Benchmarking in E-Mobility -
Measurement Applications, Efficient Solutions

CSM web seminars

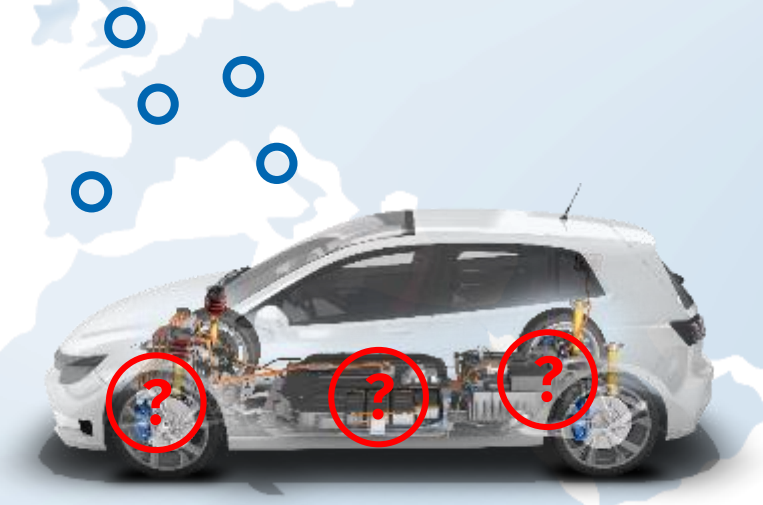
CSM Xplained
measurement technology

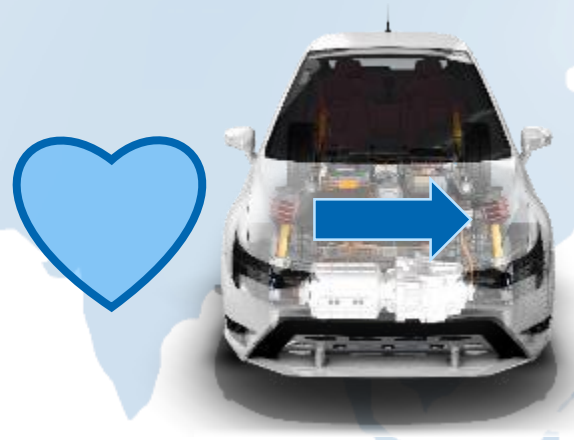
VECTOR

Innovative Measurement and Data Technology

Why Benchmarking?

	1	2
A	+	-
B	+	+
C	-	+
D	+	+





x, y, z

Technical and commercial comparison

Insights into solution strategies

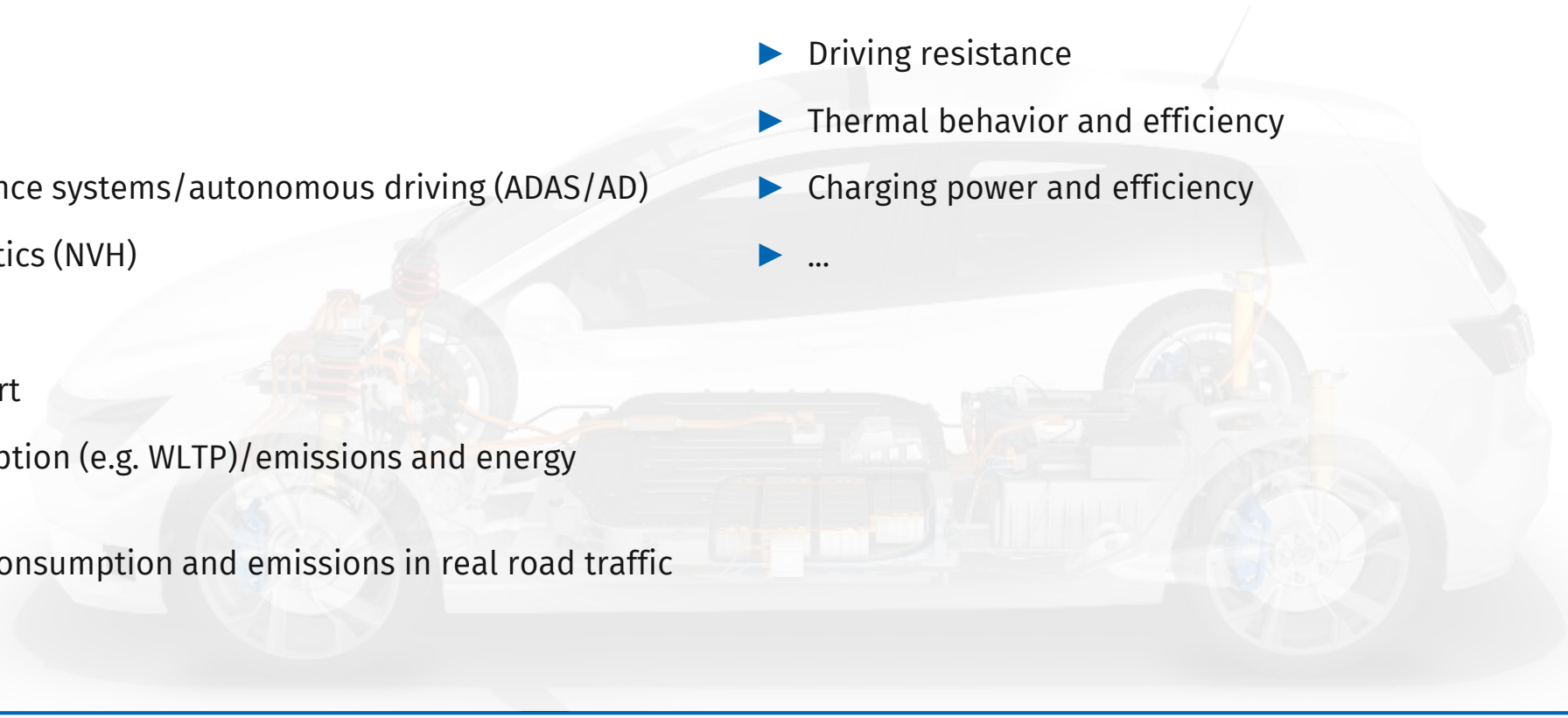
Objectification of subjective impressions

Forward-looking analysis of the market and competitors in order to design your own model strategies as profitably as possible

How is benchmarking done?

Determination of the characteristics to be examined

- Performance
- Driveability
- Driver assistance systems/autonomous driving (ADAS/AD)
- Vehicle acoustics (NVH)
- Handling
- Driving comfort
- Cycle consumption (e.g. WLTP)/emissions and energy management
- Fuel/energy consumption and emissions in real road traffic
- Driving resistance
- Thermal behavior and efficiency
- Charging power and efficiency
- ...



How is benchmarking done?

Determination of the characteristics to be examined

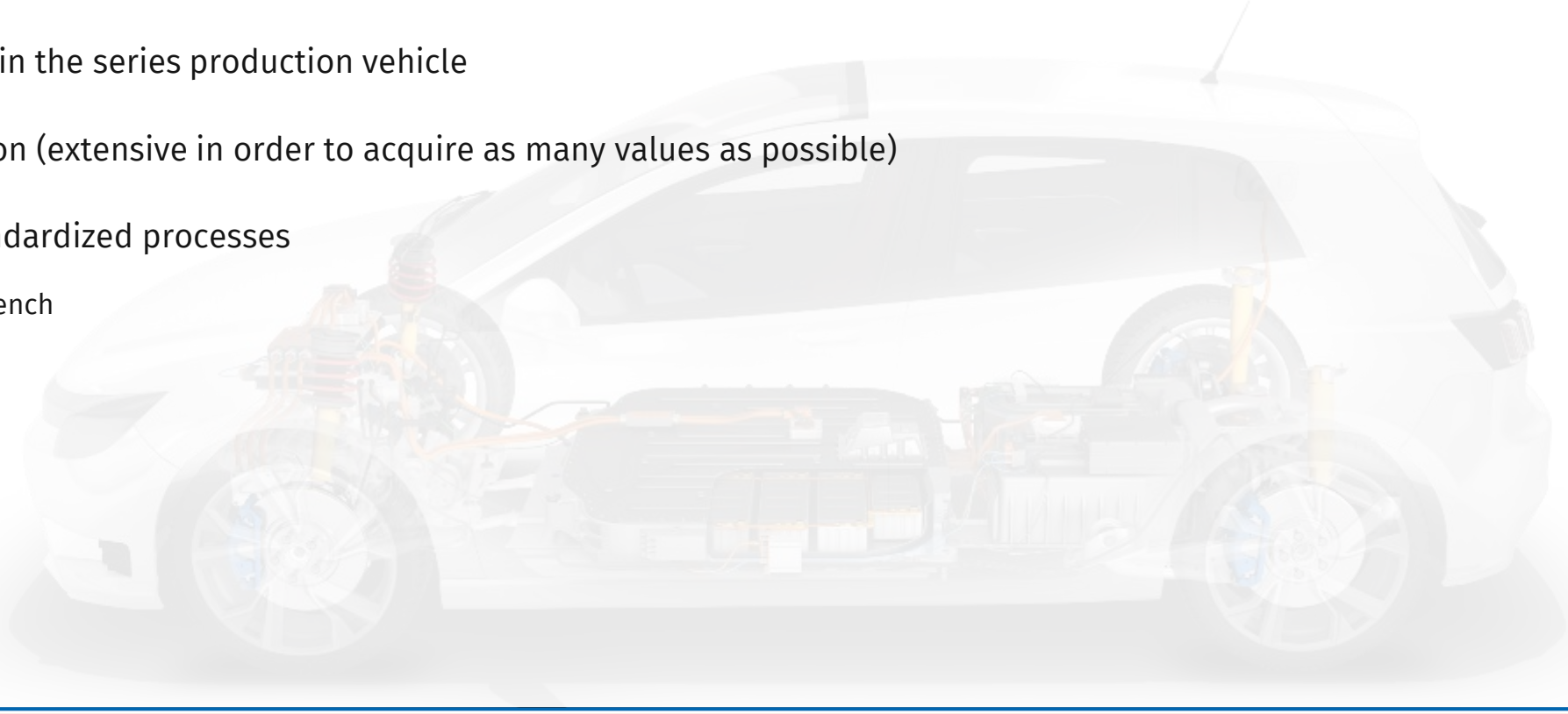
Definition of metrics / physical measured values

Metric to be determined (example)	Real measured value(s)
Performance e-axle peak power [kW]	HV voltage, HV current
Performance e-axle peak torque [Nm]	Torque (by means of torque measuring shaft)
Cooling temperature On [°C]	Temperature sensor (e.g. PT100 or thermocouple)
Cooling temperature Off [°C]	Temperature sensor (e.g. PT100 or thermocouple)
Cooling flow rate [l/min]	Flow turbine (with analog or frequency output)
Efficiency in the WLTC [%]	HV voltage & current + electrical power calculation, as well as determination of mechanical output power from speed and torque of the measurement shaft
Energy consumption in the WLTC [kWh/100km]	Integral of the electrical power over time
Max. vehicle speed [km/h]	Optical speed sensor, max. determination
Acceleration 0-100 km/h and repeatability [s]	Analysis of speed signals over time
DC current (max./nominal) [A]	HV current
System voltage [V]	HV voltage

How is benchmarking done?

