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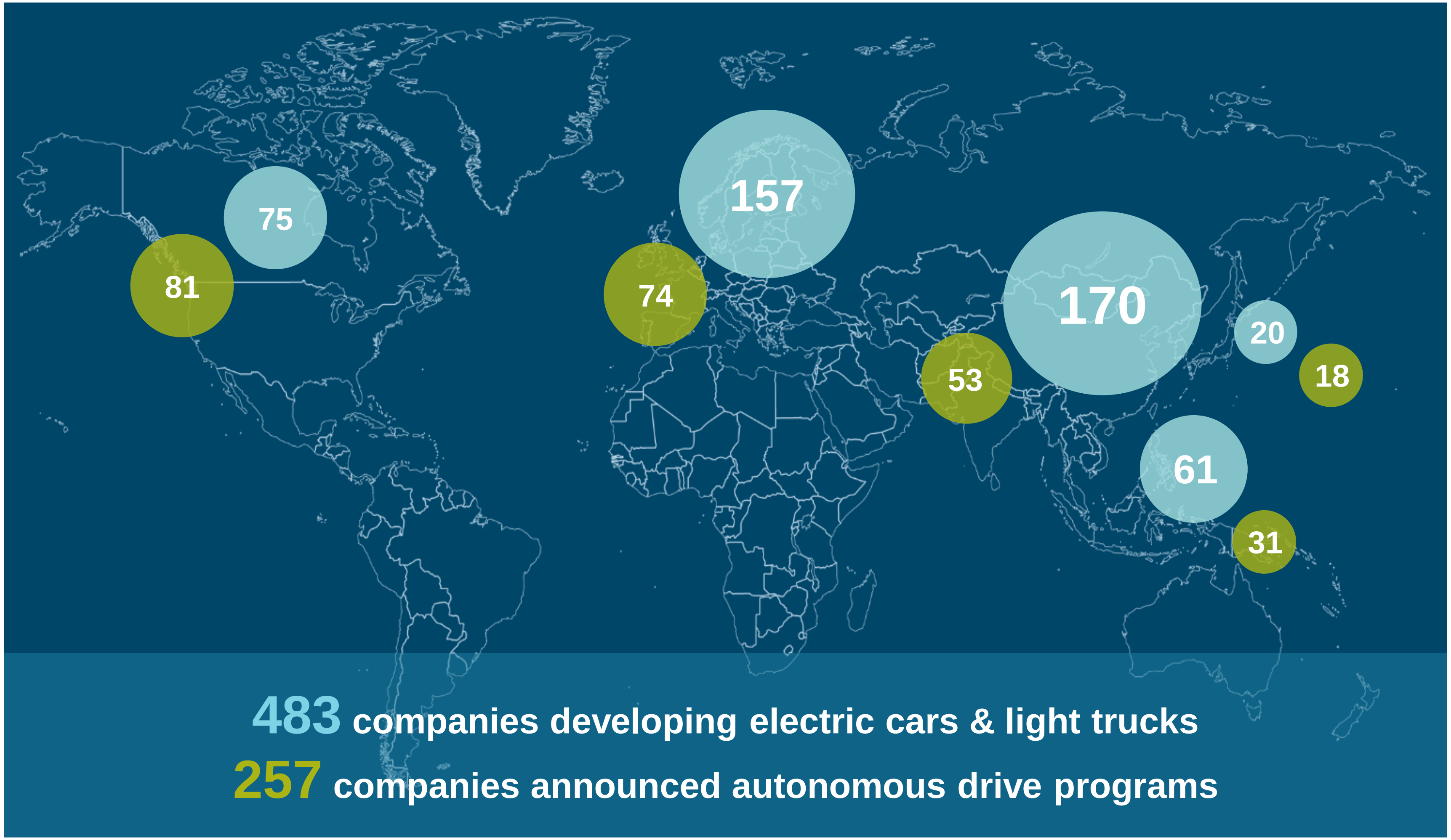
Powertrain testing: Embrace the new role of testing to develop green drivetrains

On-demand Webinar

Where today meets tomorrow.

The RACE to full-electrification is on

Surviving the distance is key to success



Context and trends driving innovation in today's vehicle market

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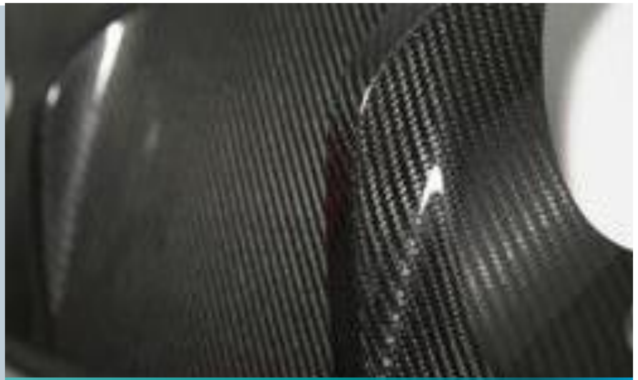
Emissions reduction & Fuel economies

Powertrain innovation

Electrification, hybridization



Lightweight Development

Global market and customers expectations

Local market requirements and variants

Reliability, comfort and perceived quality

Reduced development time and cost

Impact on product life cycle and cost

Model-Driven Design to evaluate upfront systems designs

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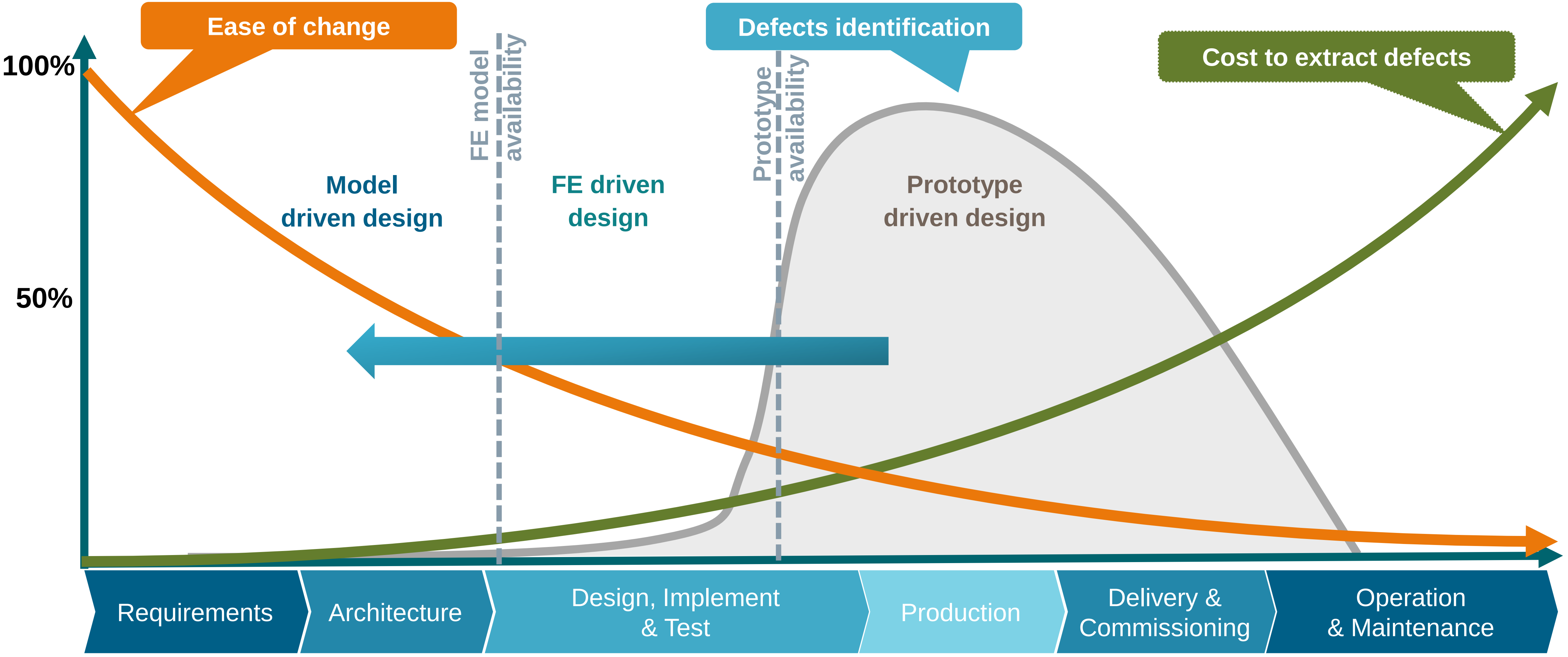

Impact on product life cycle and cost

Model-Driven Design to evaluate upfront systems designs

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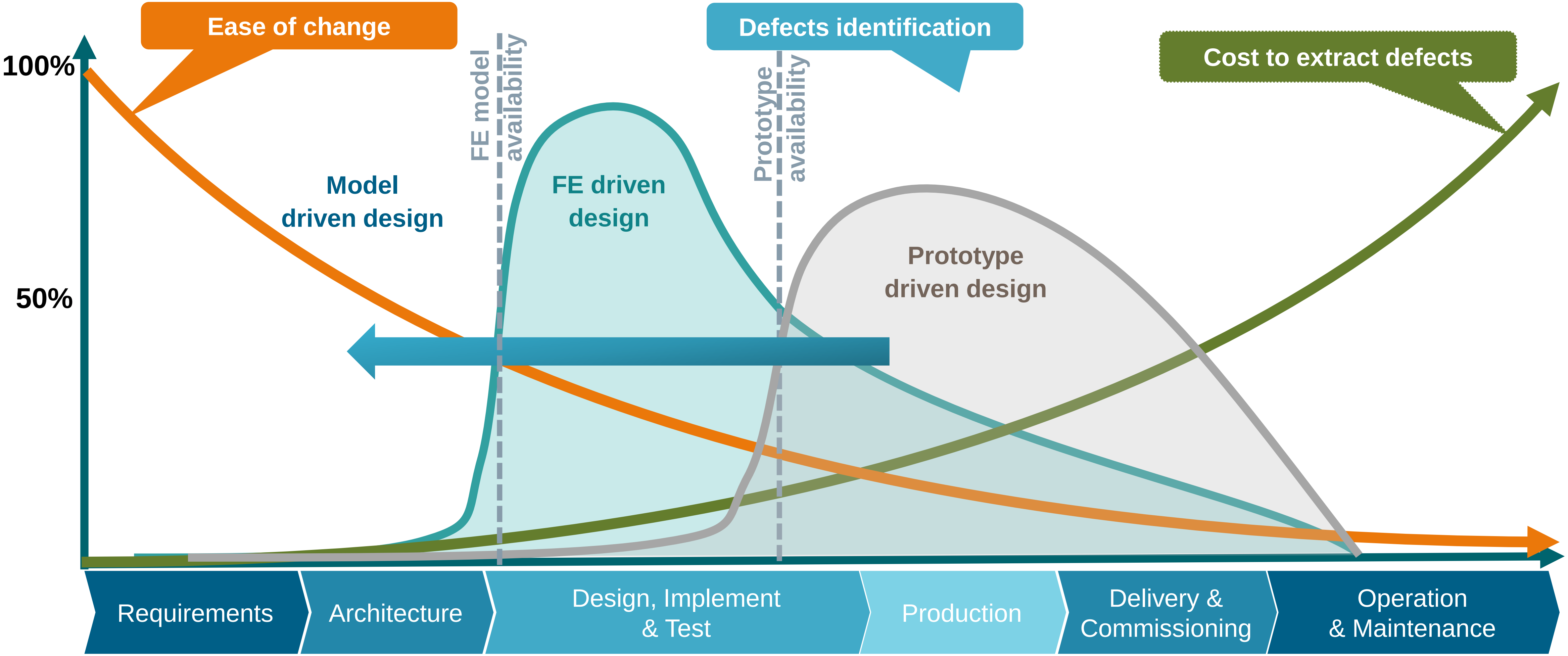
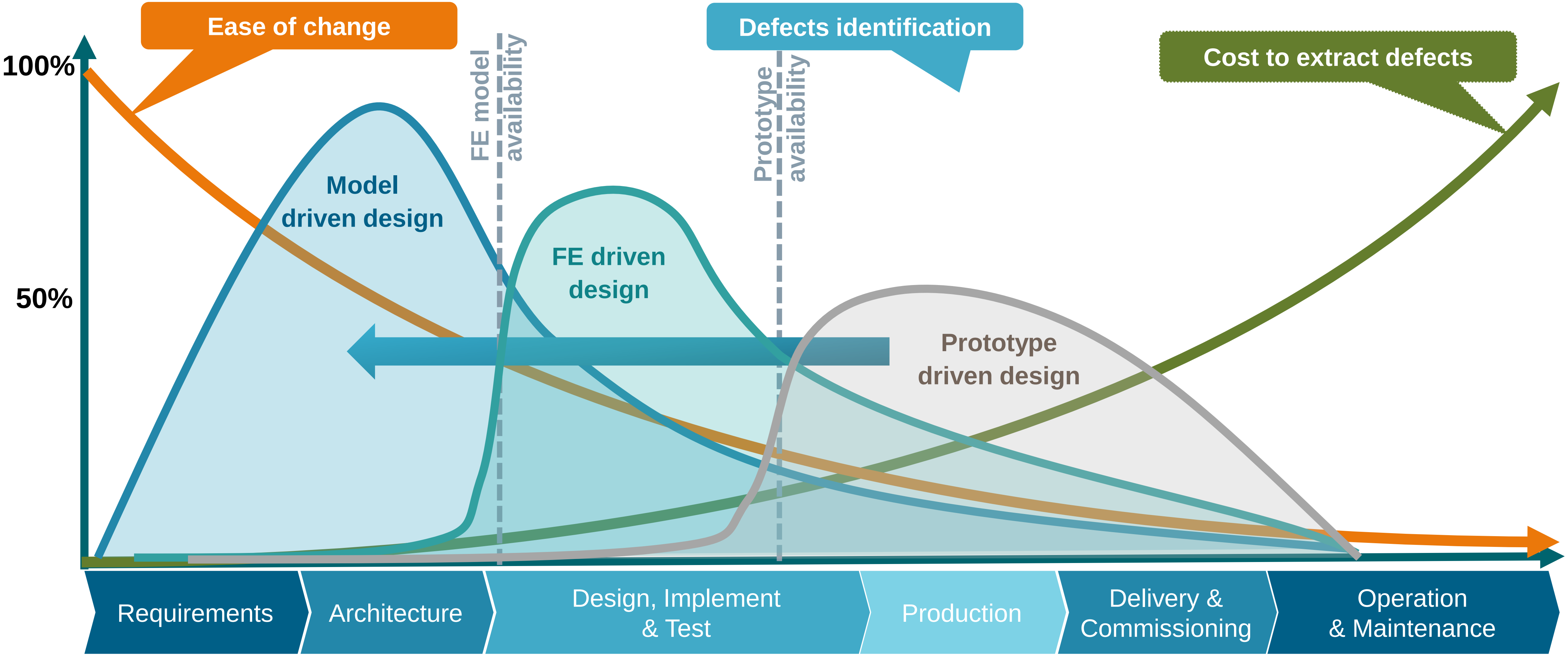


