Testing of Emissions-Relevant Driving Cycles on an Engine Testbed

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RDE as a Challenge for the Development

RANDOMNESS

Driving style has a strong impact on the equipment – shocks and vibrations.

AMBIENT TEMPERATURE

Changing ambient temperatures can strongly impact the quality of RDE test data.

AMBIENT PRESSURE

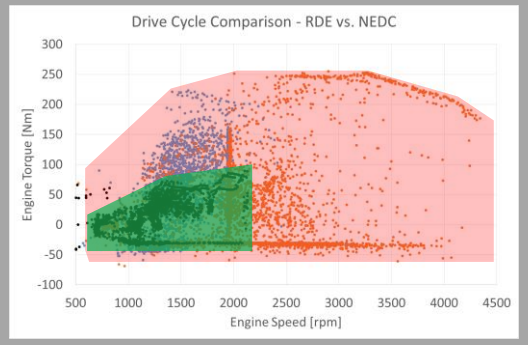
Changing ambient pressure is the key decision criterion for the selection of PEMS analyzers..

RDE READY

RDE as a Challenge for Methods and Processes

Robustness Validation

- No clearly defined targets, cycles, etc.
- Vehicles must be robust against the environment (road, traffic, etc.) and the driver (behaviour)



Robustness Validation Approaches necessary

Increase of Simulation

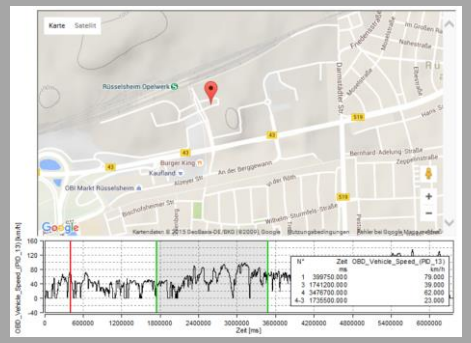
- Real roads and drivers must be simulated
- Easy physical models for vehicles are necessary (parameter studies)

Testbench: Engine out emissions	Nox	HC	CO	CO2
Test variation	g/km	g/km	g/km	g/km
Driver mild_no_traffic	0.237	0.042	0.105	123
Driver mild_traffic	0.333	0.041	0.121	150
Driver_mild_traffic_add_200kg	0.350	0.032	0.078	160
Driver_hot_no_traffic	0.320	0.041	0.107	129
Driver_hot_no_traffic_V2	0.323	0.033	0.084	129
Driver_hot_traffic	0.471	0.040	0.106	161

Process integratable simulation is needed

Advanced Evaluation and Data Management

- Big data and long cycles
- Data / Configuration / Model Management
- Patterns are hard to recognize due to changing cycles