Determination of the characteristics to be examined	Definition of metrics / physical measured values	**Measurement**

- Measurement in the series production vehicle
- Instrumentation (extensive in order to acquire as many values as possible)
- Testing in standardized processes
  - Roller test bench
  - Road test



How is benchmarking done?

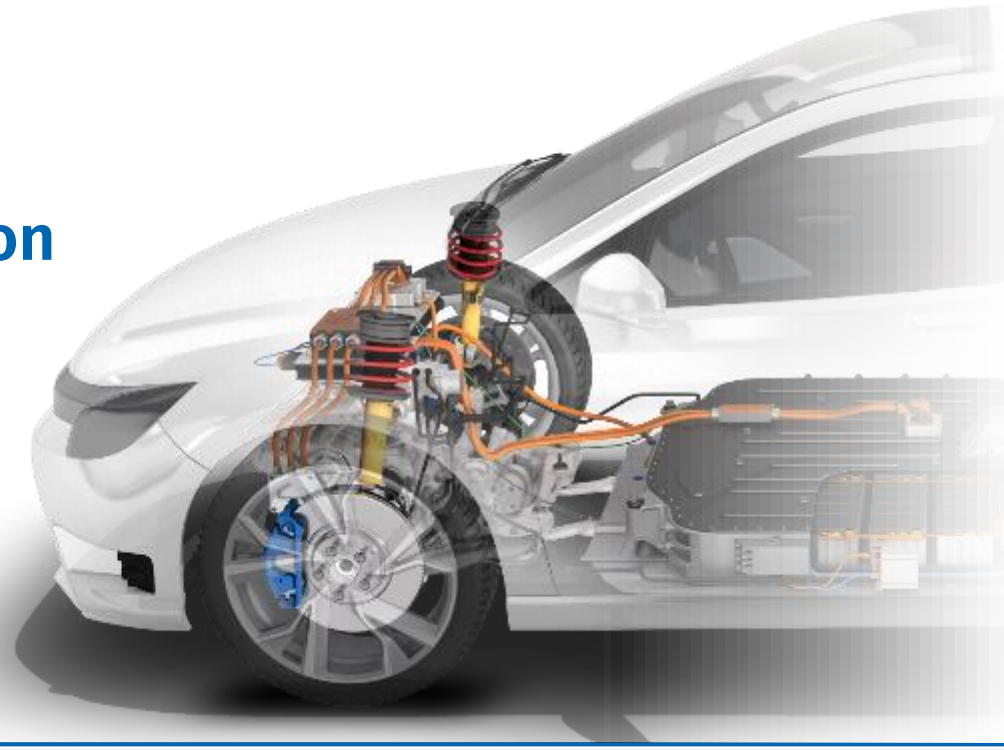
Determination of the characteristics to be examined	Definition of metrics / physical measured values	Measurement	Analysis / Comparison

- Transferring the measurement data to databases
- Analysis and comparison

Challenges for measurement technology

- Acquisition of measurement data
  - In the engine compartment
  - In the trunk
  - In the interior
  - On the chassis and running gear
  - On rotating parts
  - In the HV environment

Installation space



- Series production vehicles only offer limited space for the installation of measurement technology
- Fairings, covers etc. make installation difficult
- Proper operation must not be impaired

The measurement technology must be as compact and robust as possible and, depending on the measurement point, ensure HV safety

Challenges for measurement technology

- Instrumentation usually takes several weeks
- Measurement technology must not be an additional time waster (budget)
- Facilitate and accelerate instrumentation with assembly aids and customized adapter solutions

Time

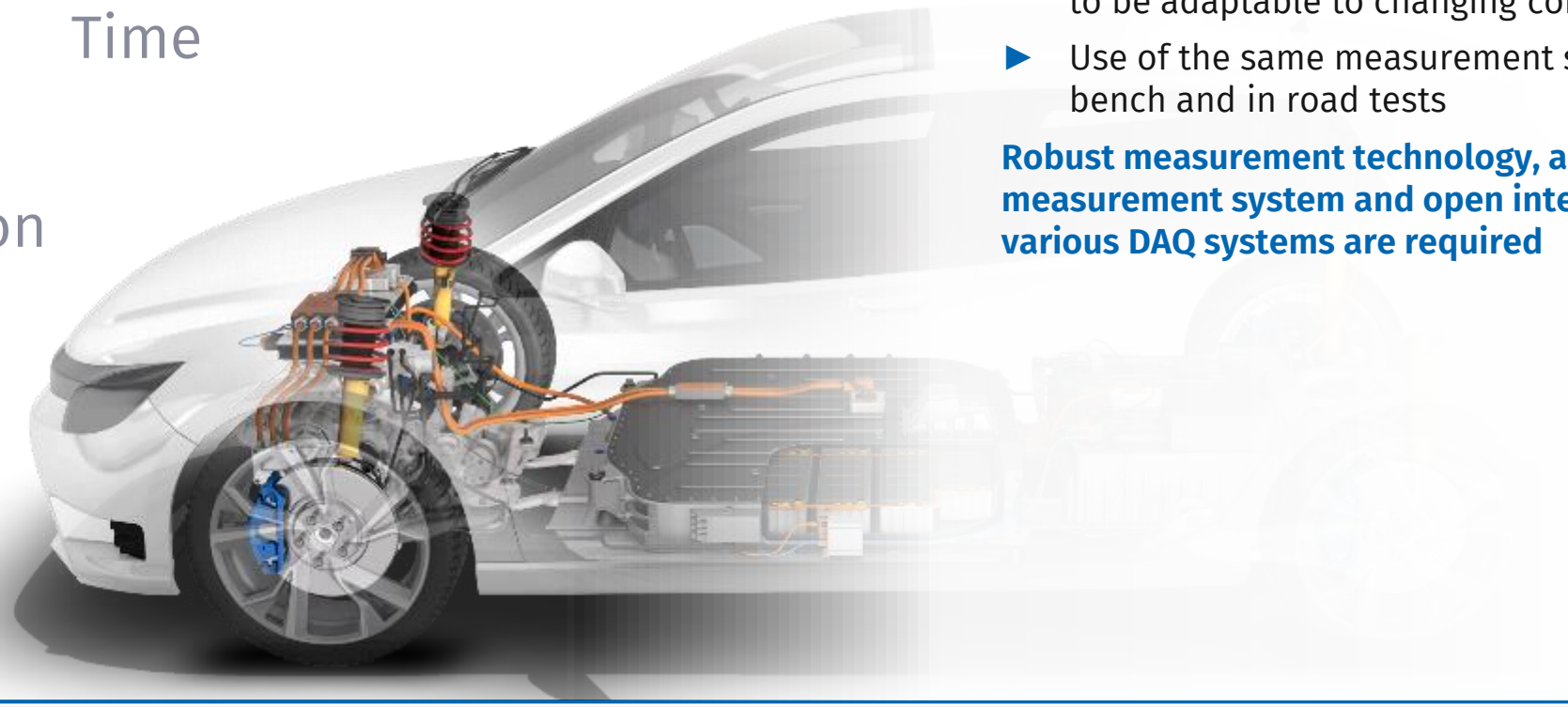
Installation space

Challenges for measurement technology

Flexibility

Time

Installation space



- Acquisition of numerous measured variables with just one measurement system
- Ideally, the measurement technology can also be used for other measurements
- The measurement setup should be flexible in order to be adaptable to changing conditions
- Use of the same measurement setup on the test bench and in road tests

Robust measurement technology, a modular measurement system and open interfaces for use with various DAQ systems are required