Impact on product life cycle and cost

Model-Driven Design to evaluate upfront systems designs



Complexity growth challenges EV engineering

Design complexity and inter-dependencies crossed a threshold

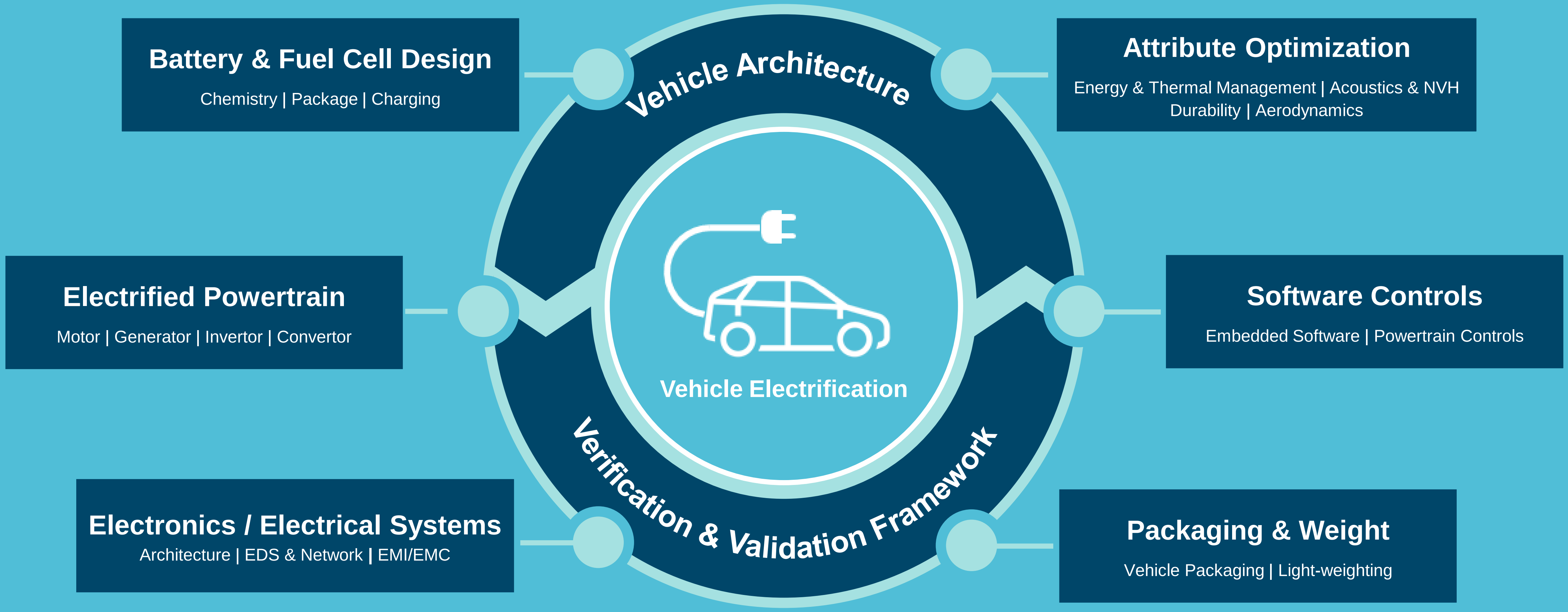
Adding engineering resource and depending on

traditional development methods is not adequate

any more

Siemens Digital Industries Software engineering solutions

Catering to a wide range of vehicle electrification needs



Agenda:

Keep increasing development efficiency

Support NVH testing for electrified powertrains

Keep control on NVH for ICE

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Keep increasing development efficiency

Support NVH testing for electrified powertrains

Keep control on NVH for ICE

How to develop powertrains faster?

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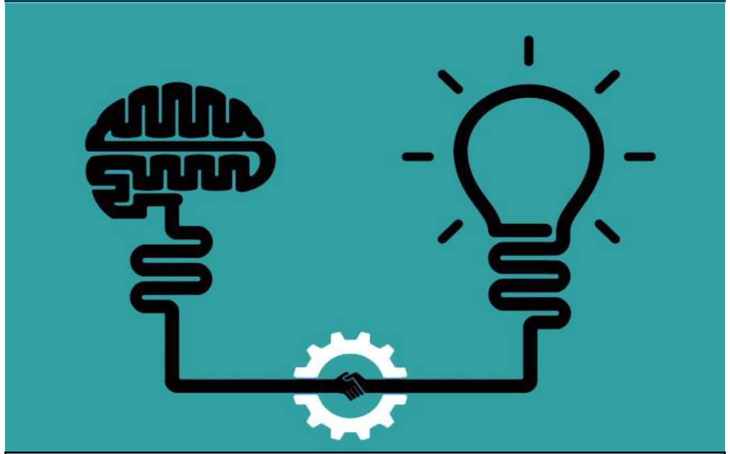
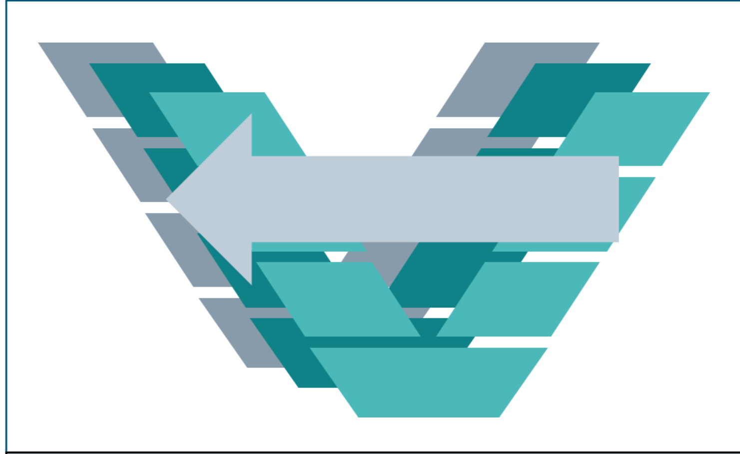
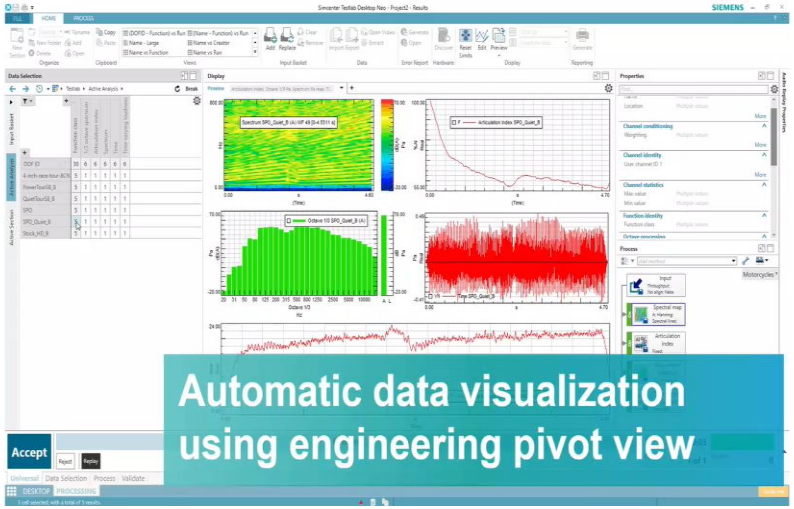
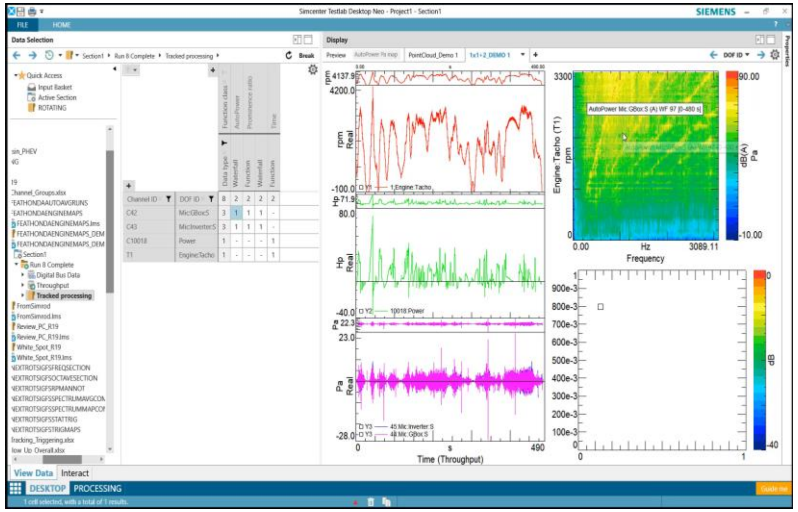
Test SMARTER	Test FASTER	FRONTLOAD Testing
		
✓ Smart interpretations ✓ Built-in intelligence	✓ More efficient testing ✓ Automate testing ✓ Data Management	✓ Early component performance evaluation ✓ Test & Simulation to make early predictions

How to develop powertrains faster?
Test Smarter



✓ **Pre-defined templates and displays**

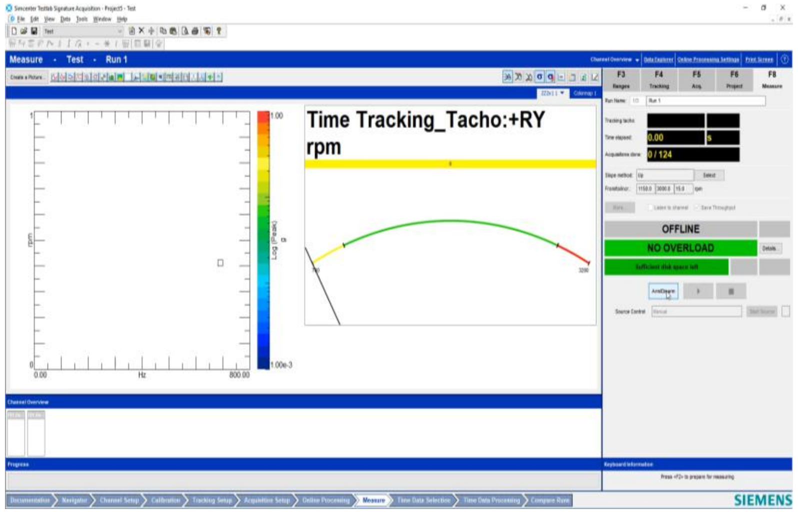
✓ **Average measurements automatically**



✓ **Intelligent overview of data – Pivot Tables**

✓ **Smart Displays**

✓ **Actionable reports with active displays**



✓ **Intelligent display to evaluate large data sets**

How to develop powertrains faster?

Test Faster by customizing / optimizing processes

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Unification of testing Example

Old Process

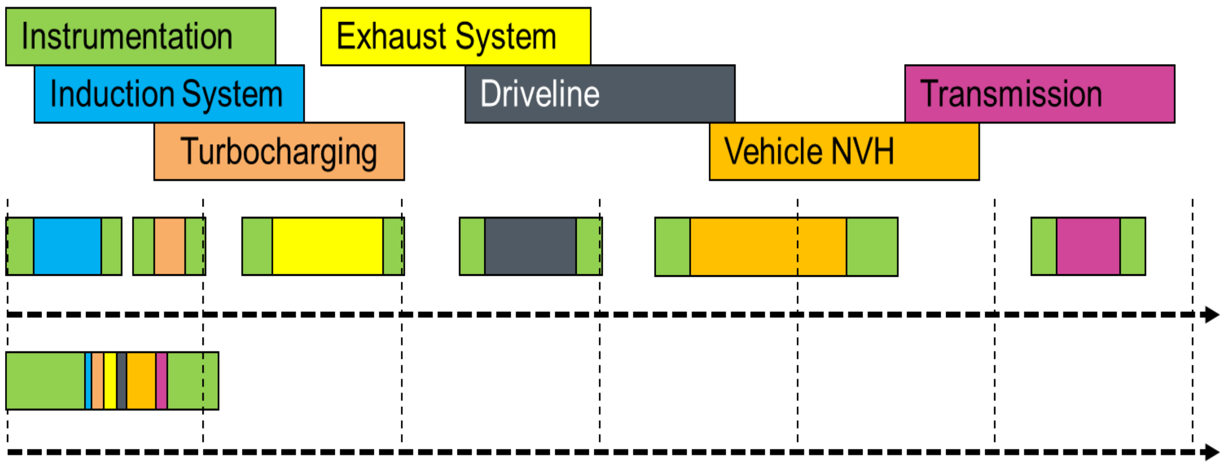
1. First Prototype test to identify which subsystems cause problem
2. Instrument & test different subsystems and acquire data
3. Analysis one by one

Total time to go through process > 2 weeks

New Process

1. Instrument complete vehicle (higher channel count)
2. Perform all test
3. **Automatic** processing for each subsystem

Total time 3 hours



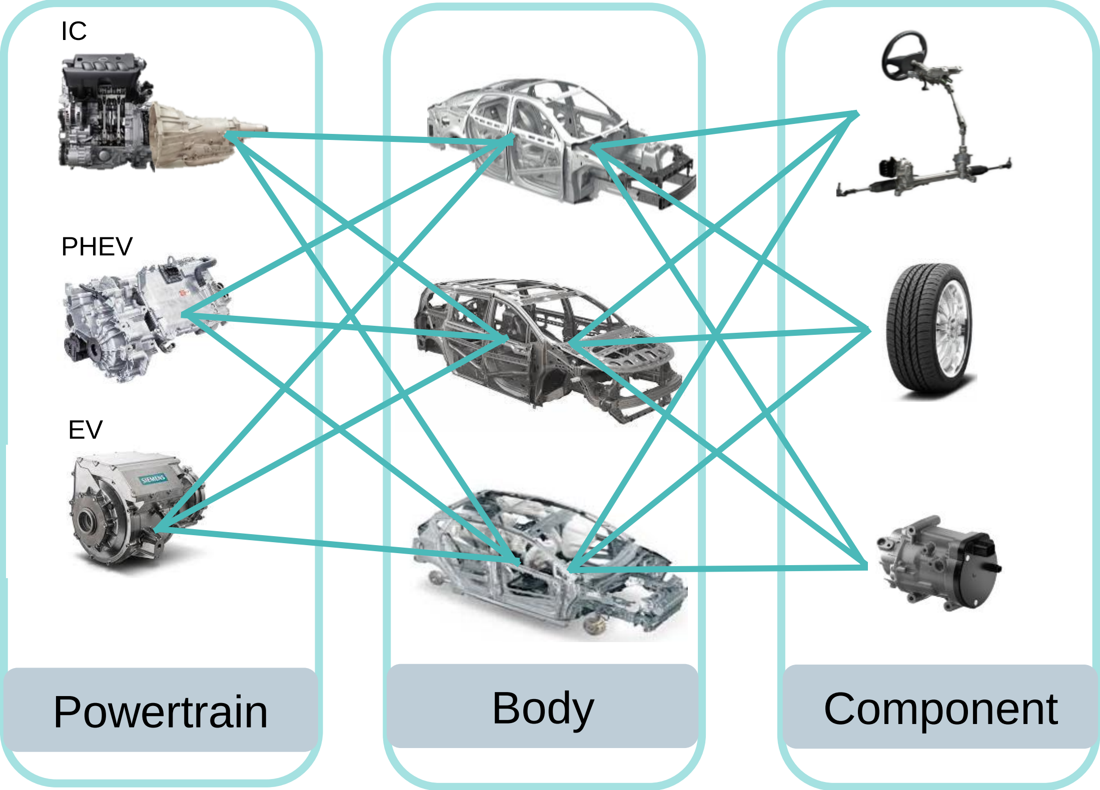
"Our design verification process is now 5 times shorter and the processing of data has gone from 2 weeks to 3 hours."