New Evaluation Methods and Tools are necessary

From Road to Lab – a continuous approach for RDE

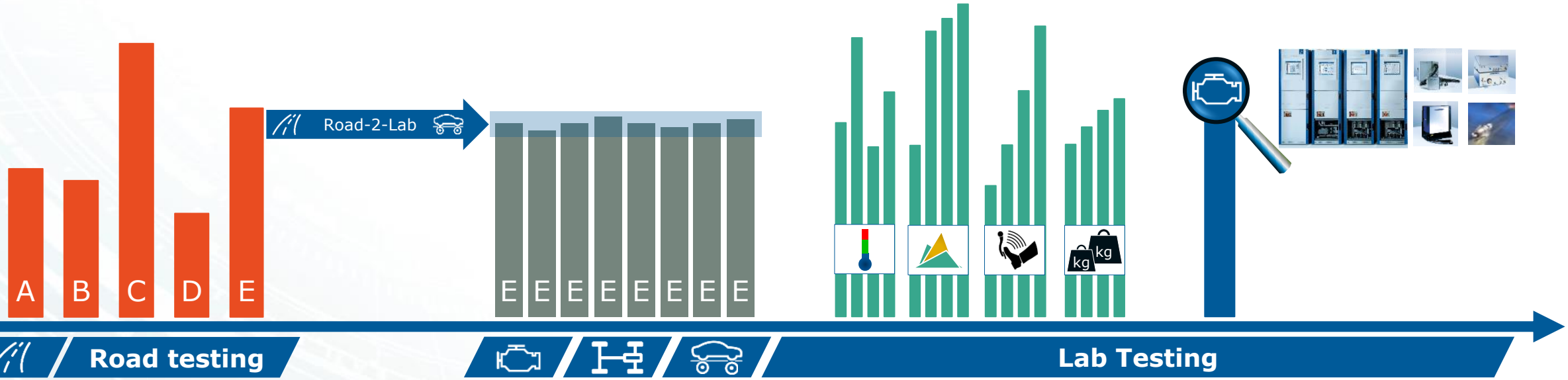
Road to Lab

RDE testing is **"random"**

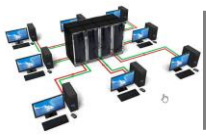
Lab tests can be **"reproduced"**

Lab tests allow **"defined variations"**

Lab tests measure **"precise"**

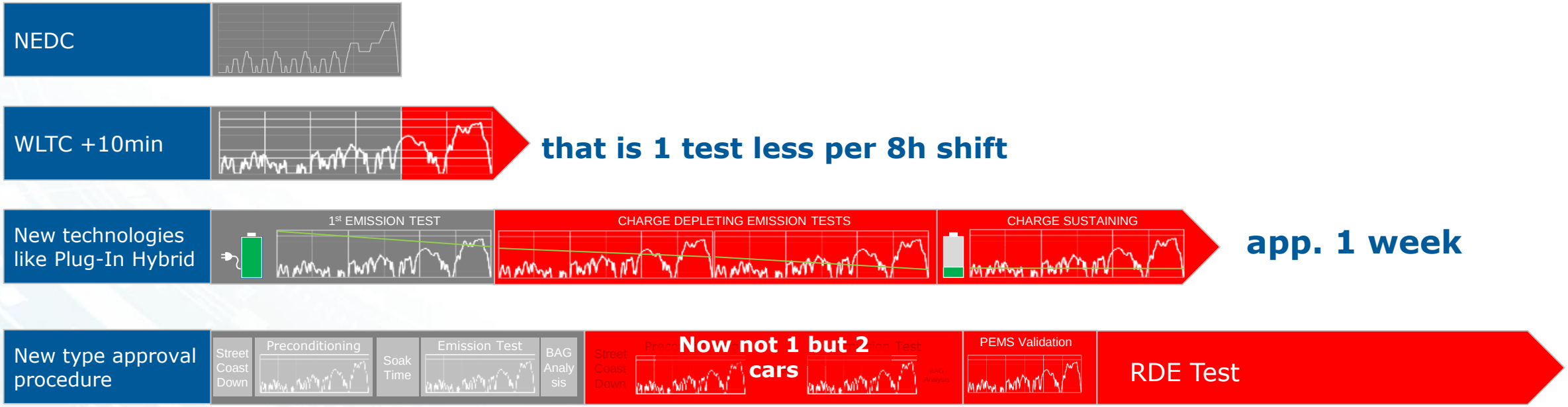


Consistent Data Management



Motivation

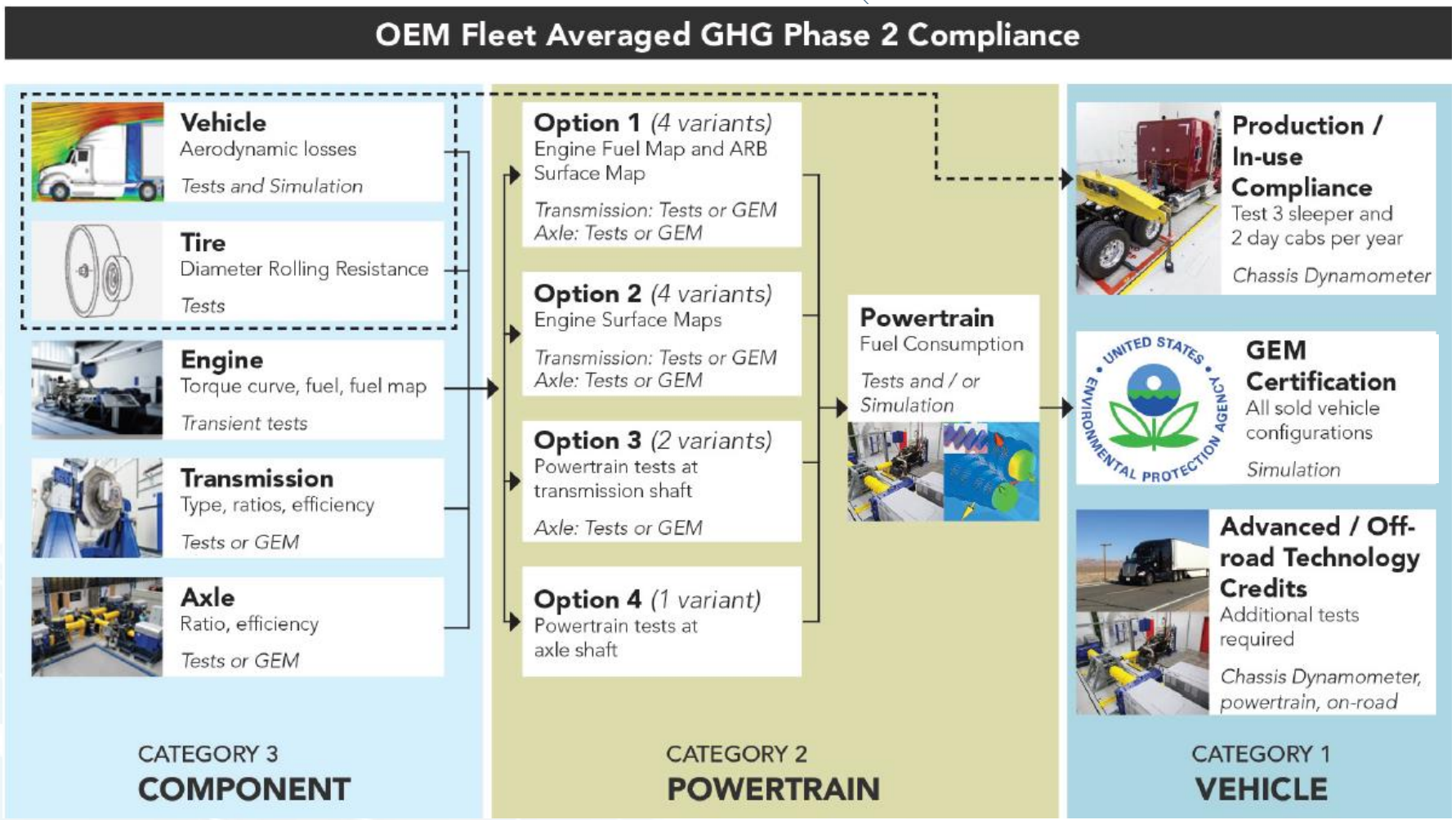
- **Chassis Dynos utilization is higher than ever**
  - Reason:



Possible Strategies:

- Build new Chassis Dynos
- **Virtual Testing: Extend existing engine test beds with simulation**