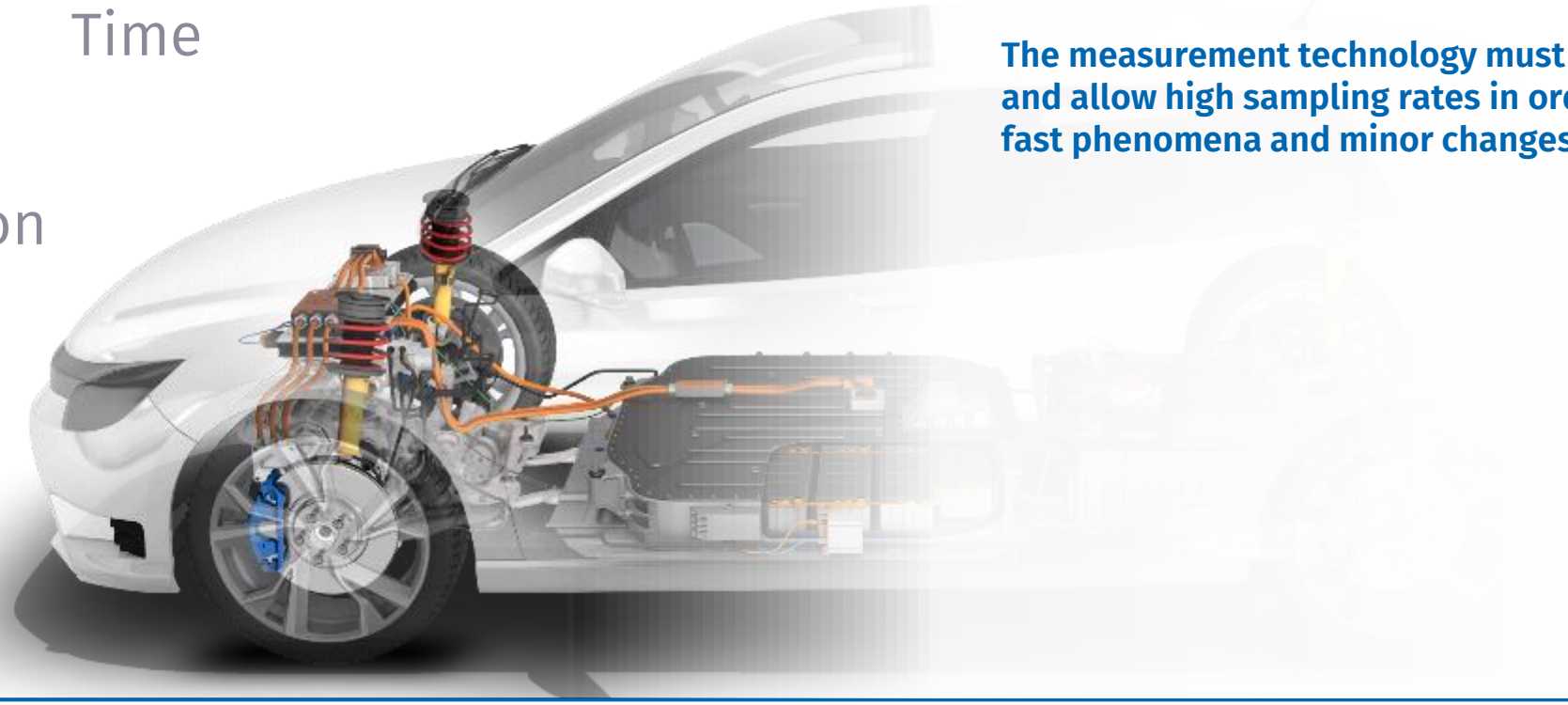
Challenges for measurement technology

Precision

Flexibility

Time

Installation space



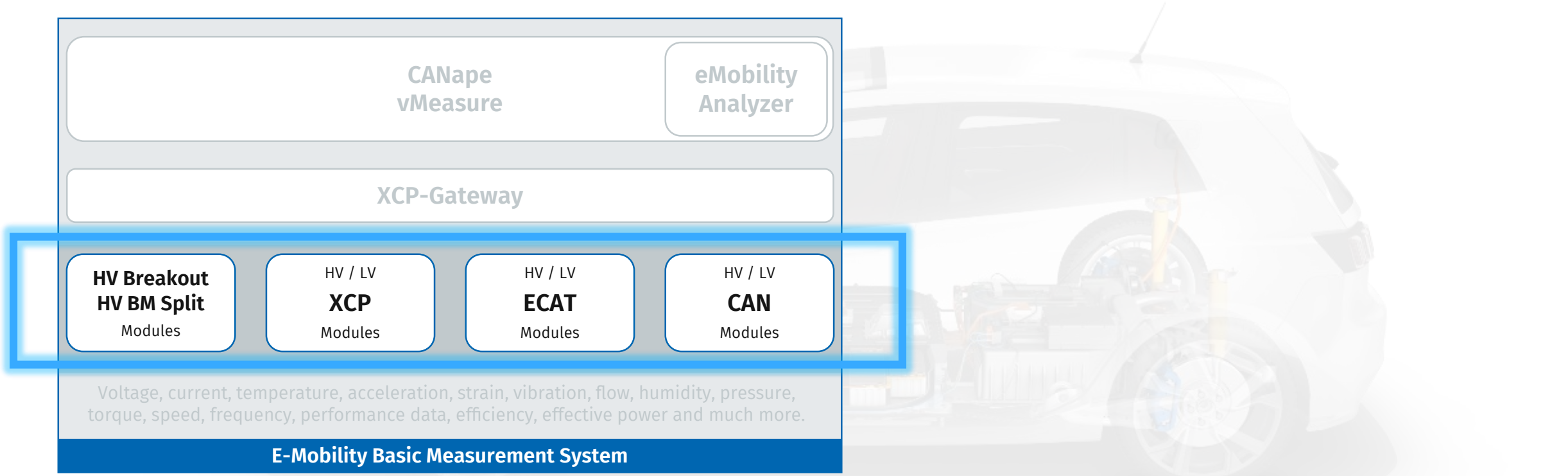
- The differences between comparison models often lie in the details
- The same measurement technology is strongly recommended in all vehicles in order to be able to compare the measurement data directly

The measurement technology must be high-resolution and allow high sampling rates in order to acquire even fast phenomena and minor changes

CSM measurement technology for benchmarking

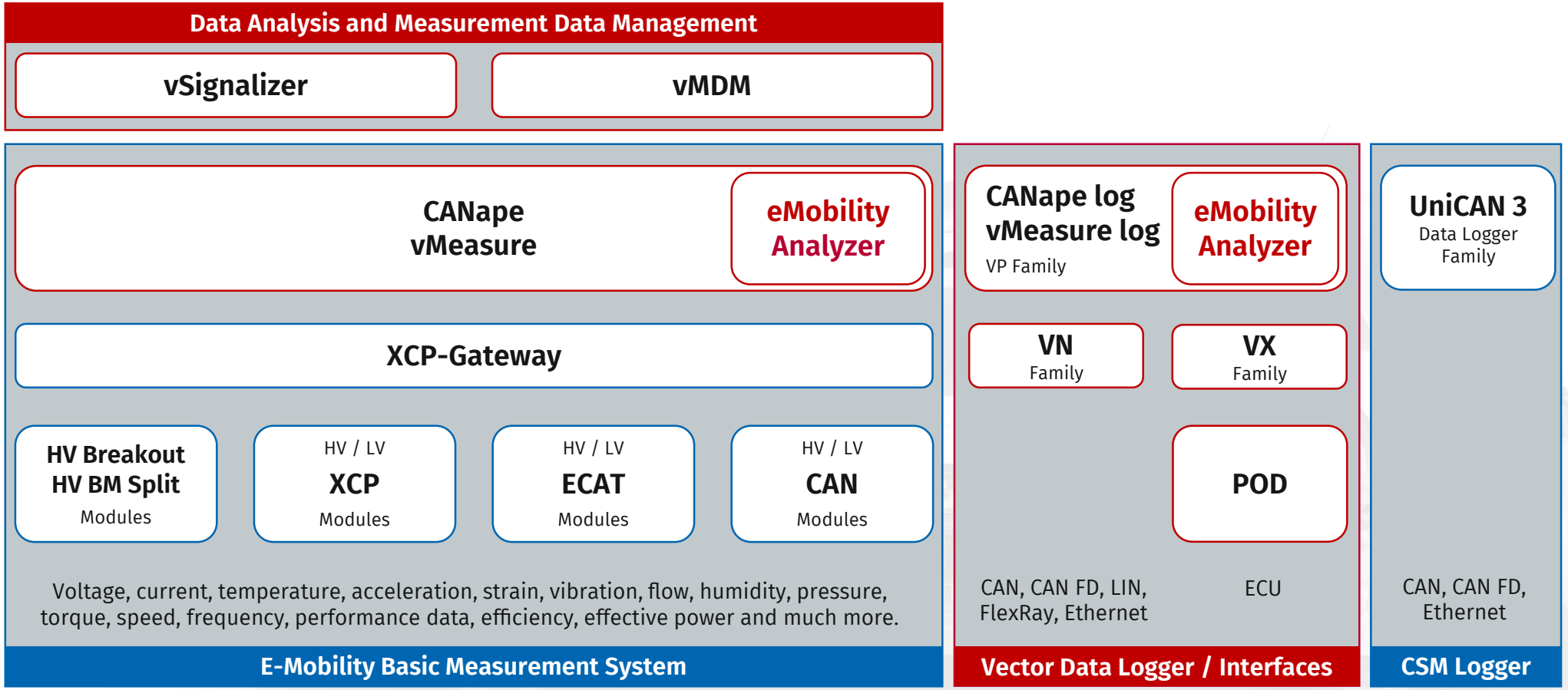
		Current	Voltage	Temperature	Sensor voltages	Strain gauges	IEPE	Frequencies
HV-safe	XCPoE							
	EtherCAT							
	CAN							
Conventional	EtherCAT							
	CAN							

The Vector CSM E-Mobility Measurement System



The Vector CSM Measurement System on www.csm.de

The Vector CSM E-Mobility Measurement System



Range benchmark

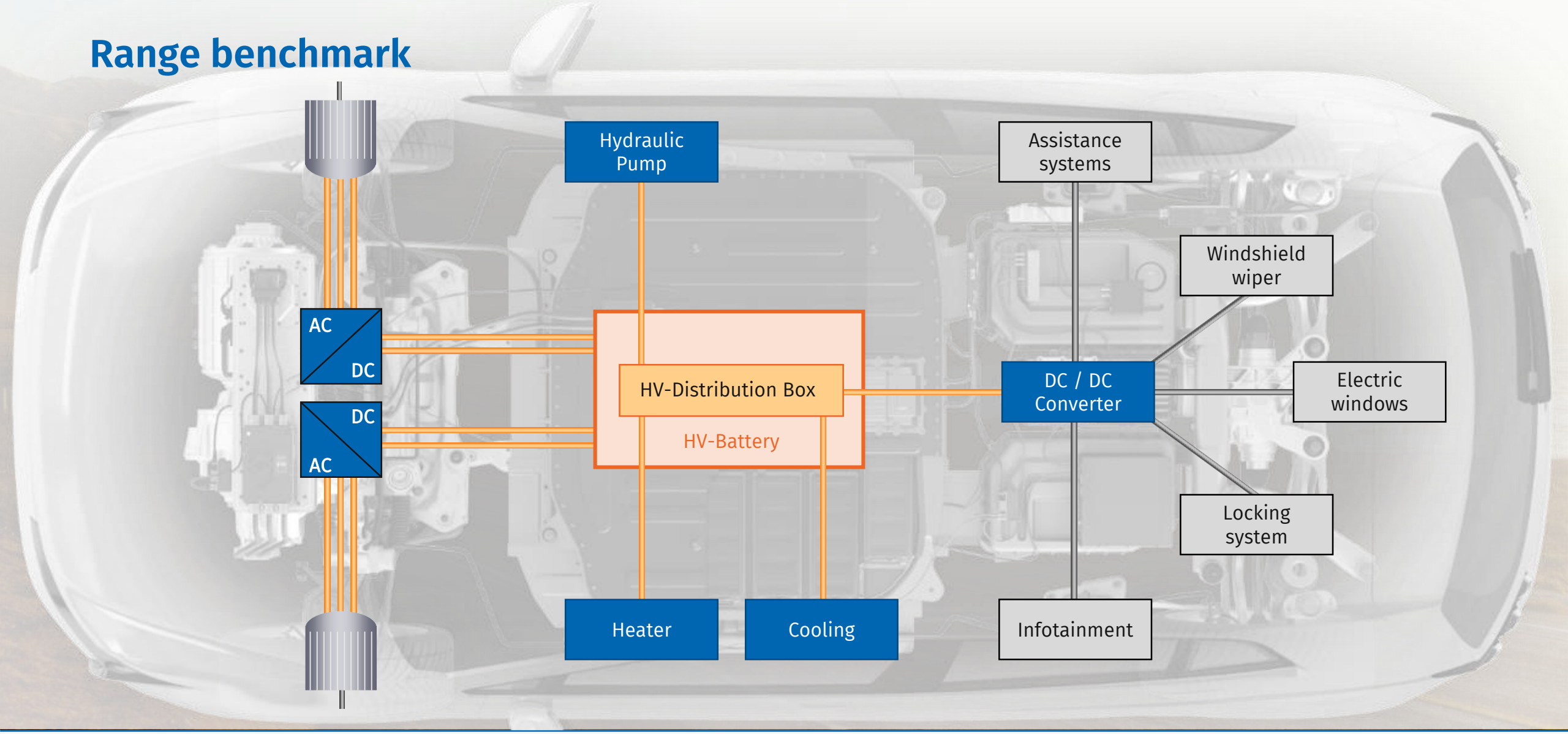
Insights into solution strategies

How can the range of a BEV be increased without sacrificing essential comfort?

Auxiliary consumers in the low-voltage on-board electrical system also use the energy from the traction battery for the electric drive.