Result of unified testing:

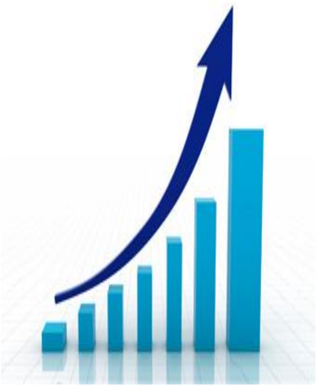
- ✓ High reduction in total measurement time
- ✓ Always availability of ALL data
- ✓ Ideal first step towards automation of data collection too (e.g. testing without driver)

Optimization of Vehicle development cycle

The challenge

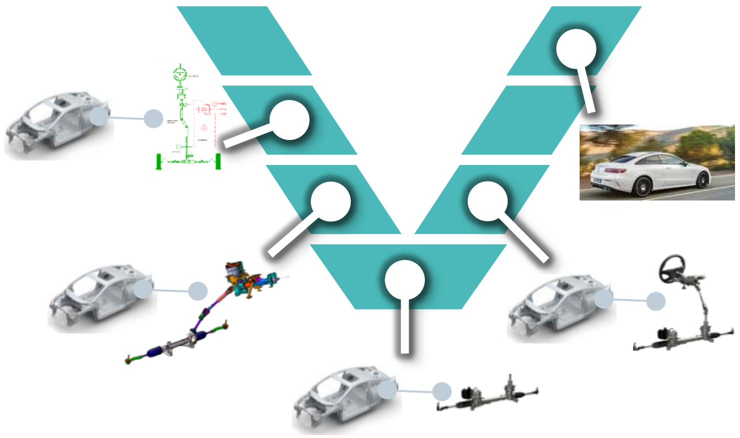


# of vehicle variants



- Increasing testing effort
- Prototype availability?
- Impact of modification?
- …

Frontloading



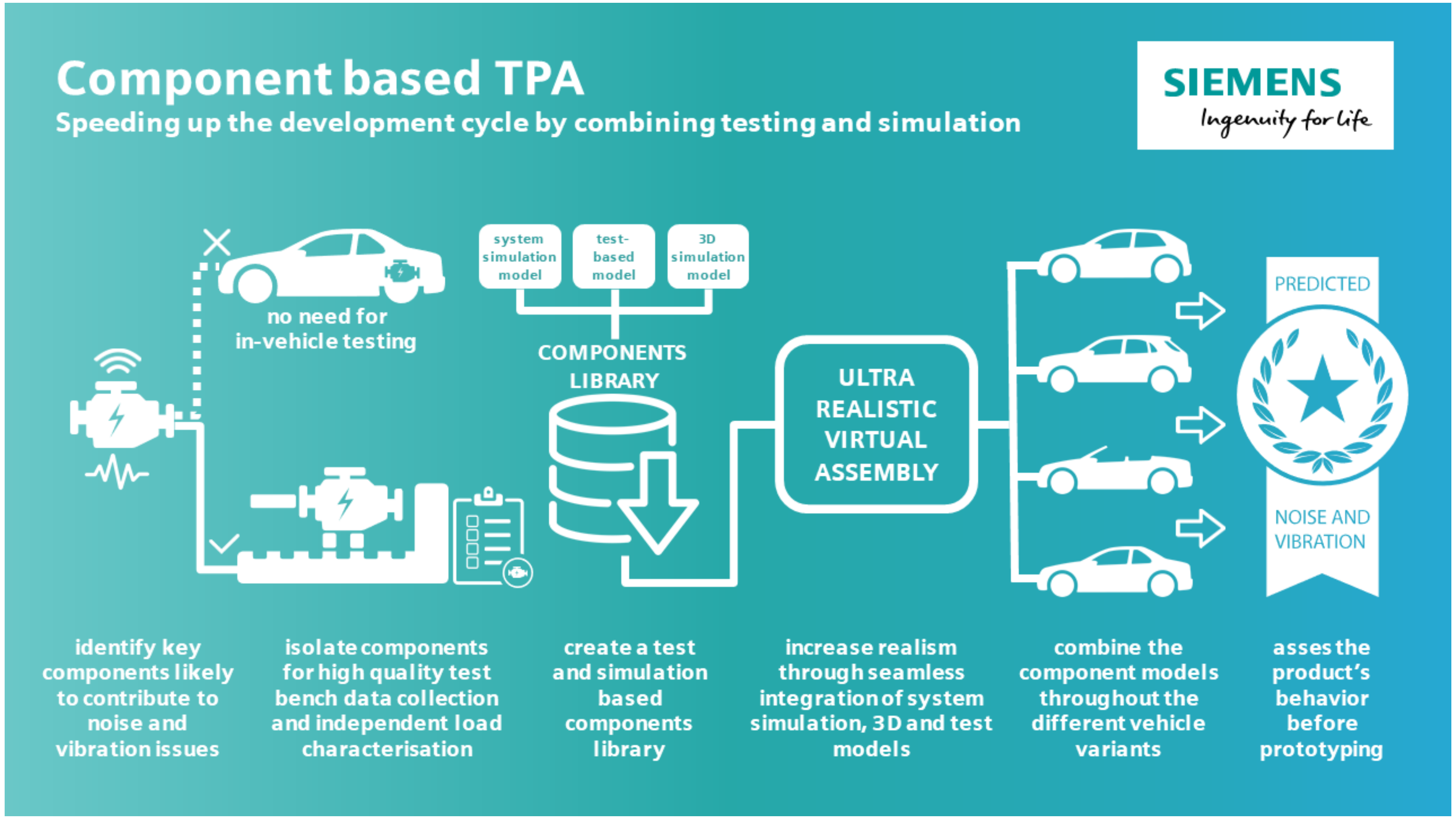
How to ensure NVH performance while keeping development time and cost under control?

Frontloading vehicle level component NVH testing

Component based TPA

Value proposition

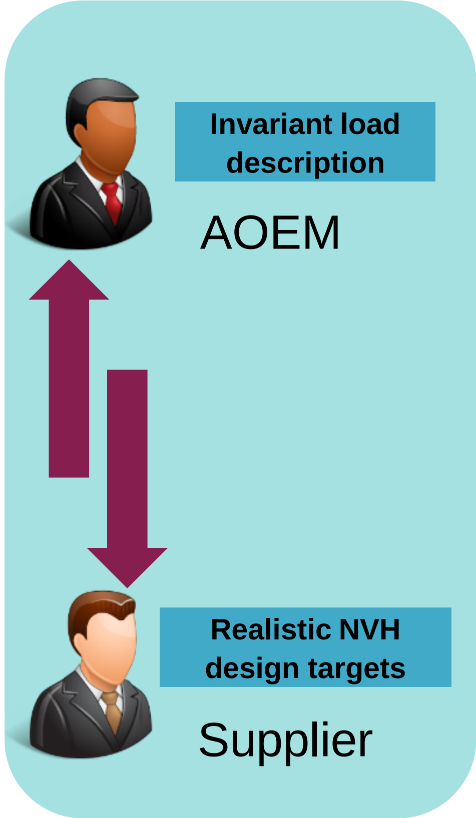
- **Integrated process to predict full vehicle levels in any arbitrary vehicle assembly**
- **Realistic component target setting and down cascading**
- **Deliver insights by frontloading the development process**
- **Provide visibility on performance to broader enterprise**
- **Reduced development timeline &costs**

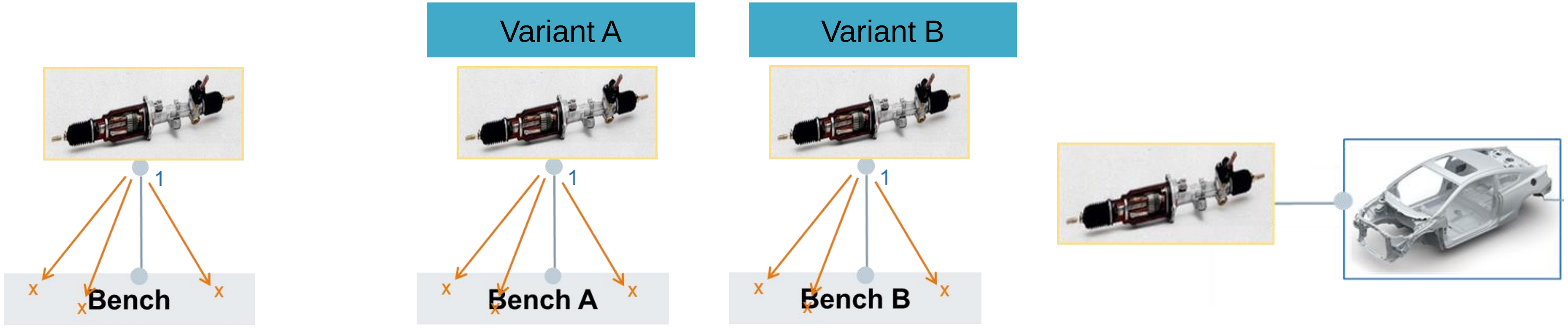


Component based TPA for component design evaluations

Enable realistic test bench based NVH target verification

OEM-Supplier cooperation





Validate performance against test bench independent targets

Validate objectively impact of design modifications or compare variants irrespective of test bench

Predict assembly NVH performance to optimize system integration

How to develop powertrains faster?

Using the C-TPA methodology

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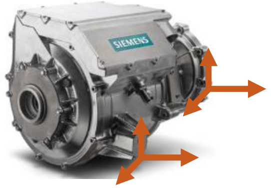
Can I predict E-motor behavior from test bench?

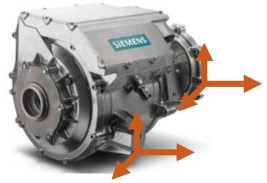
Predict Target Response

Source`

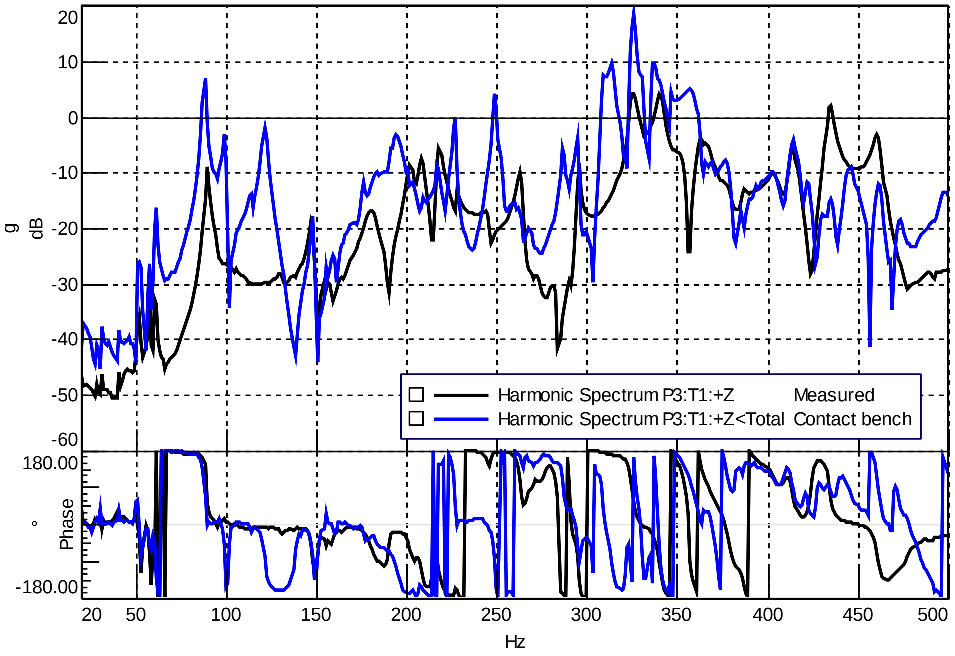


Test Bench

Source



Vehicle / Receiver



1. Test contact loads on test bench

2. Combine Loads with Transfer to predict performance

3. High deviation between predicted and measured response

Strong coupling between source & receiver does NOT allow to exchange contact forces from bench with vehicle

Contact forces on test bench can NOT be used

How to develop powertrains faster?

Using the C-TPA methodology

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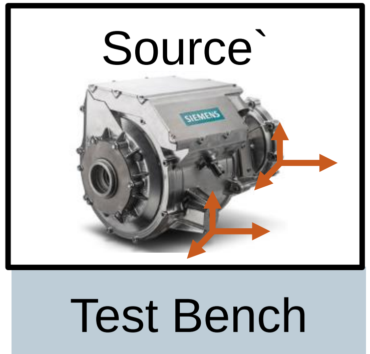
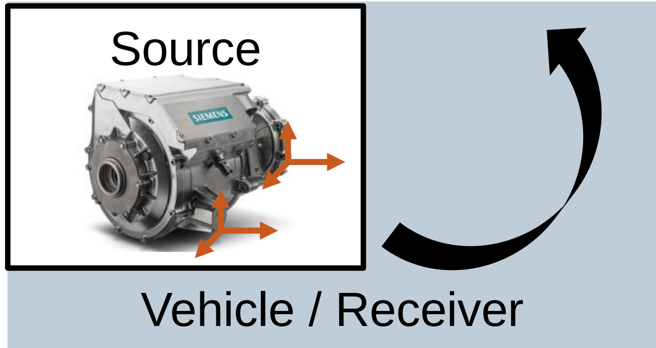
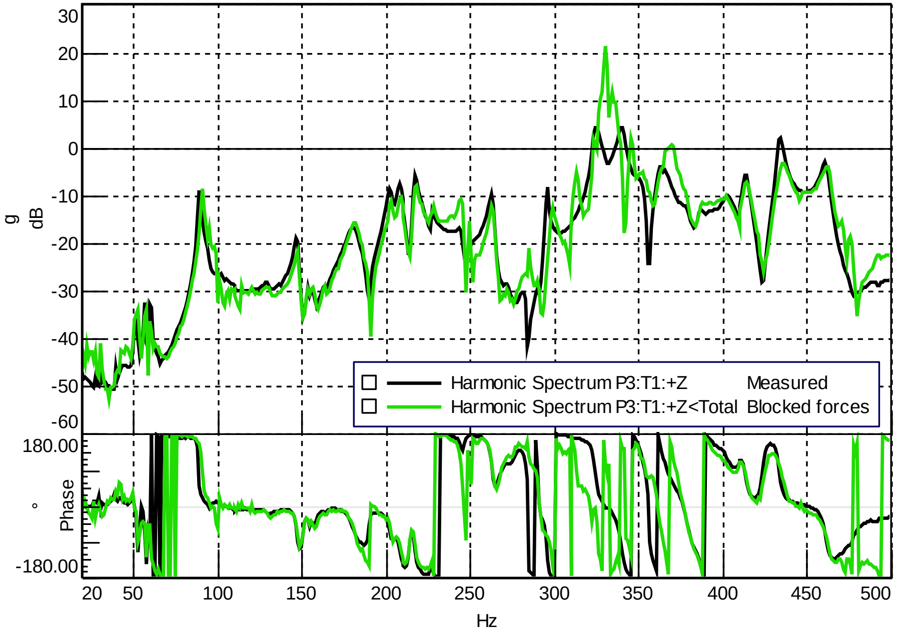
Can I predict E-motor behavior from test bench?



