALL the time  
Be able to use results during test campaign & reduce the number of tested modifications

**Work with a trusted partner**

## Essentials of aero-acoustic testing

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## You can grow step by step

- **Scalable solution**
- **No limit to number of channels, you can extend one day with additional front array on top of nozzle**
- **Ready to extend with new technology**

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# Professional project deployment



## Deployment team



- Experienced expert project team
- Full project ownership from A-Z

## Customized solution



- Customized arrays
- Integration with wind tunnel controller
- Customized testing process

## BUT with local support



- Teaming with local Siemens STS during full project
- Local training & support of the system

## Essentials of aero-acoustic testing



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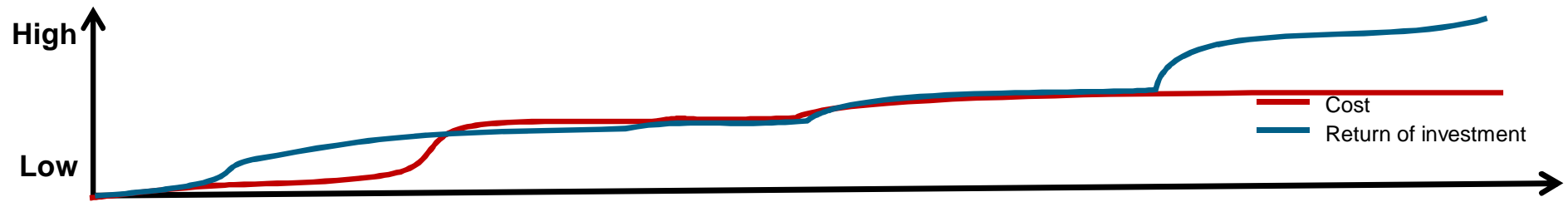
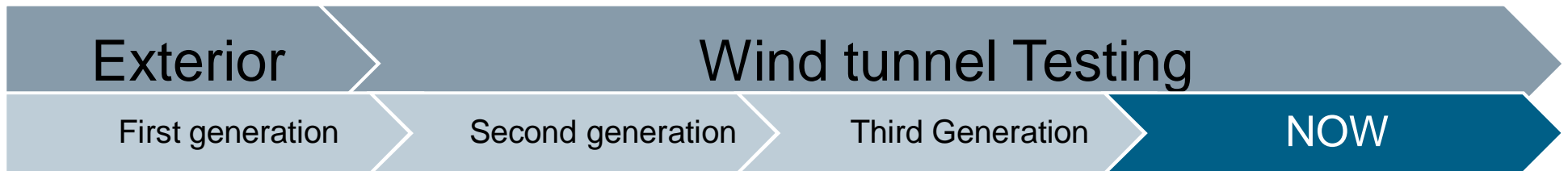
**Get maximum out of your test campaign**

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**Work with a trusted partner**

Full portfolio including simulation through Simcenter  
Full project deployment  
Continued innovation & research

# Conclusion







Thank you!

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Realize innovation.