- Power consumption of the auxiliary consumers (LV vehicle electrical system)
- Investigation of the interactions of the LV vehicle electrical system with the HV vehicle electrical system
- Efficiency of the powertrain
- Verification of air conditioning and temperatures in components
- Monitoring switching operations of the control units

Range benchmark

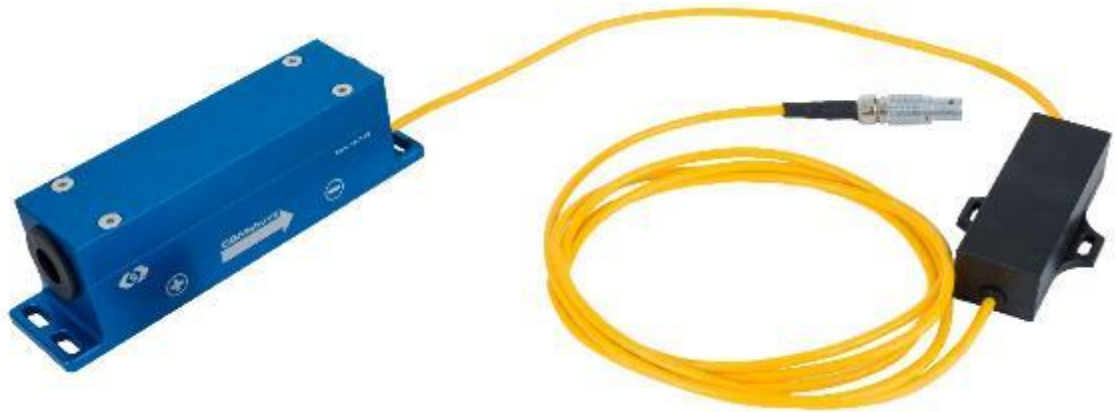


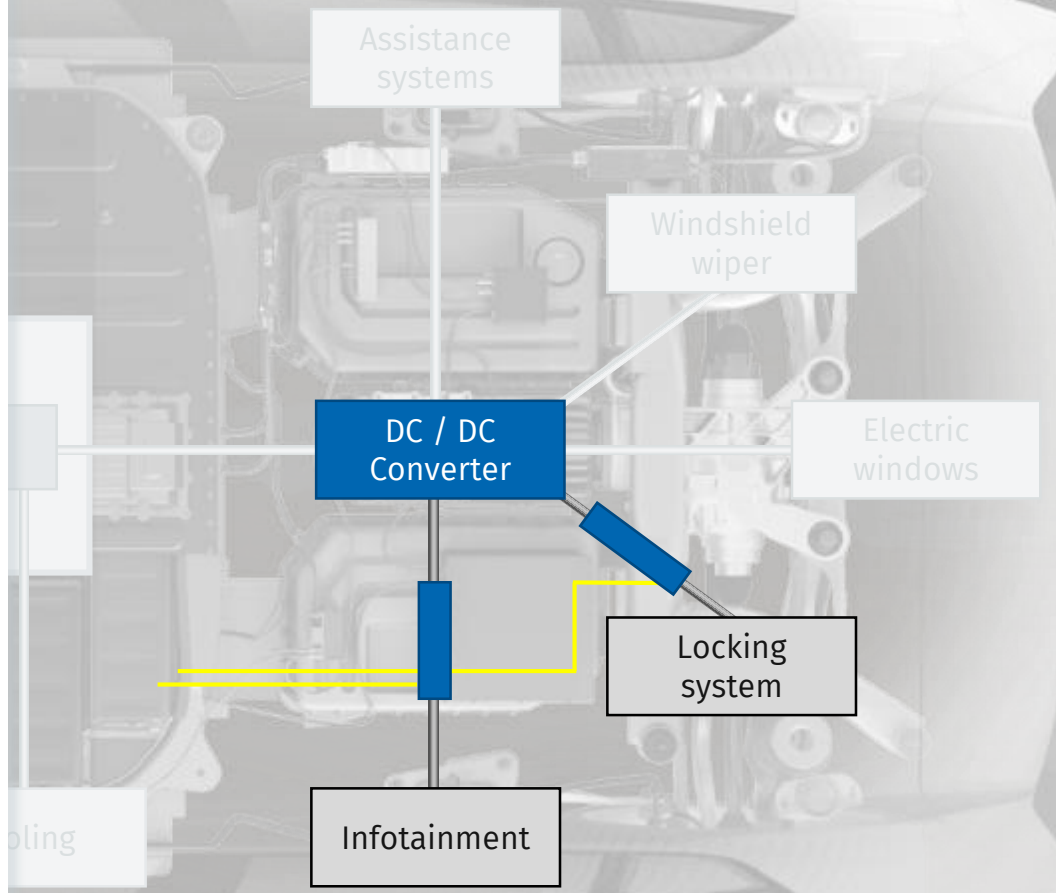
Power consumption of the auxiliary consumers

CSMshunts
on www.csm.de

CSMshunts

- Precision resistor for current measurement
- Active measurement amplifier
- Temperature compensation over the entire operating range from -40°C to +125°C
- Small version for ±2.5 A and ±25 A measurement range and direct tap for the vehicle fuse box (ATO fuses)
- Slightly larger version for measurement ranges ±125 A and ±250 A

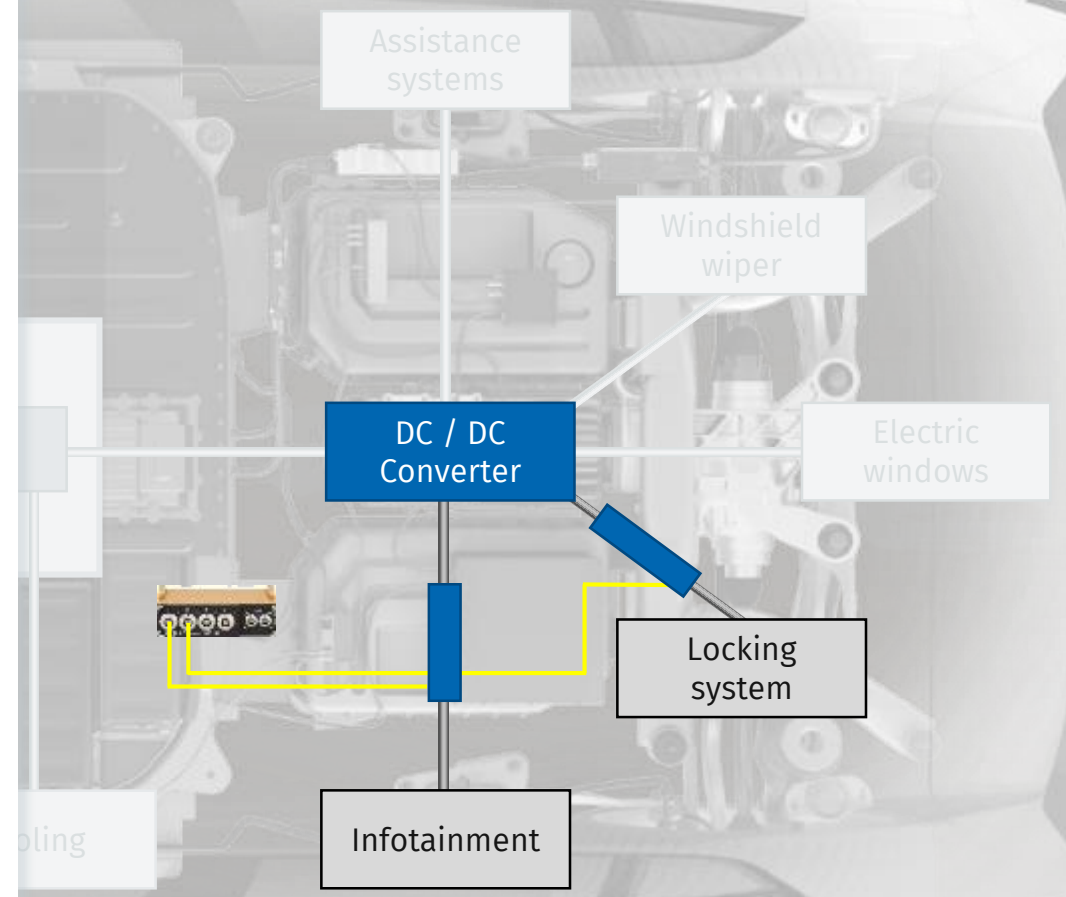




Power consumption of the auxiliary consumers

CSMshunts

- Small version for ±2.5 A and ±25 A measurement range and direct tap for the vehicle fuse box (ATO fuses)
- Slightly larger version for measurement ranges ±125 A and ±250 A
- Connection to AD measurement modules

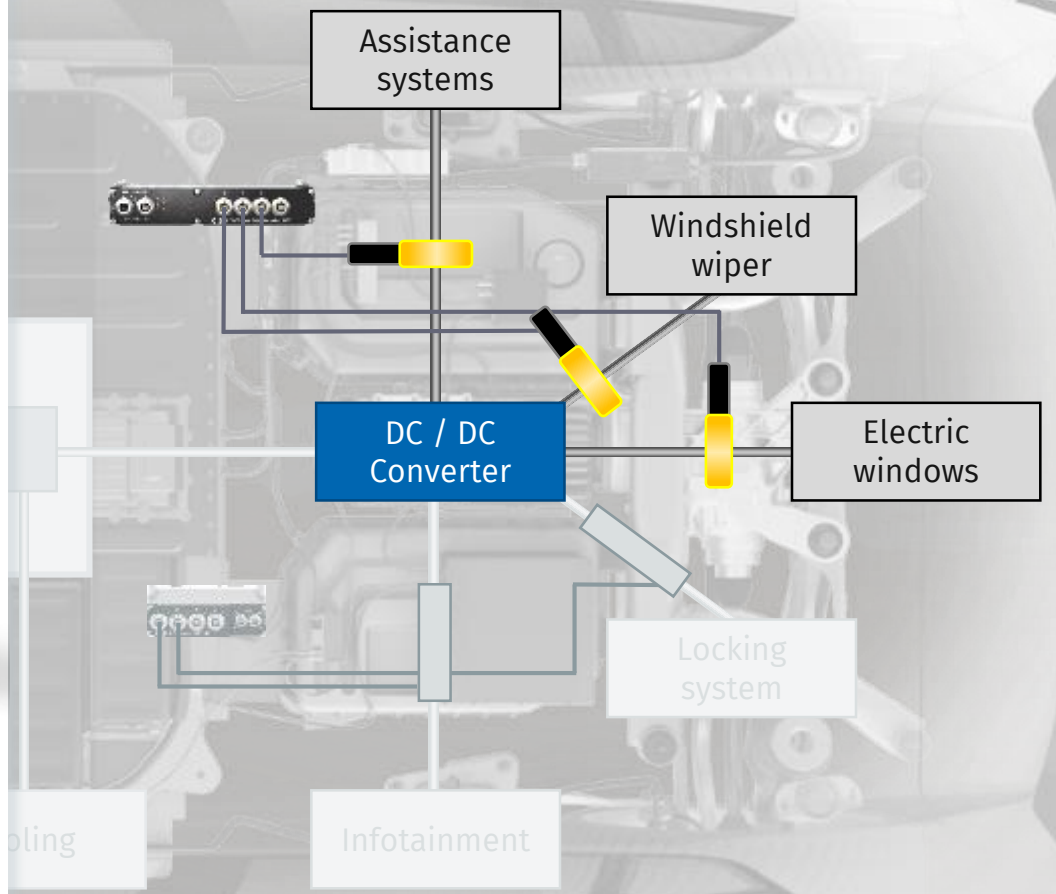


Power consumption of the auxiliary consumers

CSM Current Clamp on www.csm.de

CSM Current Clamp

- Measurement ranges from ±20 A to ±1,000 A
- Threshold frequency up to 2 MHz (depending on current measurement range)
- Pre-wired with supply module