Predict Target Response





1. **Identify BLOCKED forces on test bench (invariant forces)**
2. **Combine Loads with Transfer to predict performance**
3. **Perfect match between Predicted and measured response**

Blocked forces are invariant and can be used to predict the performance before integration

Concept of Component-based TPA
Enables Virtual Vehicle Assembly

Frontload Testing through combination of Test & Simulation
Model Based System Testing

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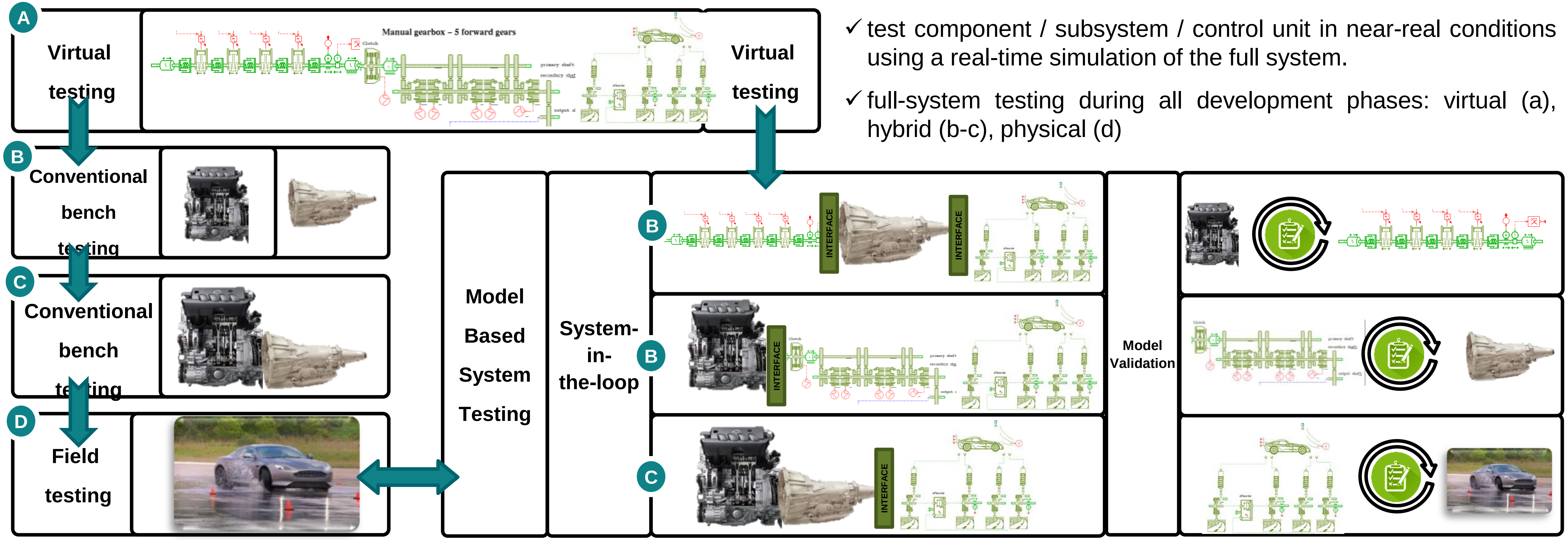
System-in-the-loop testing in support of Model-Based Development
Consistent testing for shorter development cycle

- ✓ test component / subsystem / control unit in near-real conditions using a real-time simulation of the full system.
- ✓ full-system testing during all development phases: virtual (a), hybrid (b-c), physical (d)



Frontload Testing through combination of Test & Simulation

Model Based System Testing Enabling unique abilities

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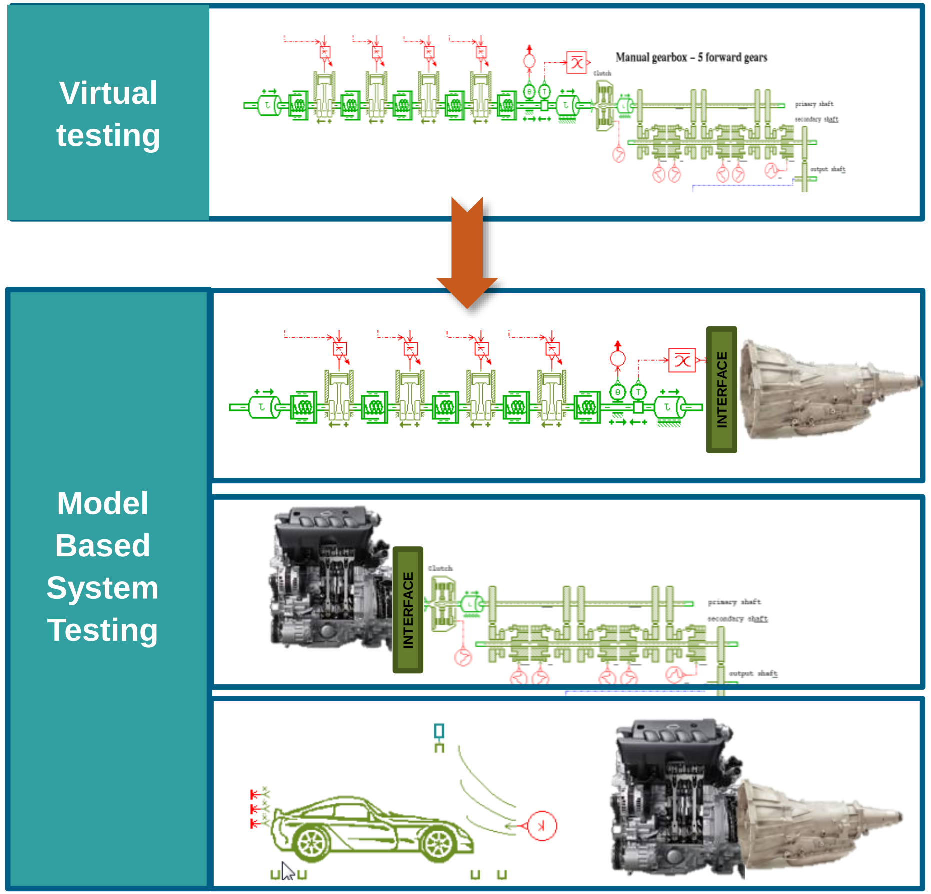

1. Test physical component/subsystem more realistically, by combining with virtual model
2. Test performance component/subsystem in combination with different variants in virtual model
3. Monitor any signal from within virtual model, which would be difficult to impossible to measure

Model Based System Testing

The Marriage of Test and Simulation

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Test for Simulation

Use test data to correlate and drive simulation models for validating functional performance in a single environment

- Model validation & updating
- Model parameter identification
- Load identification
- Test data analysis expertise

Improve accuracy and ensure consistency throughout the development process

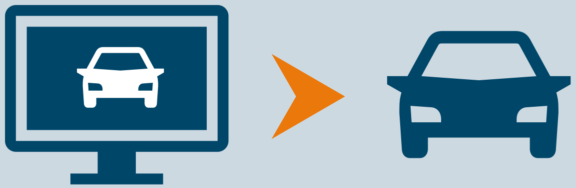
Test with Simulation

Use real-time simulation models to improve realism of subsystem testing

- Hardware-in-the-loop testing
- System-in-the-loop testing
- Human-in-the-loop testing

Enable earlier prototype validation and reduce integration risks

Simulation for Test



Use simulation models to define, improve and augment testing in a single environment

- Virtual testing
- Optimal sensor/excitation
- Virtual sensing

Provide better system insight and facilitate product performance engineering

Frontload Testing through combination of Test & Simulation

Introducing the concept of model based system testing (MBST)

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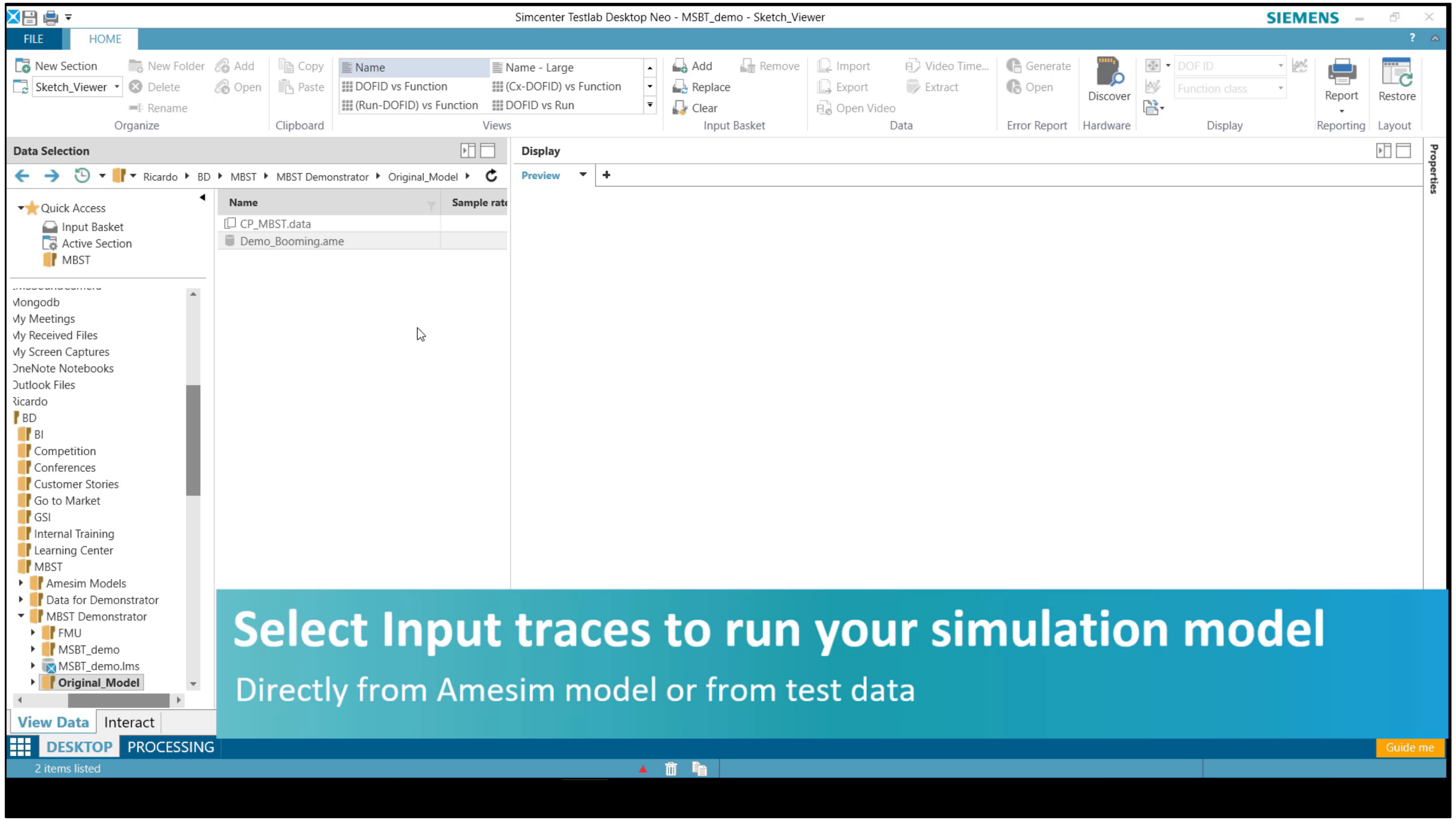


- ✓ Sketchviewer:
  - access & process Simcenter Amesim data
  - Easy viewing & comparison data
- ✓ Model updating from within Simcenter Testlab to match simulation with test

Agenda:

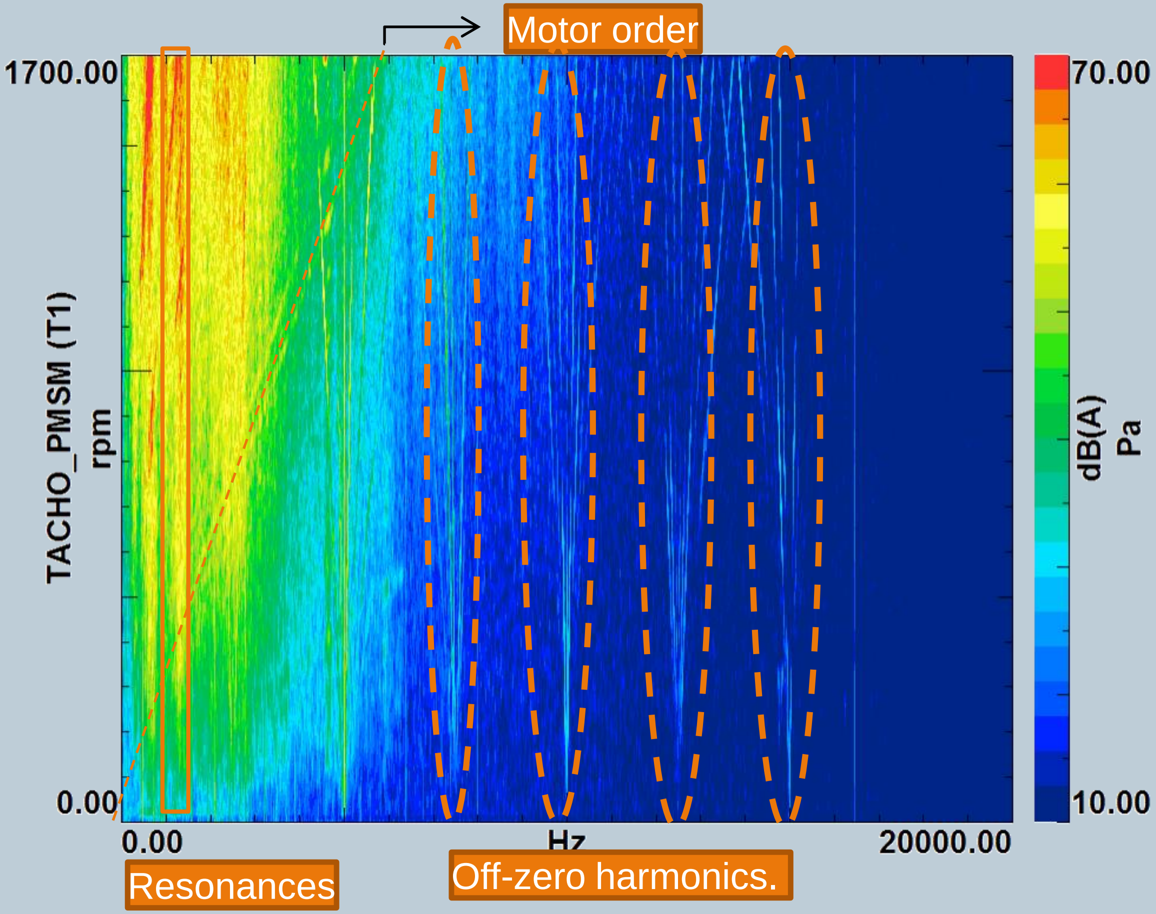
Keep increasing development efficiency

Support NVH testing for electrified powertrains

Keep control on NVH for ICE

Electric Motors Noise challenge

What is so different from ICE driven vehicles?