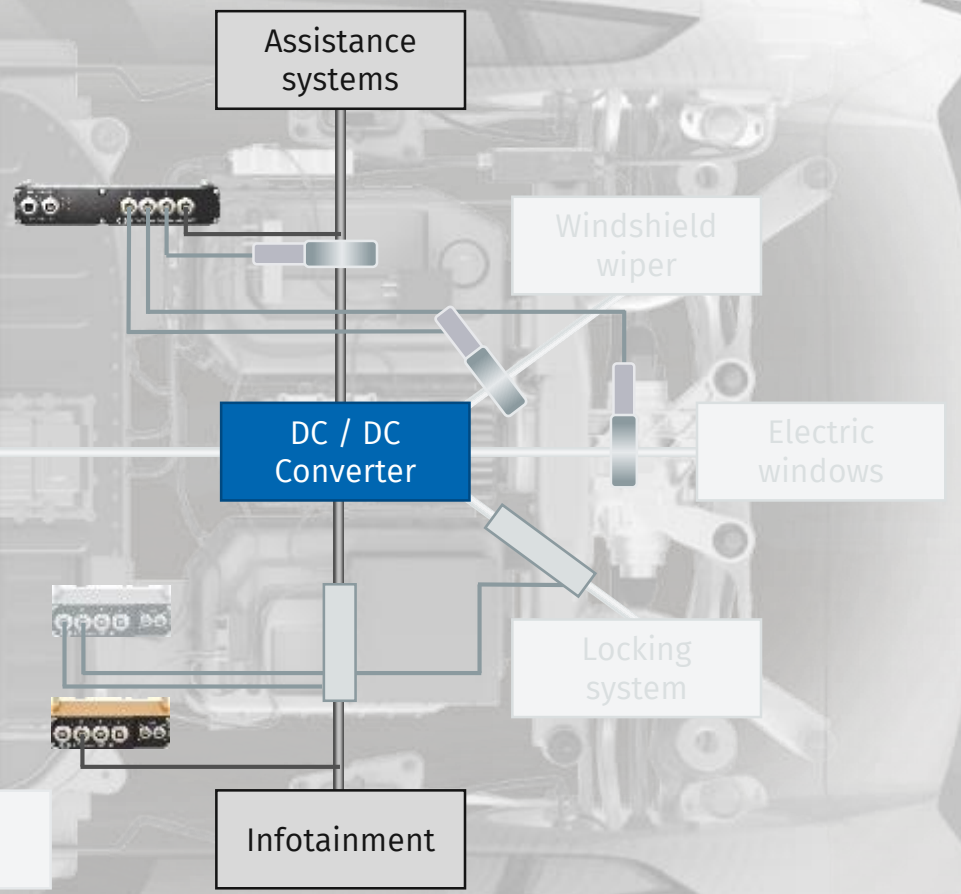


Power consumption of the auxiliary consumers

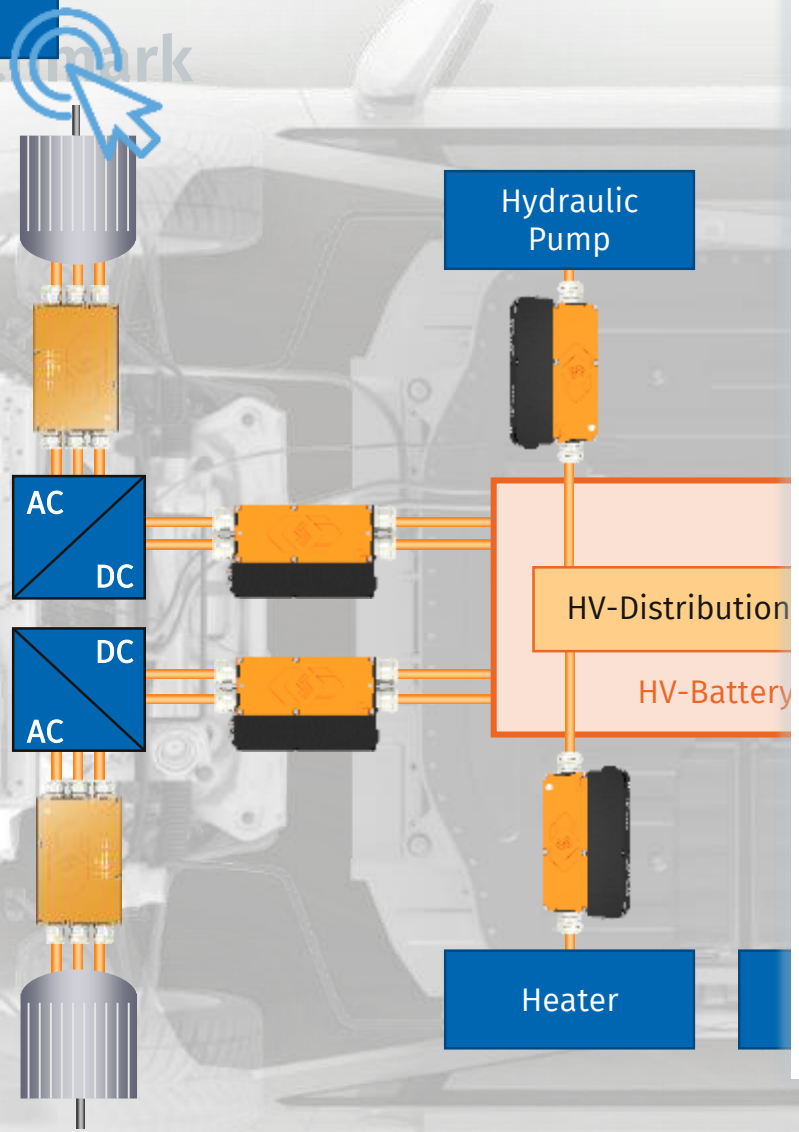
AD measurement modules on www.csm.de

Signal connection current sensors / voltage tapping

- Using CAN or EtherCAT® measurement modules
- Many measuring ranges for different measuring tasks
- Low-noise signal processing, even at extreme temperatures
- High effective resolution and measurement accuracy (typ. 0.05%)
- Integrated sensor supply
- Protection class IP67
- Operating temperature range: -40°C to +125°C



HV Breakout Modules
on www.csm.de

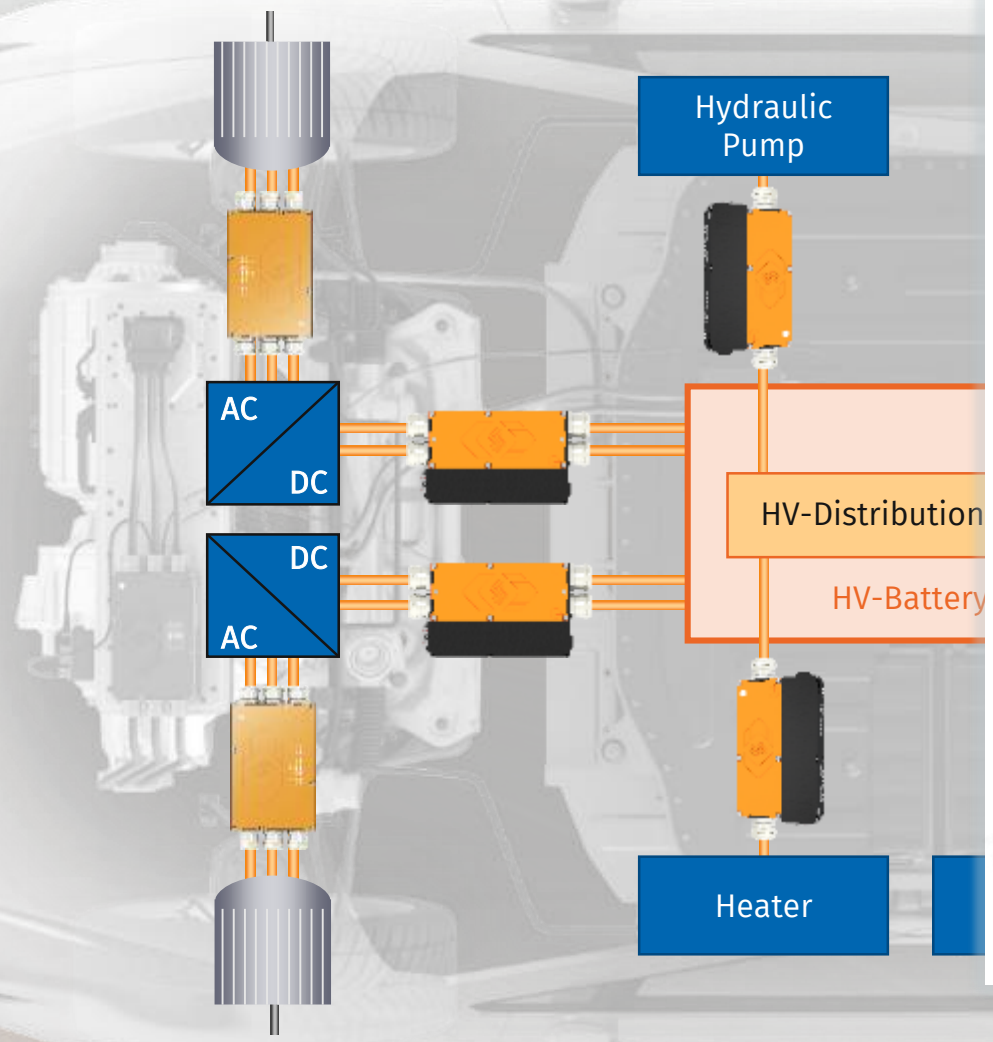


Investigation of the interactions of the LV electrical system with the HV electrical system

HV Breakout Modules

Measurement of high currents and voltages

- Everything in one compact solution
- Measurement directly in the HV power cables
- For vehicle and test bench applications
  - IP67
  - Operating temperature range: -40 °C to +125 °C

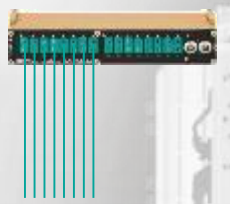


Investigation of the interactions of the LV electrical system with the HV electrical system

- Cable connection via cable glands
  - Optional plug & play with customized plug-in adapters

HV Breakout Module 1.2 with pre-assembled customer-specific plug-in adapters

TH measurement modules on www.csm.de

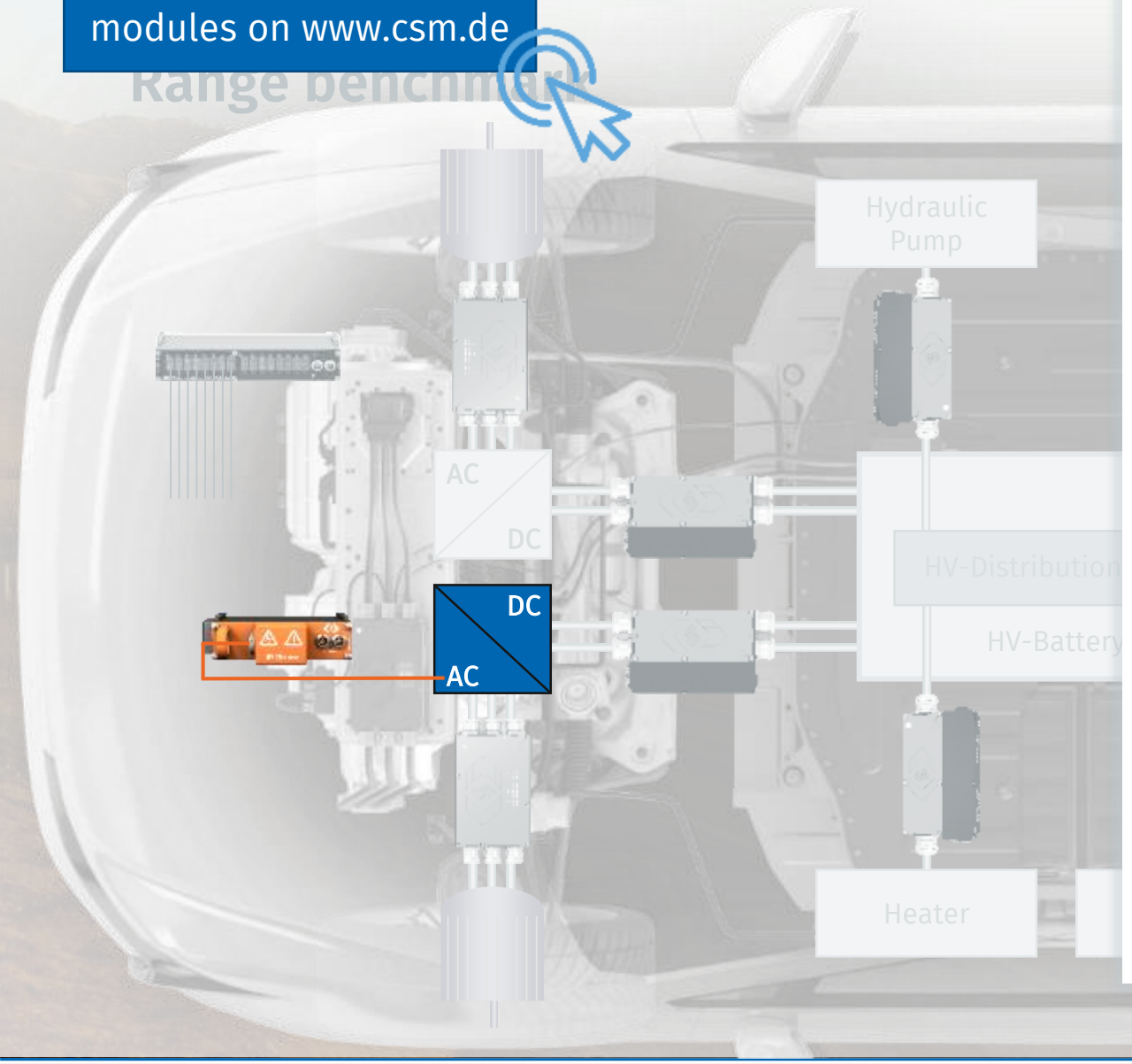


Verification of air conditioning and temperatures in components

Thermo Measurement Modules

- Proven and robust measurement modules for
  - Thermocouples
  - PT100 / PT1000 resistance sensors

HV TH measurement modules on www.csm.de



Verification of air conditioning and temperatures in components

HV Thermo Measurement Modules

- Safe use of standard sensors in HV environments
  - Thermocouples
  - PT100 / PT1000 resistance sensors
  - IC sensors
- MiniModule or test bench module

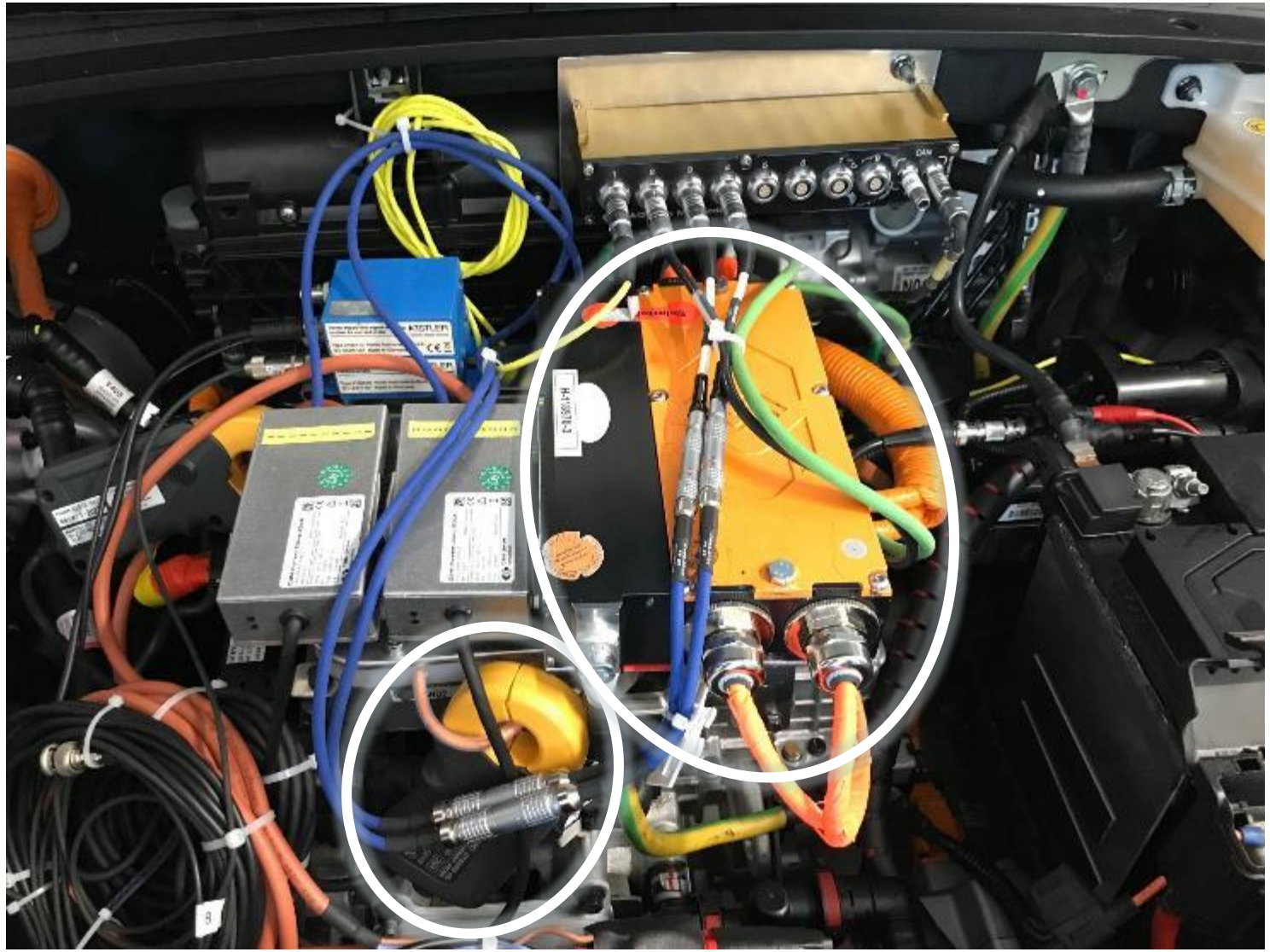
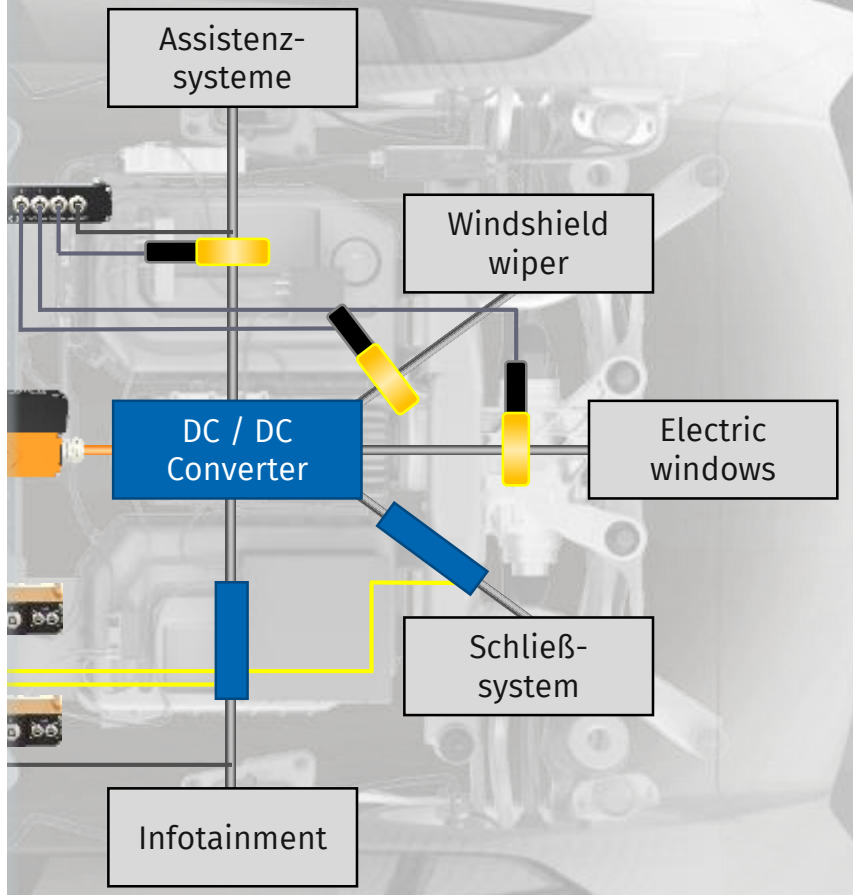