- **Lower overall level**
- **Higher motor orders due to electric machine construction**
- **Very high frequency sounds**
  - Off-zero orders
  - Related to PWM switching frequency
- **Road Noise dominant** due to lack of powertrain-related noise

New required functionalities in NVH testing for EV

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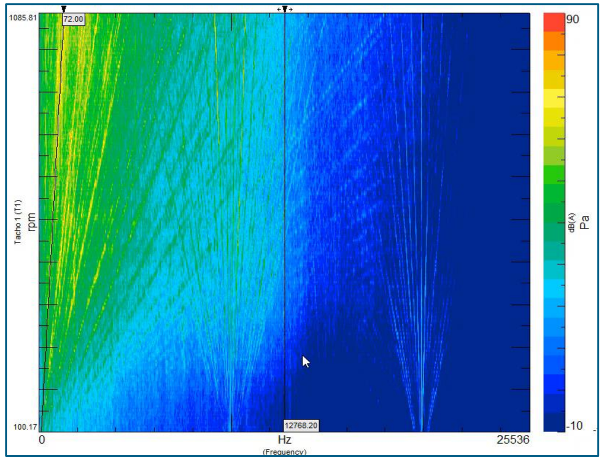
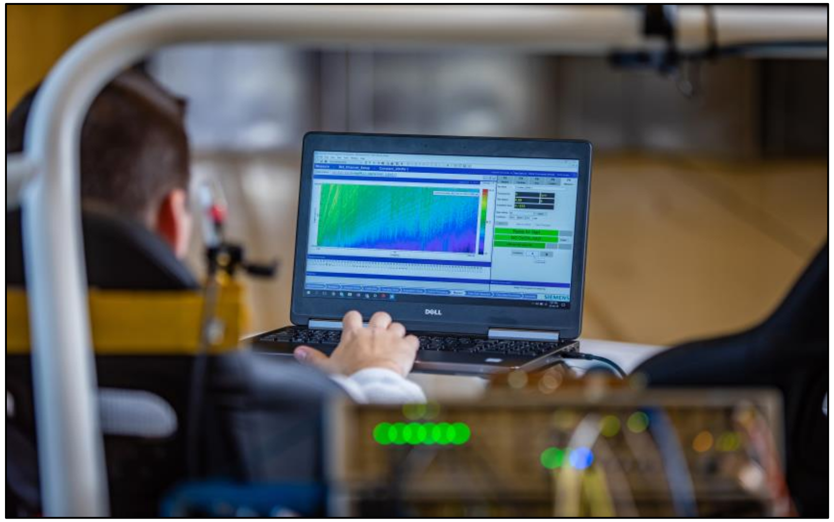
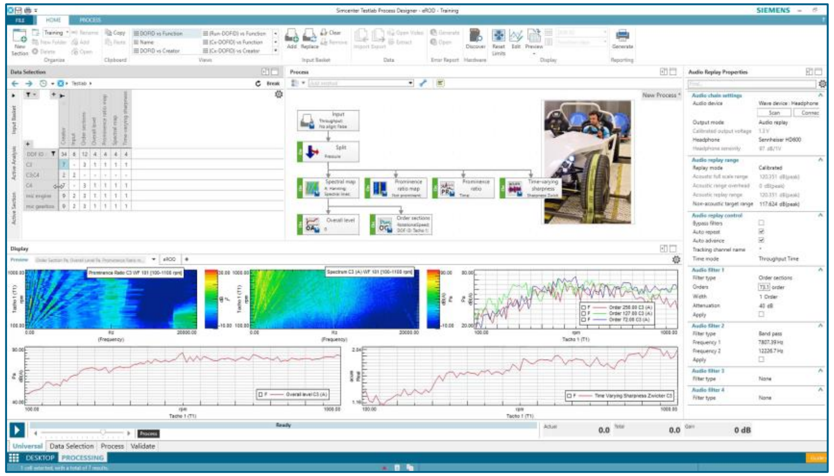
Support to handle new sound signature





Support of new sensors



Increased need for Sound Quality

From Realistic data recording to analysis & Sound Design

Handling new important noise sources

Gear whine, Battery cooling, …

New required functionalities in NVH testing for EV

1. Handling the different NVH signature from EV powertrains

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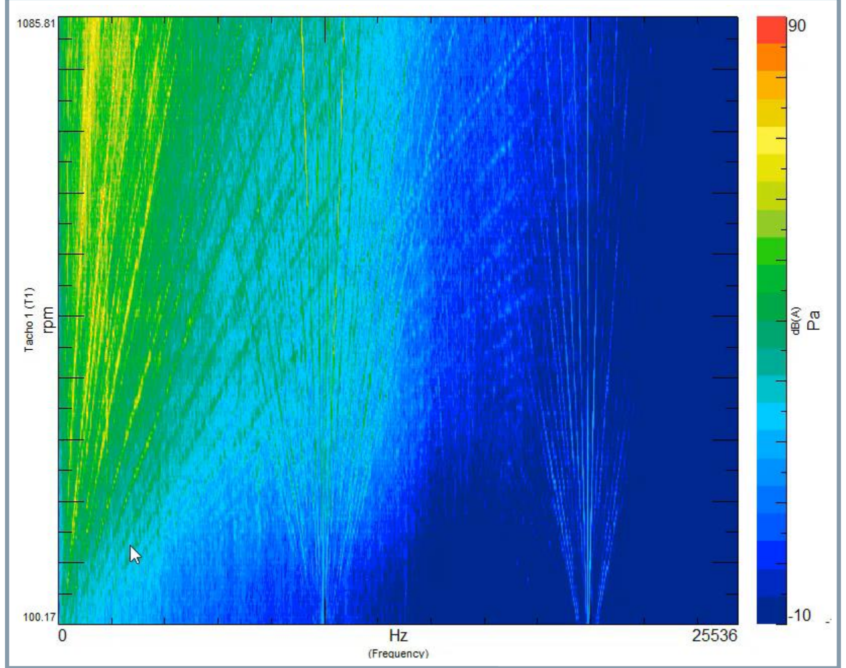
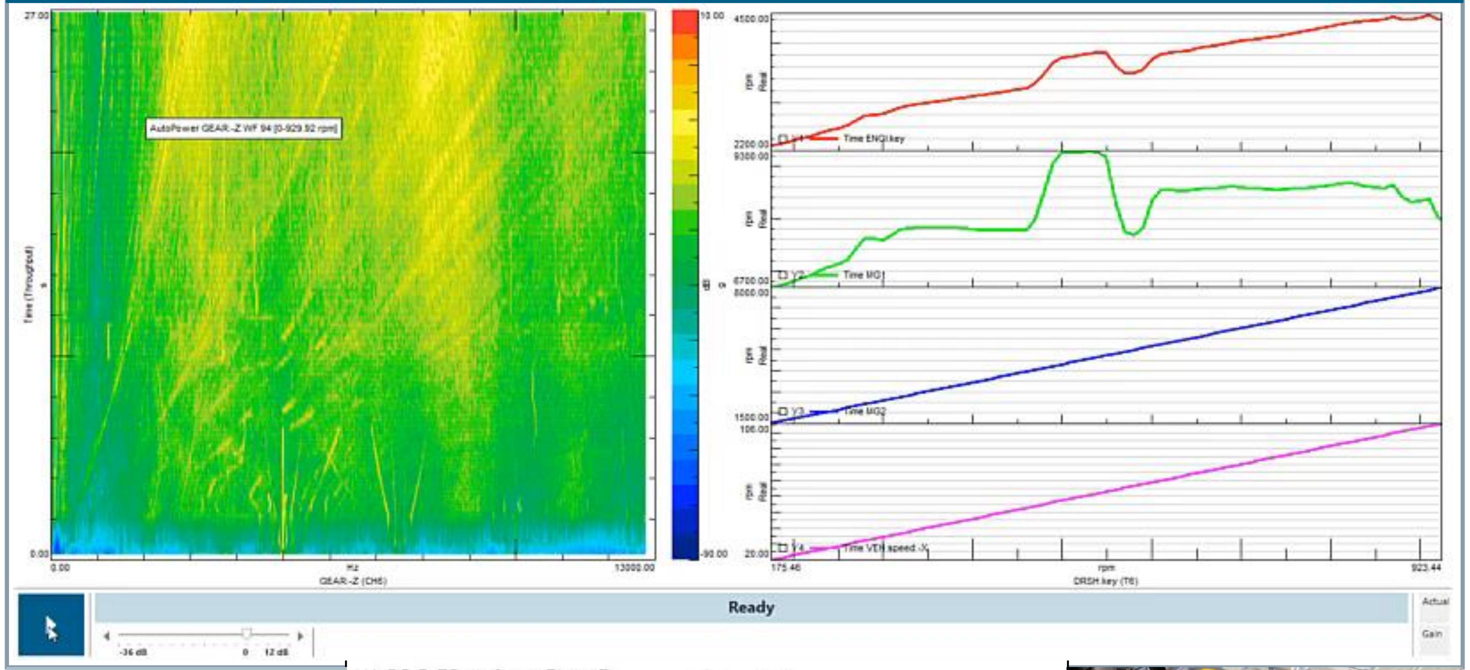
Analysis of high frequent off-zero orders

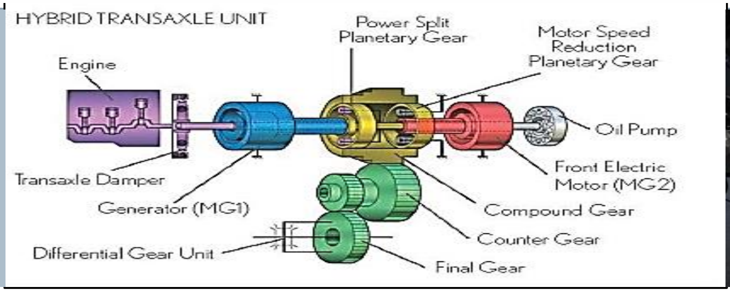


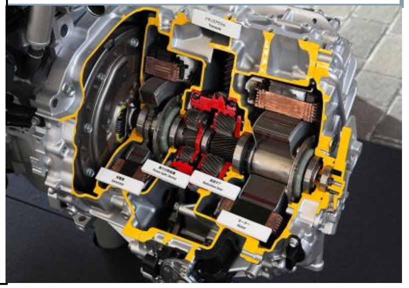
Electric Vehicle

Handling multiple RPM axis for Hybrid EV



Hybrid Vehicle





New required functionalities in NVH testing for EV

2. Adapting to use new sensors

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Measurement of Electric motor (EM) RPM:

- Usually difficult to impossible (no access)
- BUT EM has resolver sensor

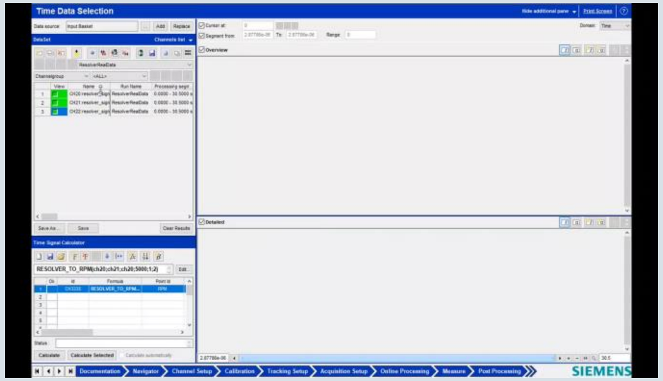
- Convert electric signals from Resolver in EM RPM & angular position
- Prerequisite: measure cosine and sine coil signals from resolver

Sensors

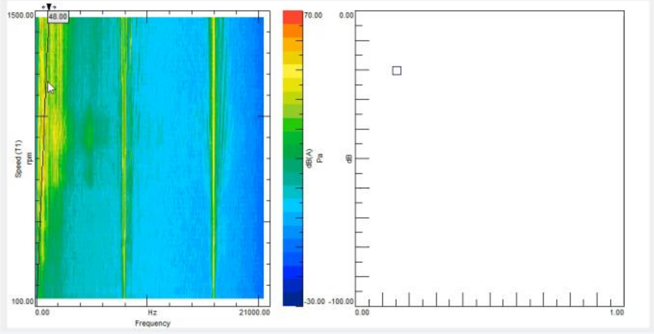
SCADAS

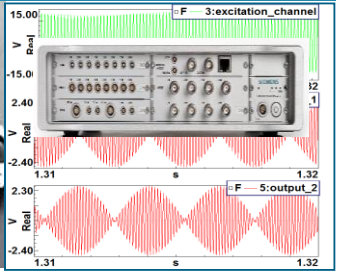
Resolver

Real-time or offline post processing of signals in RPM and/or angle



Process data as with regular tacho signals





New required functionalities in NVH testing for EV

3. Sound Quality Analysis

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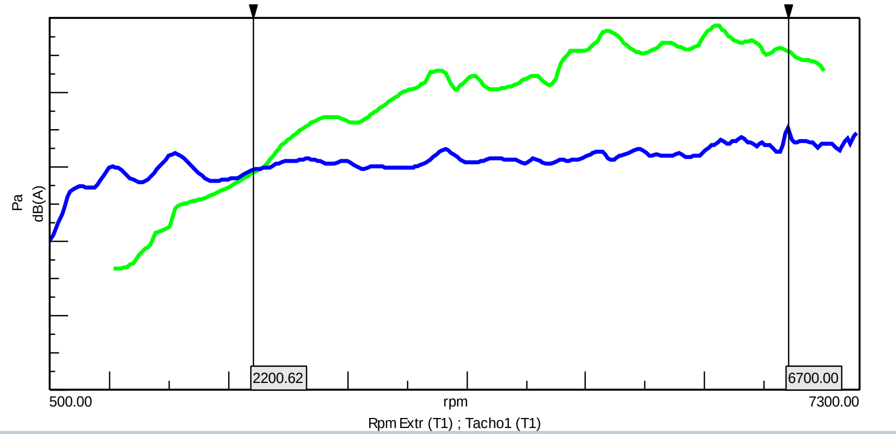
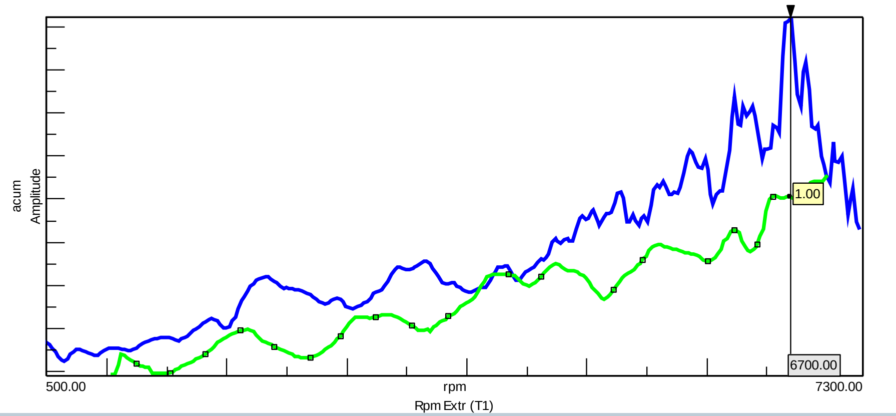
EV & ICE Overall noise level (dB-A)



EV & ICE Sharpness



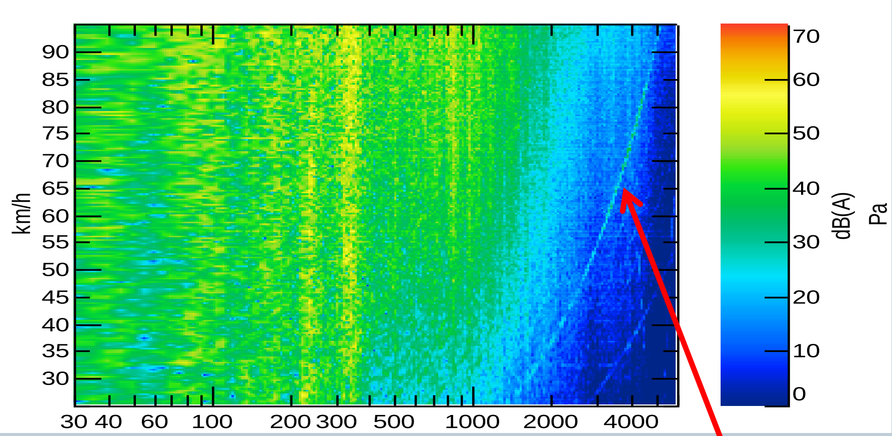
Objective assessment

Analyze your sound with measures that can be quantified


ICE

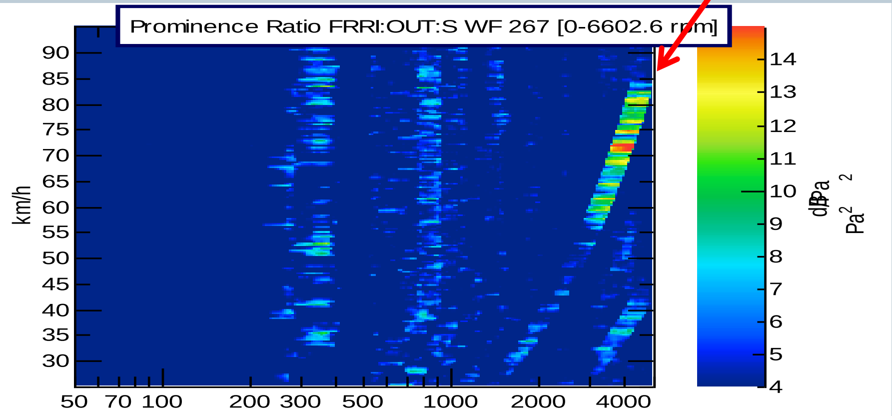

EV

EV - Sound Pressure Level



48th Order

EV - Prominence Ratio



New required functionalities in NVH testing for EV

3. Sound Quality Analysis

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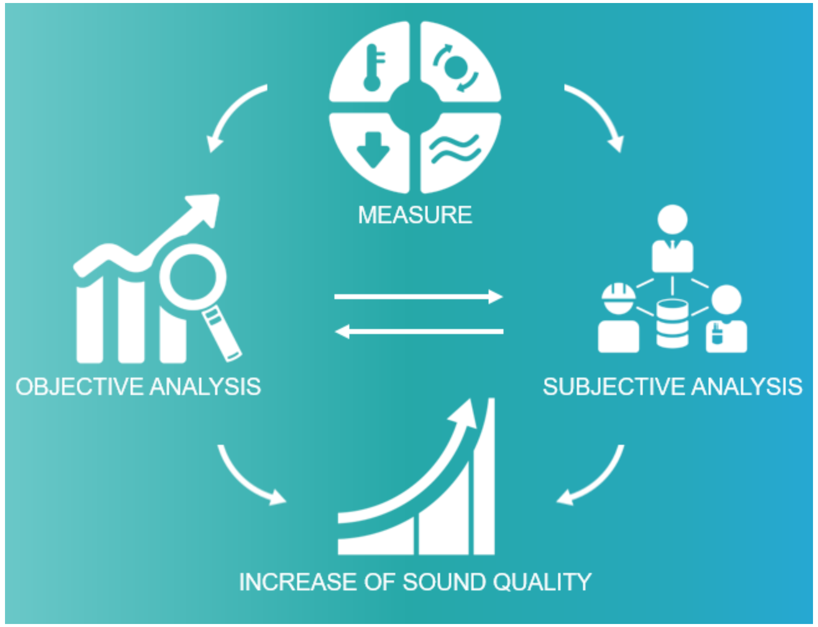
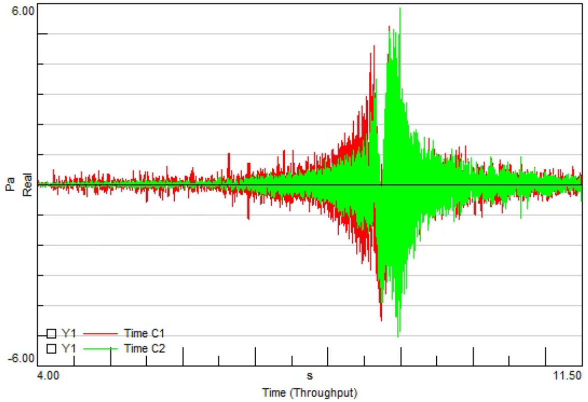


Objective assessment

Analyze your sound with measures that can be quantified

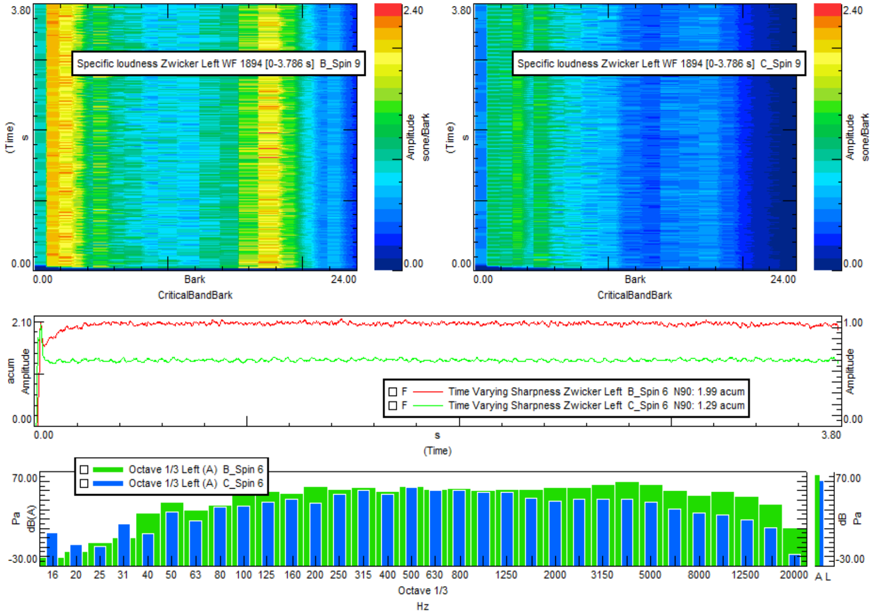


Subjective assessment

Study the *perception* of the sound

What are the positive and negative contributors to your products sound

Psychoacoustics is the science of sound perception. It studies the psychological and physiological responses associated with sound



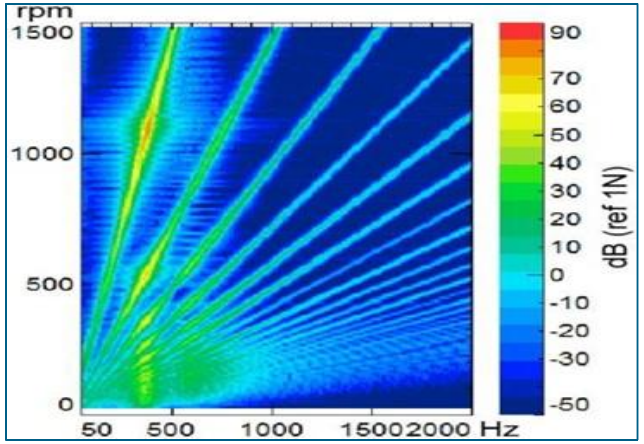
Control contribution of new noise sources

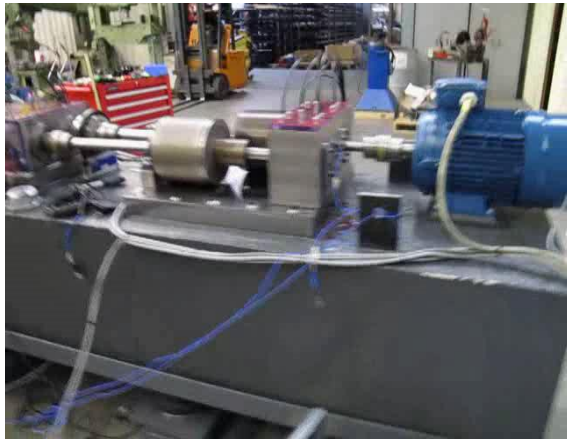
Gear Whine

Gear Whine becomes more audible:

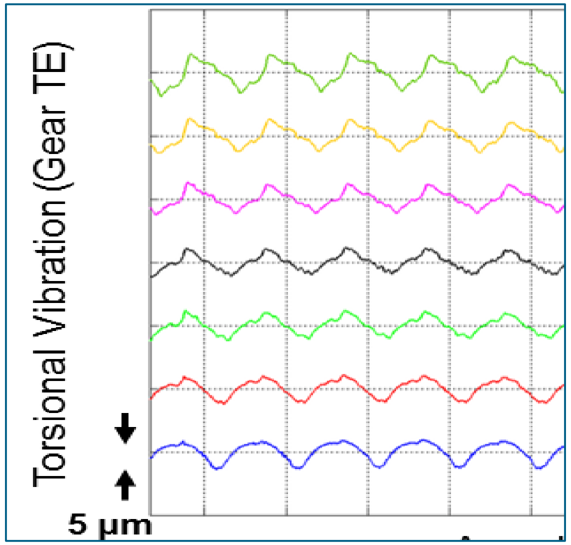
- Reduced masking effect of EM
- Potentially gearboxes running at very high RPM (> 100 000 RPM)

- Gear whine caused on level of gear teeth (bending, clearances, eccentricity)
- Can be seen in error in transmission output RPM
- Test transmission error for different gear designs (difference in gear design)





Measurement of input and output RPM with incremental encoder



Active Sound Design
How to support key brand values with changing technology?

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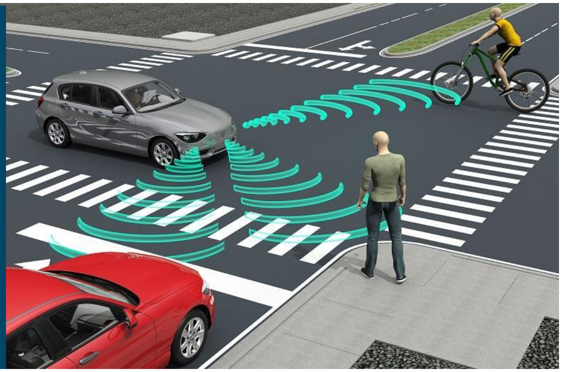
(H) EV
Exterior

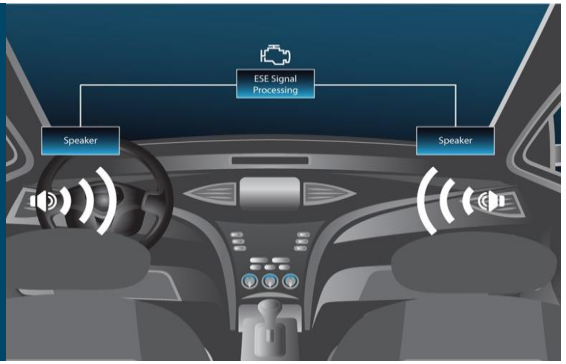
Low speed pedestrian warning, AVAS system



(H) EV
Interior

Great acceleration

No real sound perception



Brand Values

Vehicle Sounds

Sound Quality

ICE

Reducing emission & weight,

Downsizing,

higher pressures

Sport >< Comfy

AV

Adaptive soundscape

Need for Active Sound Design for Automotive
New challenges & opportunities require dedicated processes, skills & tools

Delivering the right sound that supports the vehicle brand

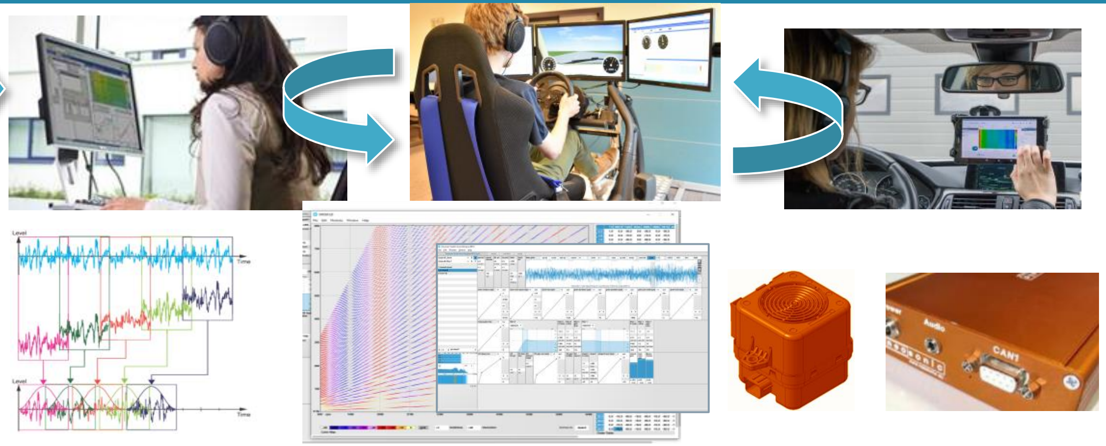
Active Sound Design for (H)EV, ICE, AVAS

Brand Definition & Sound Branding Strategy

Active Sound Design tool

Creation, evaluation & refinement of Sound Signatures

In Office – On simulator – In vehicle



Implementation in Production vehicles

Agenda:

Keep increasing development efficiency

Support NVH testing for electrified powertrains

Keep control on NVH for ICE

How to balance NVH against performance & efficiency?