Image courtesy of APL Automobil-Prüftechnik Landau GmbH



Range benchmark

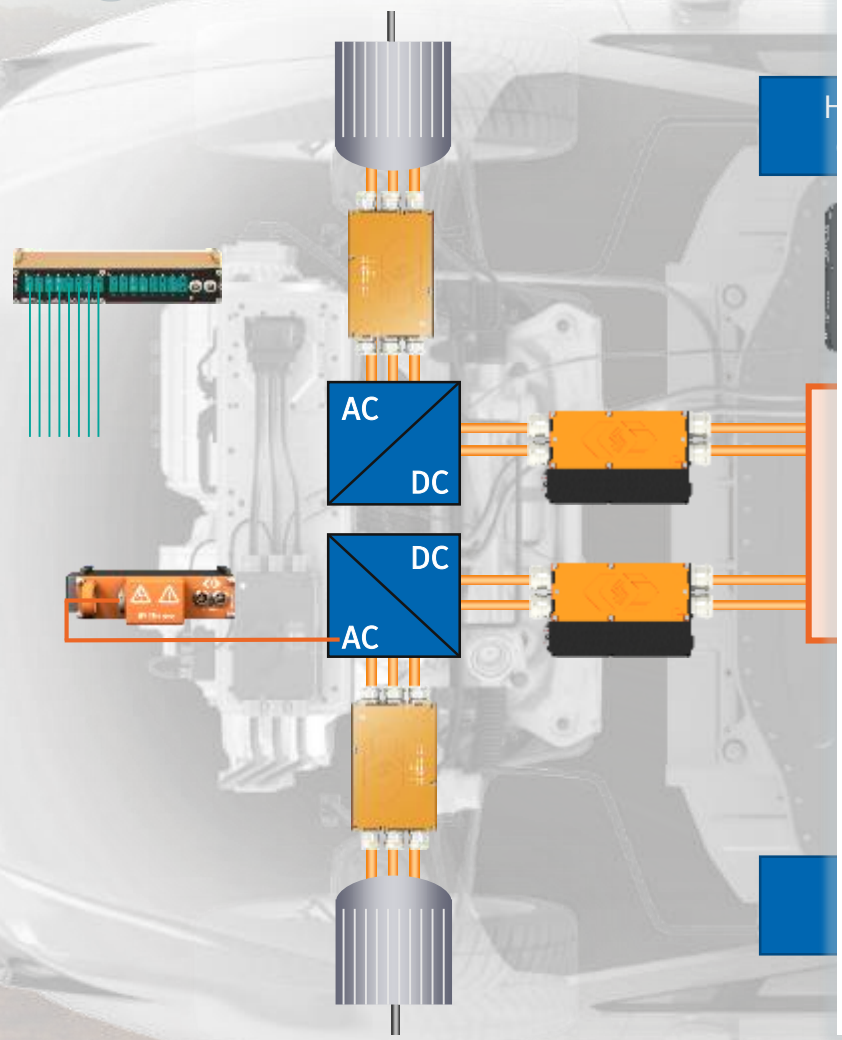


Image courtesy of APL Automobil-Prüftechnik Landau GmbH

CSM measurement technology for benchmarking

		Current	Voltage	Temperature	Sensor voltages	Strain gauges	IEPE	Frequencies
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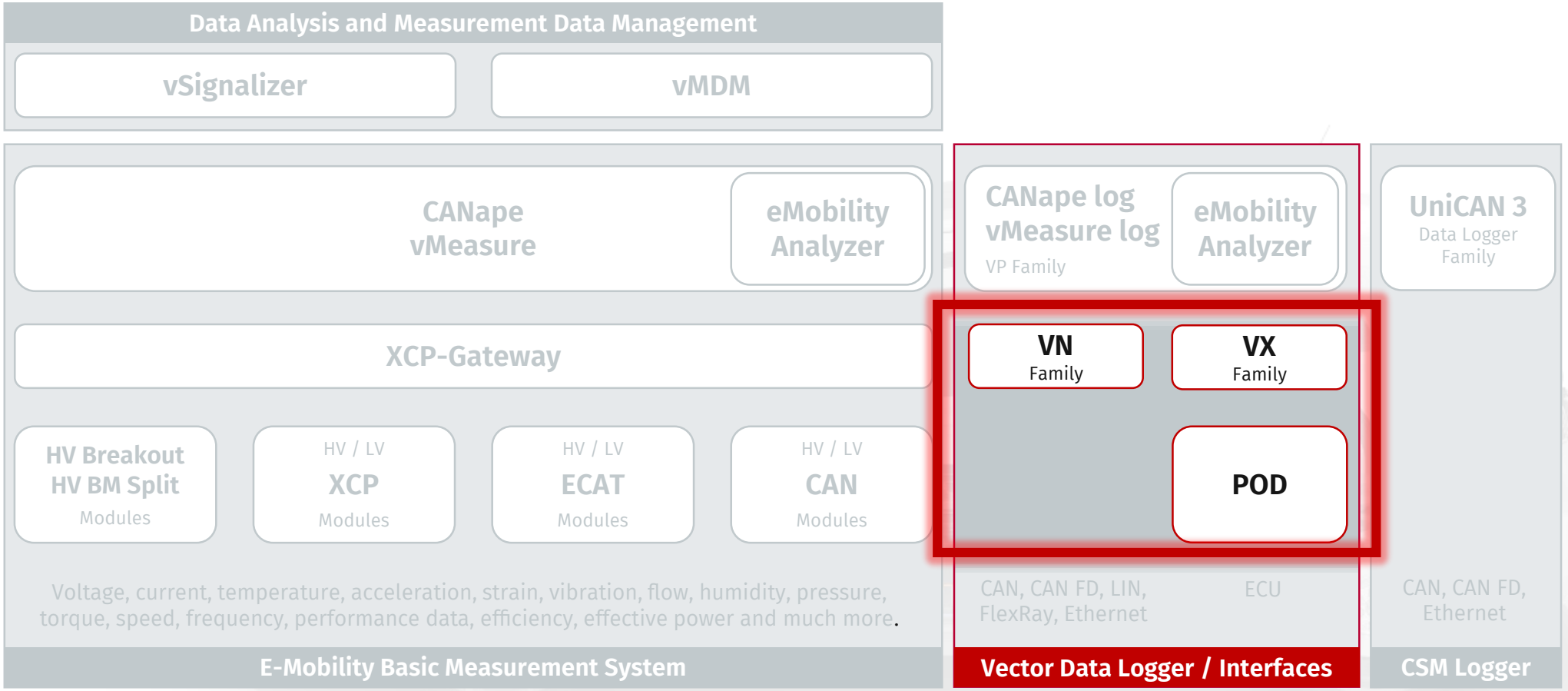
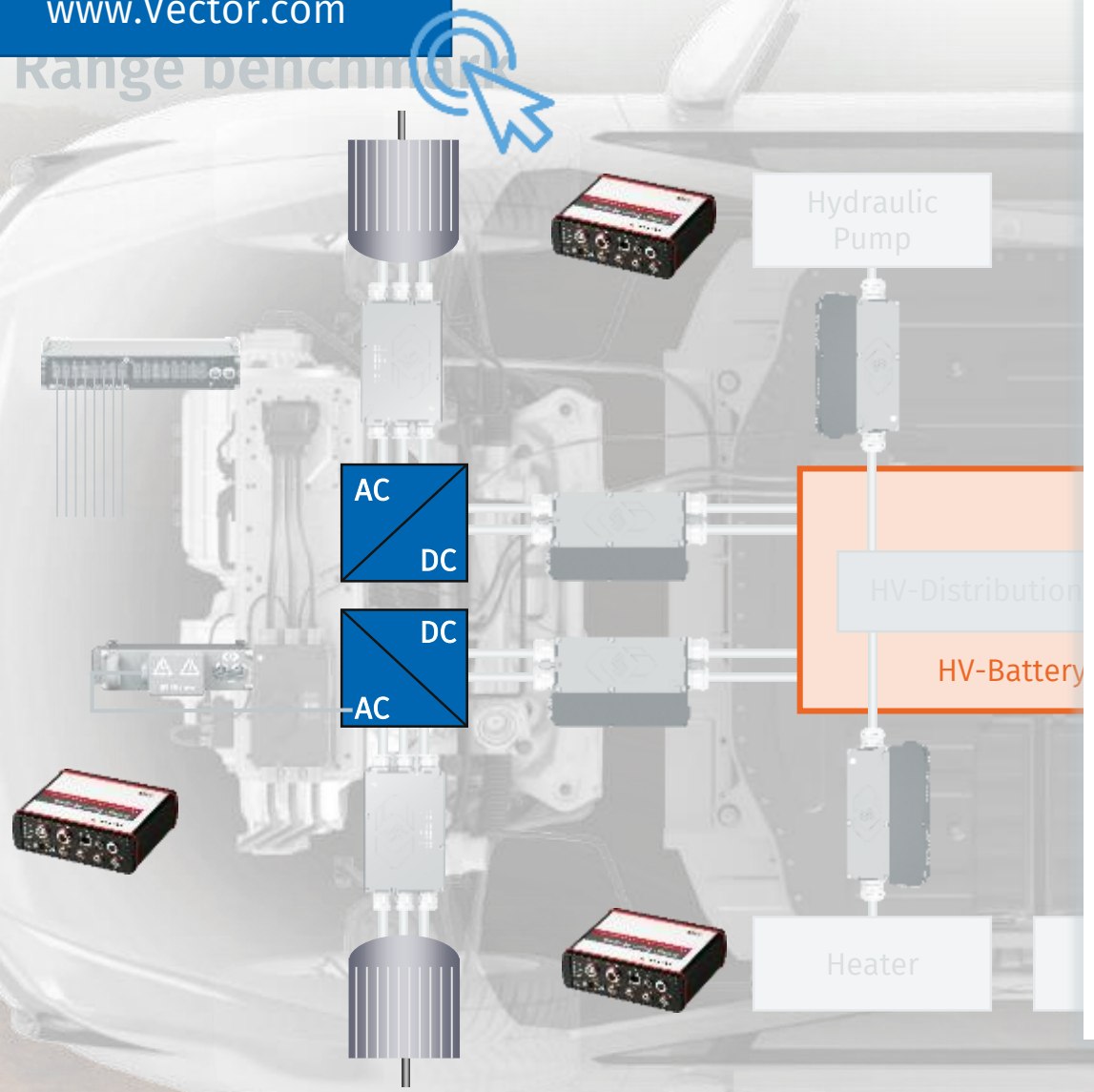