NVH performance does not stand alone

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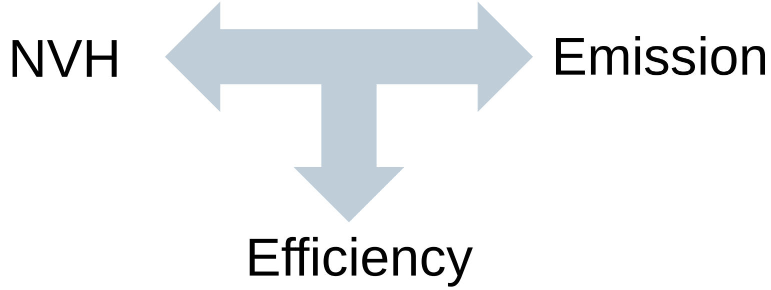
Implemented control strategies of ECU have direct impact on the NVH, but also overall performance & fuel efficiency!

Keep control on Powertrain NVH has become increasingly challenging
How to avoid (late) control changes impact NVH?

Solution:
Go beyond assessment of purely the powertrain NVH



How to balance NVH against performance & efficiency?

Solution: Combine 5 traditionally separate systems into one synchronized measurement on the powertrain test bench

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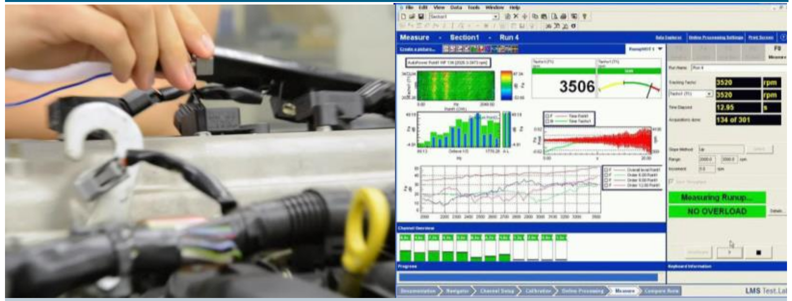
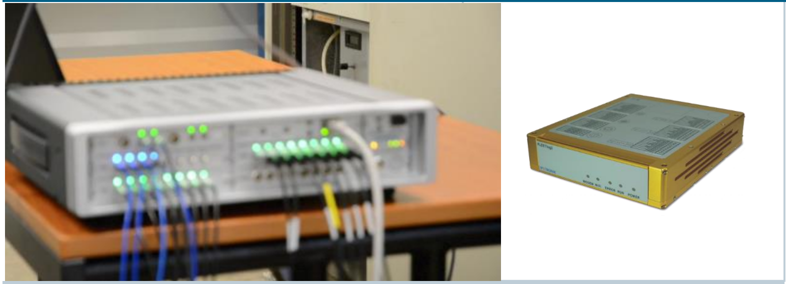
NVH assessment



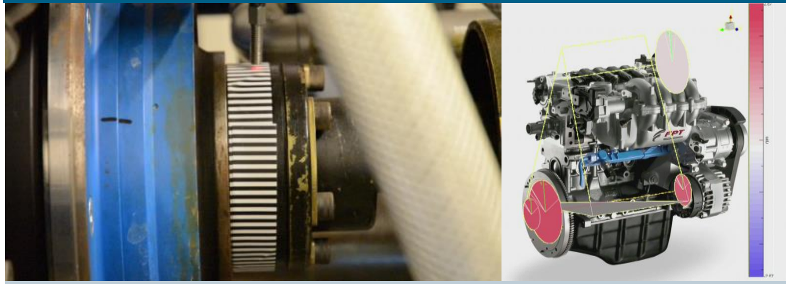
Orders, ODS, Sound Power, …

Access data from ECU



Access any parameter from ECU through support of CCP or XCP

Torsional Vibration Assessment

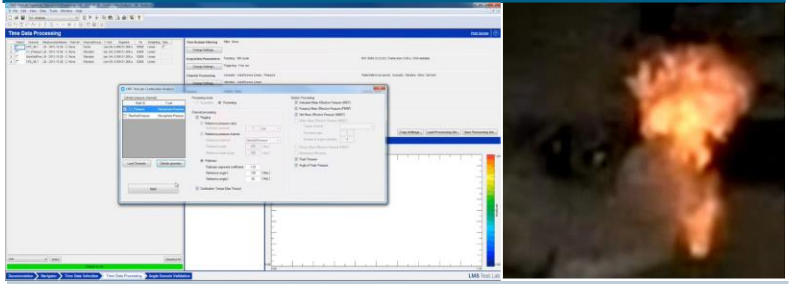


Torsional Resonances, Front-end Accessory drive performance, …

Localize Sound Source

Gain insight in weak acoustic spots & components

Combustion Analysis



Assess engine performance (e.g. IMEP) & efficiency

How to balance NVH against performance & efficiency?

1- Powertrain NVH Testing

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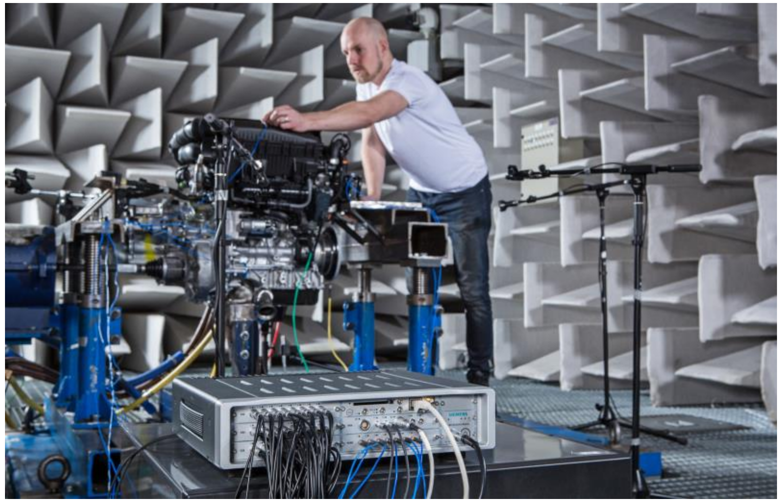
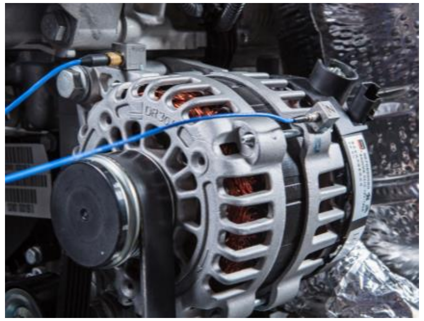
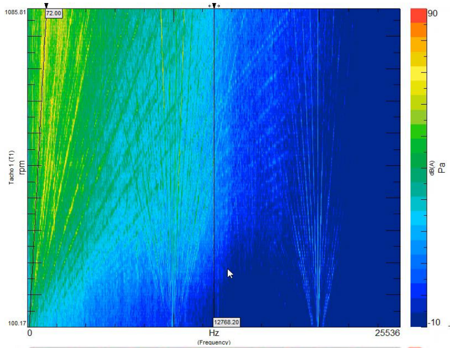
Assess Operational NVH

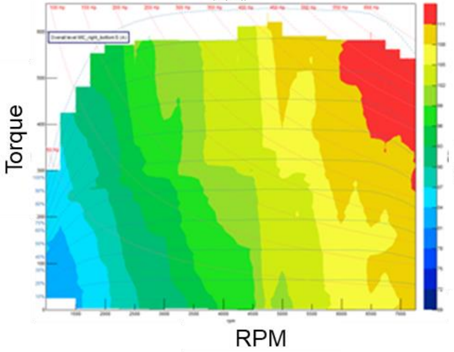


Acceleration, Sound Pressure, Torque, RPM, Torsional vibration, Voltage, Current, Strain, CAN, Flexray, Cylinder Pressure, GPS, …

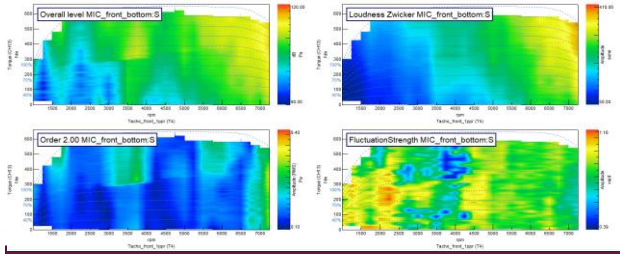
Signature Analysis
Orders, OA levels, …



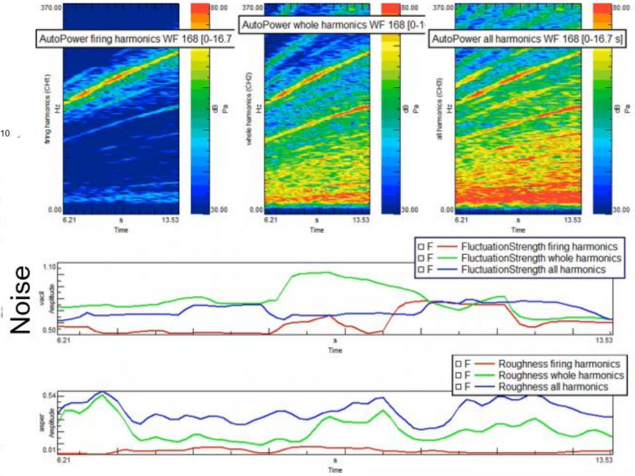




Assess Sound Quality



Sound Power, Loudness, Roughness, Sharpness, …



… and more

Assess Structural behavior

Modal testing & Assess transfer functions

How to balance NVH against performance & efficiency?

2- Link ECU information with NVH & performance

LOW — **Amount of information accessible** — High

Diagnostics protocol

- OBD-II (even used for car maintenance)
- Gives access to limited information such as RPM, vehicle speed
- NO dbc file required

RPM, SPEED

FAST & IDEAL for benchmarking

CAN traffic protocol

- Requires **dbc** file to interpret information
- Also support for FlexRay traffic (fibex file)
- Support of CAN-FD

	Ok	OnOff	PhysicalChannelId	Point
1		☑	Input10000	XSI 1::DDCM_CANLSFT_R_01::ExternalTemp
2		☑	Input10001	XSI 1::ECM_CANHS_RNr_02::EngineCoolantTemp
3		☑	Input10002	XSI 1::ECM_CANHS_RNr_02::MaxEngineSpeedR...
4		☑	Input10003	XSI 1::TORQUE_ECM_CANHS_RNr_01::EngineRPM

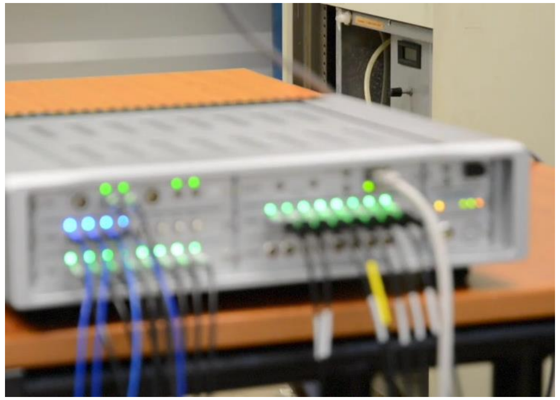
Only for own cars

Calibration protocol (CCP/XCP)

- Direct Access to memory of ECU
- Requires A2L file
- Requires third party partner

For instance IPEtronik Fleetlog2 configured as gateway

Only for own cars & typically less experience in NVH teams



How to balance NVH against performance & efficiency?

3- Assess Torsional Vibrations: From prediction to visualization

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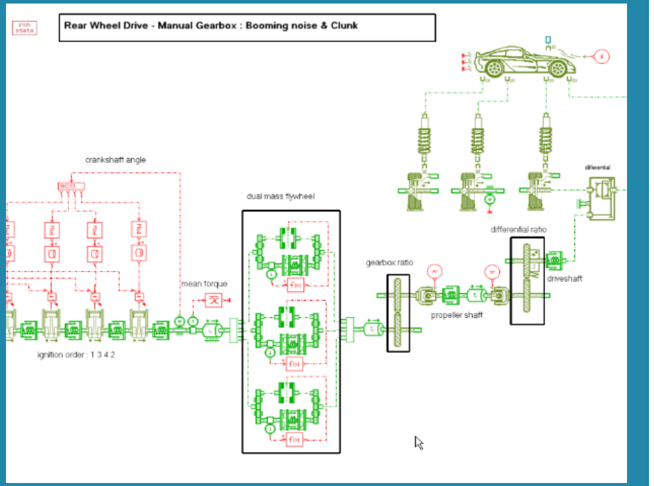
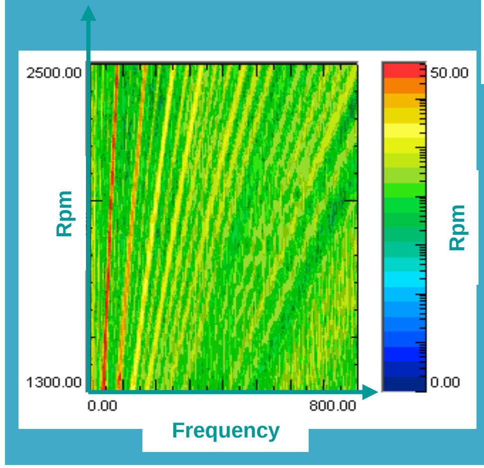
Predict torsional vibration using simulation models

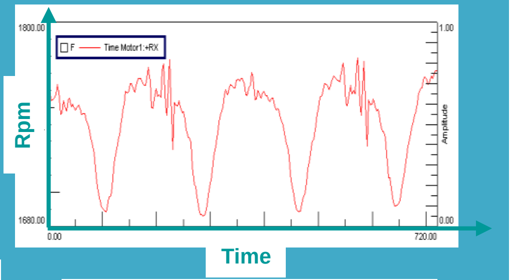
- ✓ **Use simulation models to predict torsional vibration**
- ✓ **Easy to modify to minimize the effect**

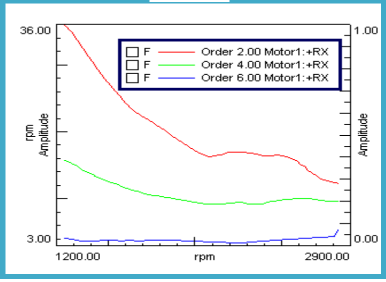


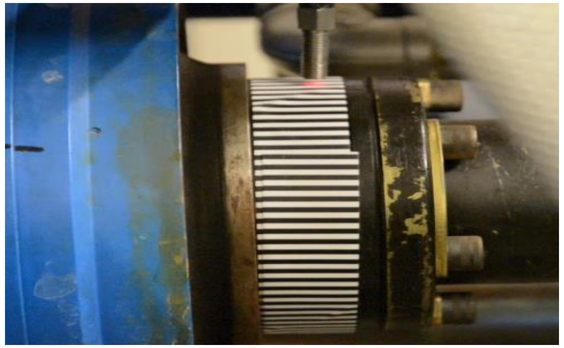
Torsional Vibration Testing

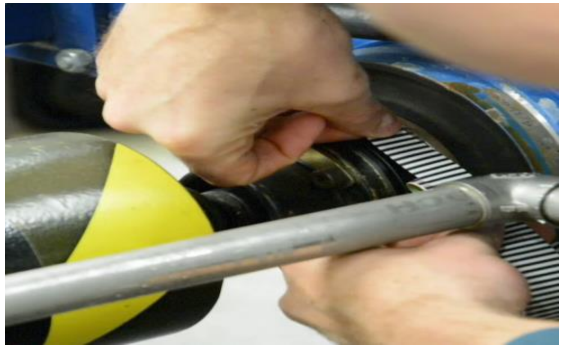
- ✓ **Optical probes, incremental encoder, magnetic pick-ups, torsional laser, etc.**
- ✓ **Measurement:**
  - ✓ **High number of pulse/rev**
  - ✓ **Torsional vibration orders**
  - ✓ **Animation of results**

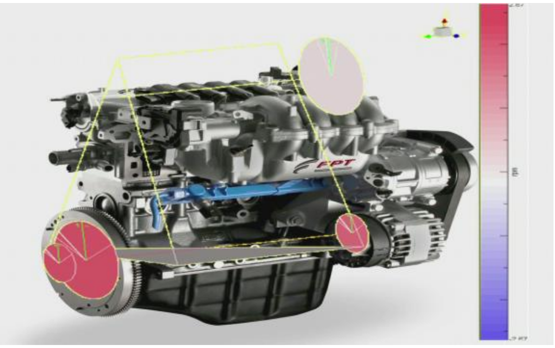












How to balance NVH against performance & efficiency?