VN interfaces on
www.Vector.com

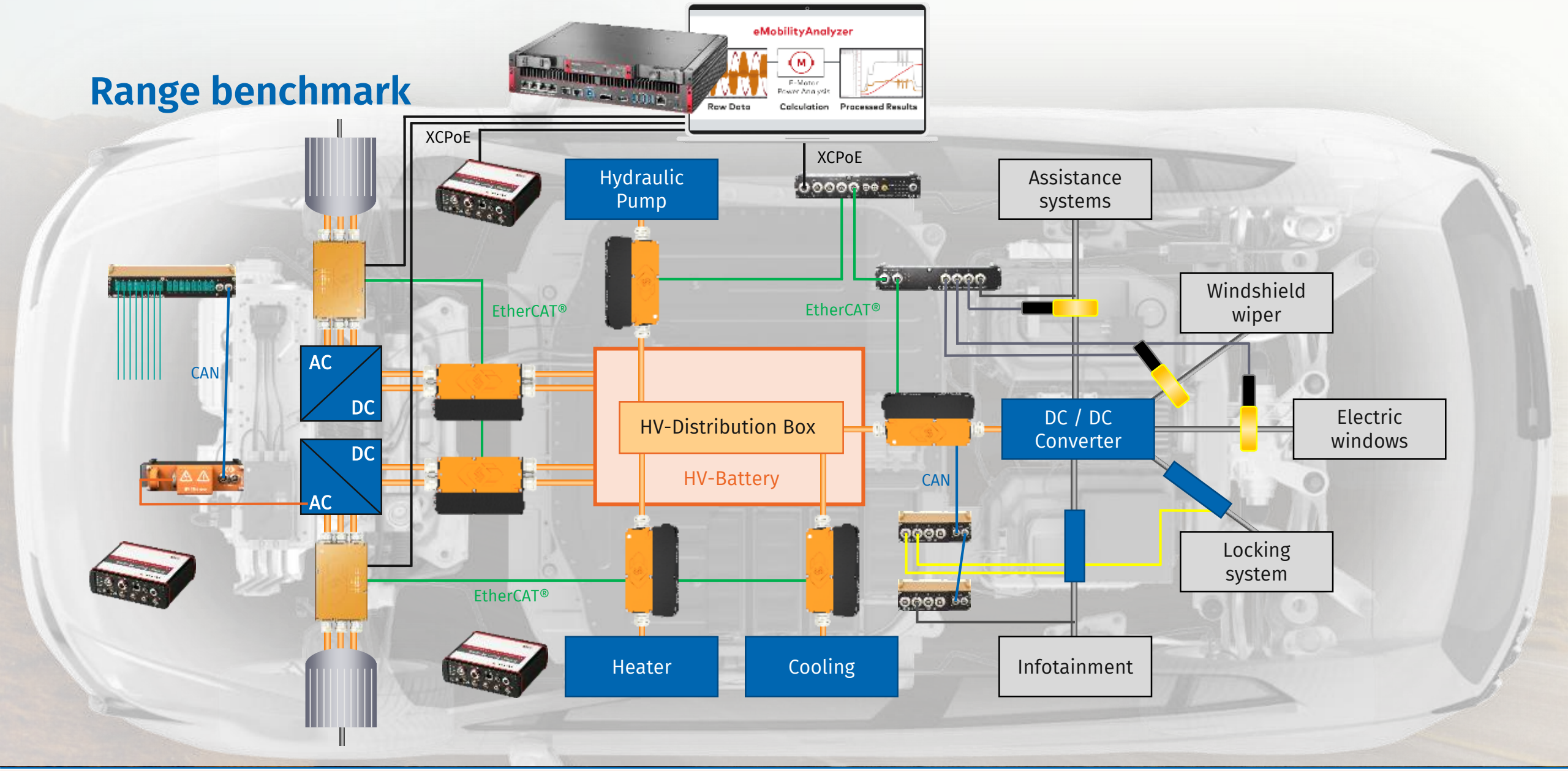


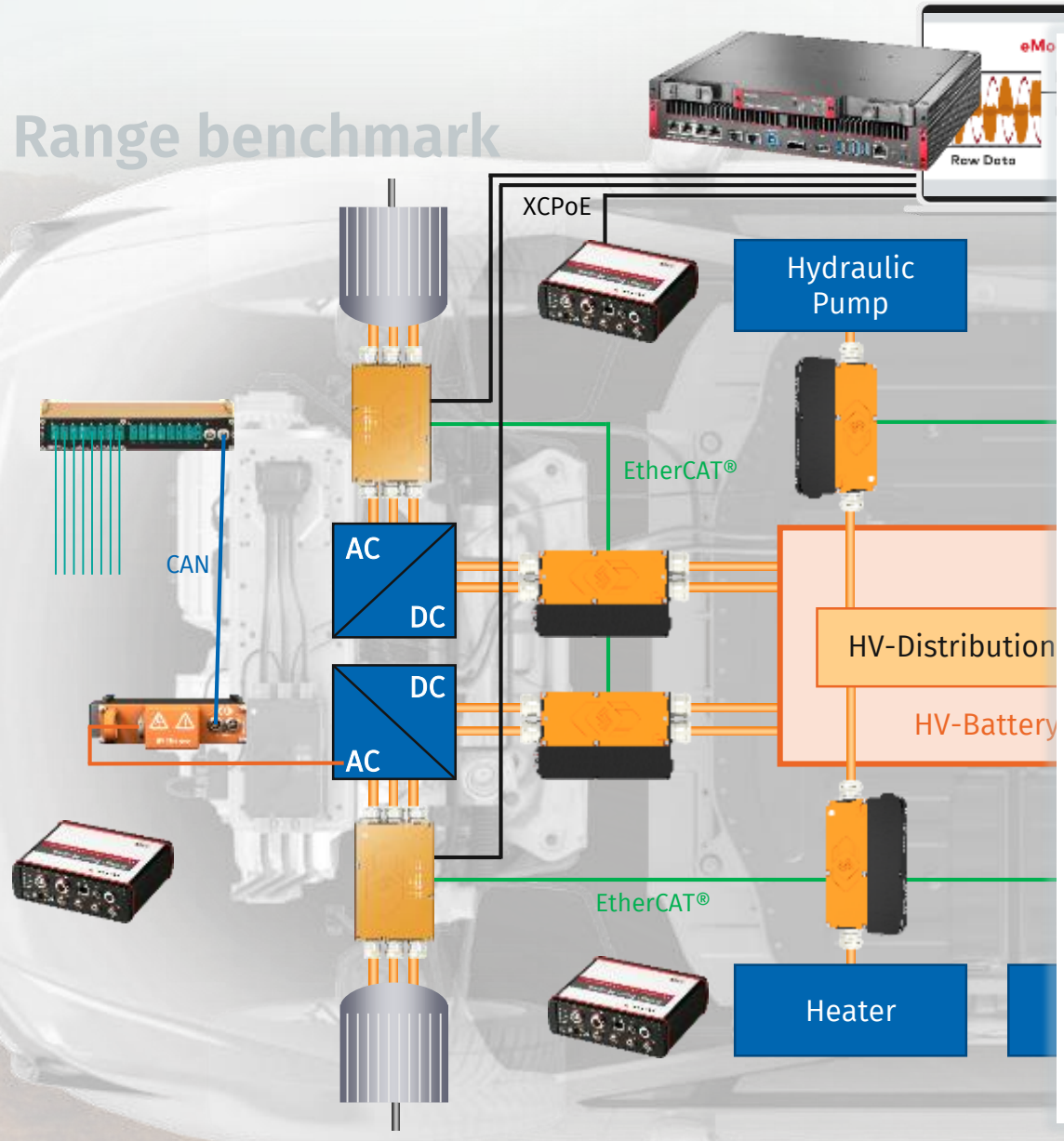
ECU Monitoring switching operations of the control units

Acquisition of fieldbus data

- Synchronous with analog measurement data
- With Vector VN interface

Range benchmark



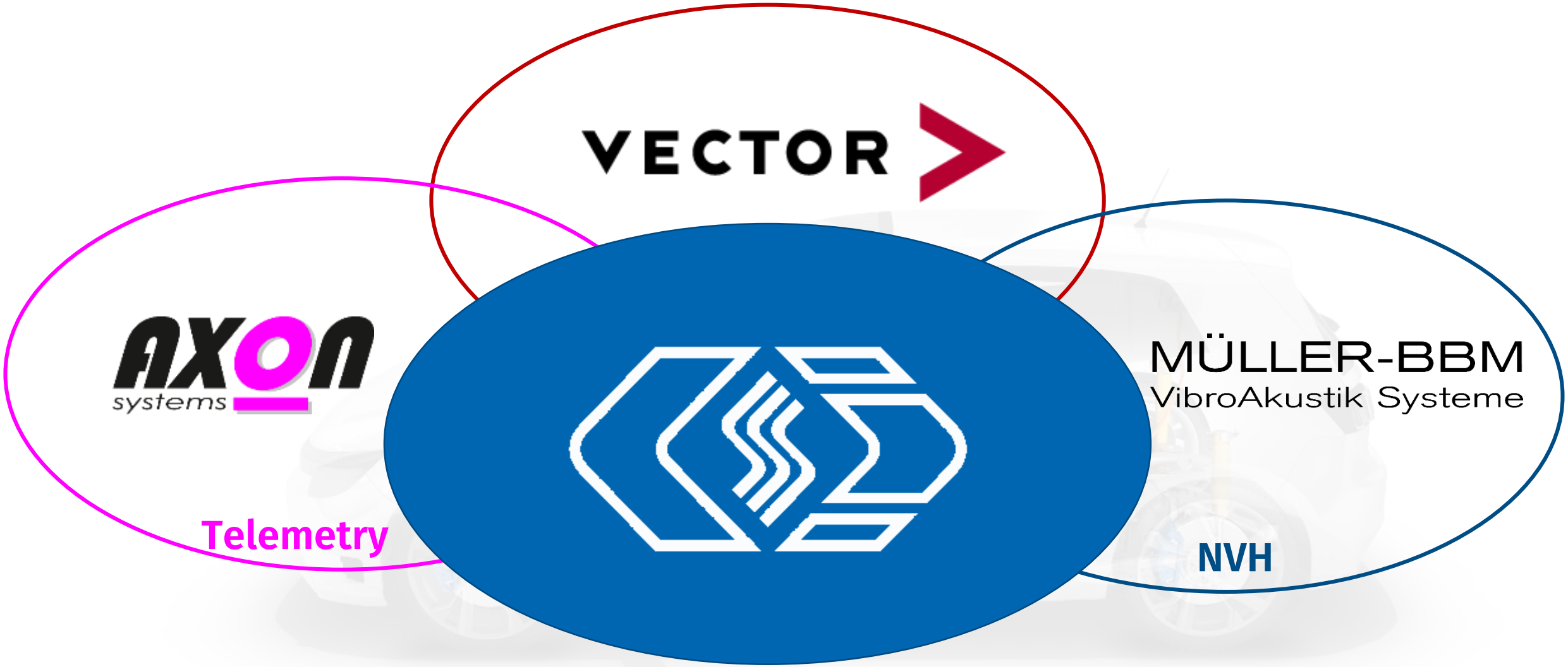


Data analysis with the Vector eMobilityAnalyzer

- Function library for CANape and vMeasure

- Numerous analyses in real time
  - DC/AC voltages and currents
    - Ripple, Slope, TrueRMS, ...
  - Power analysis
    - Active power, apparent and reactive power, power factor
  - Harmonic analysis
  - PWM analysis
  - Mechanical power and axis power
  - Energy consumption
  - Efficiency
    - Inverter, charging system, electric motor

All measurement data is also available for offline data processing.


VECTOR
AXON systems
Telemetry
MÜLLER-BBM
VibroAkustik Systeme
NVH

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About CSM

CSM has been setting technological standards for decentralized measurement technology in vehicle development for over 35 years. Our CAN bus and EtherCAT® measurement devices support worldwide renowned vehicle manufacturers, suppliers and service providers in their developments.

Continuous innovation and long-term satisfied customers are our guarantee for success. Together with our partner Vector Informatik, we have developed an easily scalable and powerful E-Mobility Measurement System for hybrid and electric vehicles and are constantly expanding the areas of application. With our high-voltage safe measurement systems designed for fast and synchronous measurements and power analyses, we actively accompany the change to **E-Mobility.**

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www.csm.de/webseminars

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measurement technology