4- Combustion Analysis to assess combustion performance

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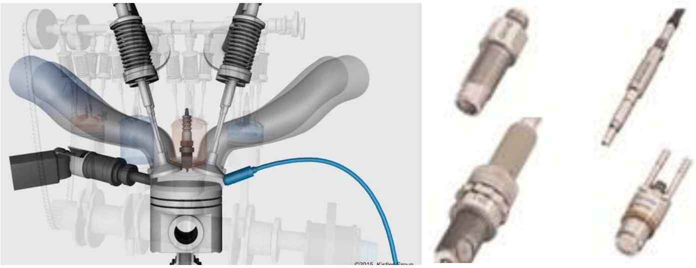
Support of required sensors

Pressure sensor

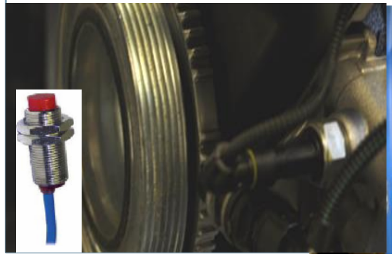
Direct connection of pressure sensor



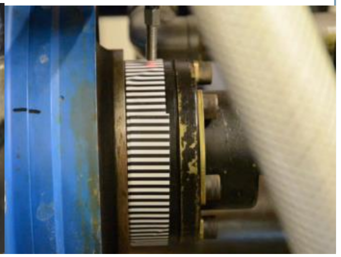
Angular Position

Crank shaft Angular position

Magnetic Pick-up



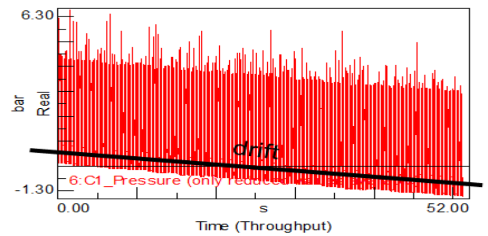
Optical Coders



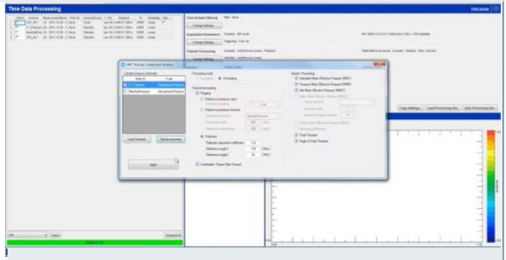
Assessment of many combustion metrics

Important metrics for Combustion Analysis

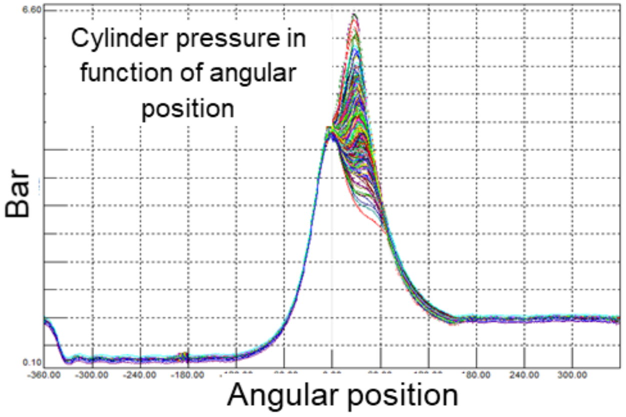
- PV-diagram
- Mean Effective Pressure:
  - IMEP/NMEP/PMEP
  - BMEP/Mechanical Efficiency
- Peak Pressure, Pressure Rise Rate, Burn Rate

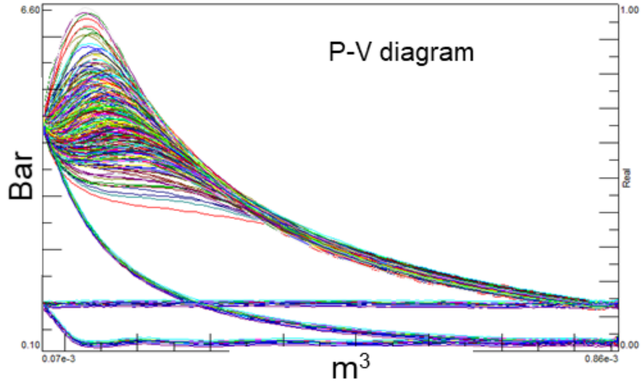


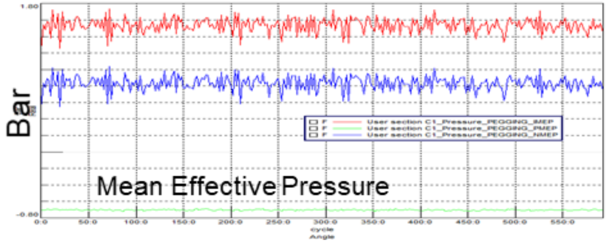
Support correction for temperature drift (Pegging)



Zero Angle Reference TDC Automatically or manually







How to balance NVH against performance & efficiency?

5- Array of microphones for Sound Source Localization

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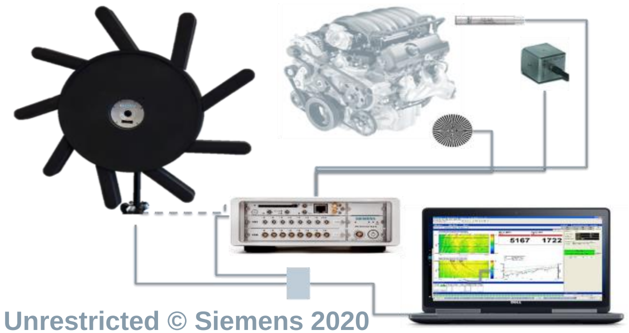
Use of array of microphones

Scalable digital array

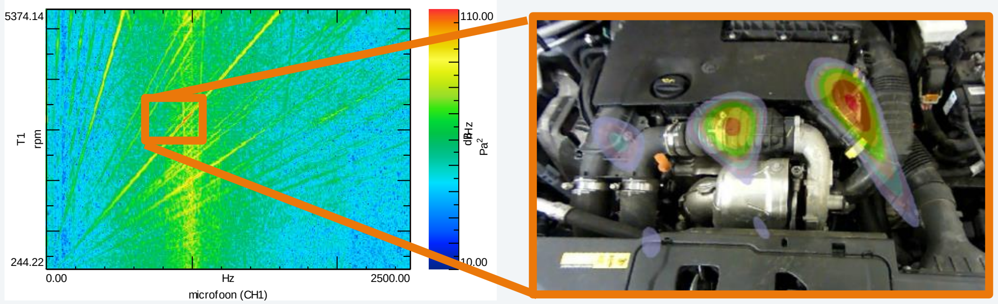
Scalable in size
- 45 mics
- 81 mics
- 117 mics

Easy to include in powertrain measurement chain

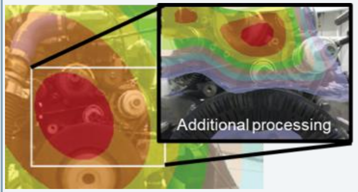


Correlation with NVH measurements

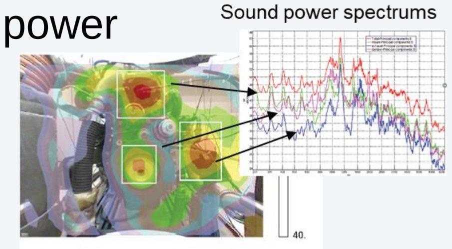
Always be ready to analyze conditions using the arrays of interest



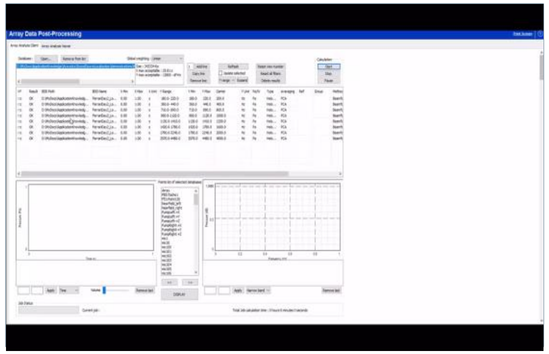
Wide frequency

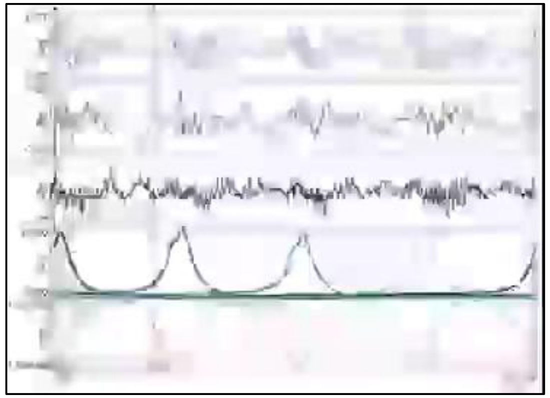


Sound power



Add-ons for:
- Focus on orders or moment within combustion cycle
- Separate combustion & mechanical noise





Value of measuring all 5 systems together

Balancing NVH against other attributes

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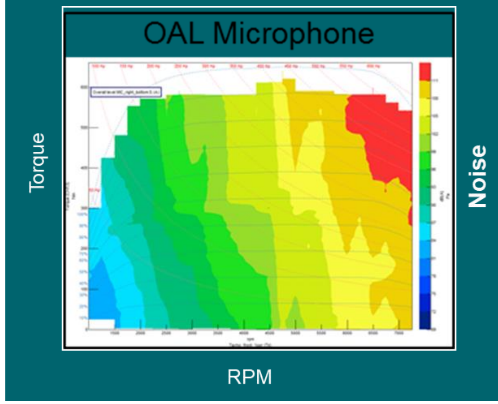
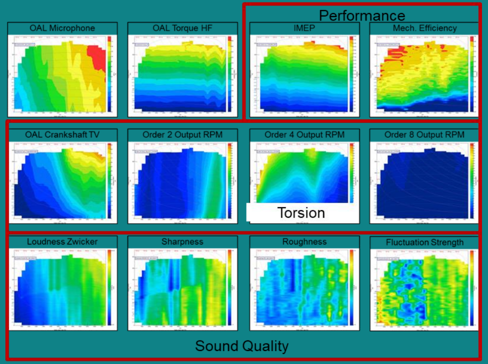
Example 2
Assess Engine map for not only NVH but also Performance metrics, torsional …

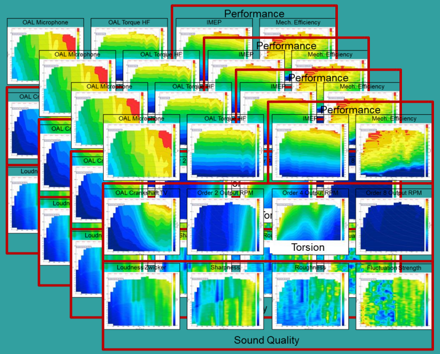
From pure NVH assessment



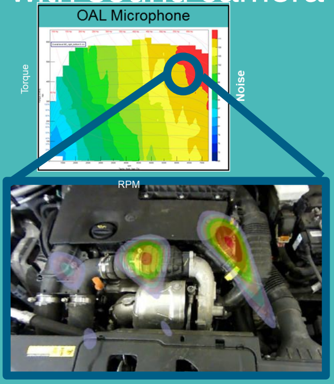
To Assessment of many metrics in parallel



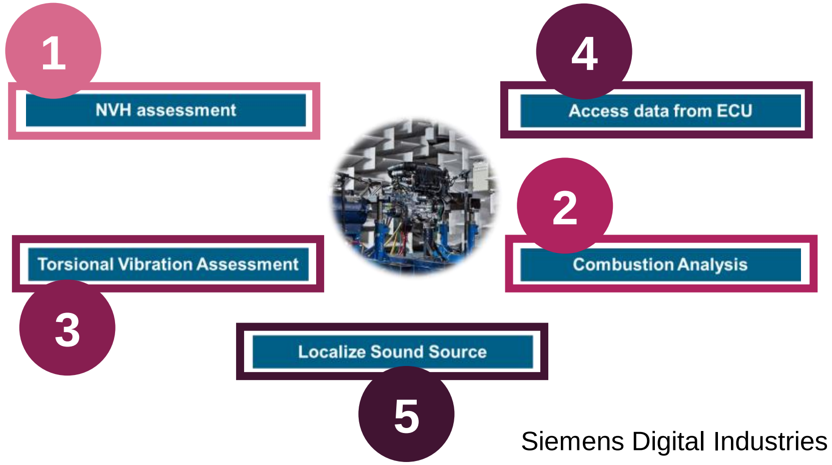
To assessment for different variations in control strategy



Analyze specific conditions with sound camera



1. Measure NVH
2. Assess IMEP & Powertrain Efficiency
3. Assess Torsional Vibration orders
4. Assess ECU parameters
5. Localize Sound Sources for certain conditions



Powertrain NVH Testing
Key take-aways

Increasing development efficiency

✓ Increase NVH testing efficiency

✓ Frontload NVH performance

Support NVH testing for electrified powertrains

✓ Cover needs for electrified powertrains

✓ Support for more important sources

Keep control on NVH for ICE

✓ Go beyond pure NVH testing

✓ Combining separate measurement systems into one integrated test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