  - ⇨ **Reduce load of Chassis Dynos for development tasks**

Only RDE?
Vehicle Compliance Demonstration – in US



- All vehicles must be simulated in GEM.
- Production testing, Technology Credits require powertrain or vehicle testing.
- Complexity of options mean more upfront analysis and impact of technology selection on certification costs.
- Certification data may be made public
  - In-use compliance

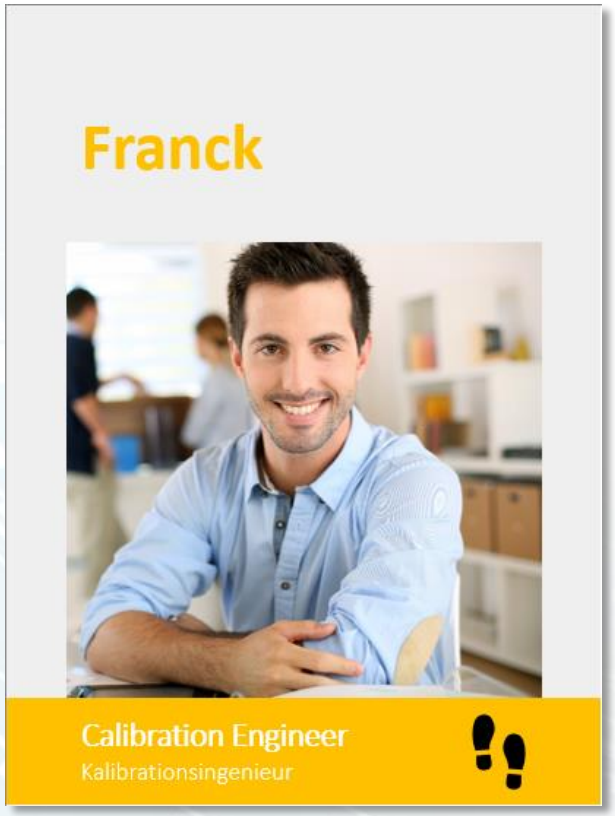
Options 2 and 3 are the most likely to be used

GEM … Greenhouse Gas Emissions Model
GHG … Greenhouse Gas Emissions

Customer Use Case

Engine Testbed

Stakeholder



- **earlier**
- **faster**
- **better**

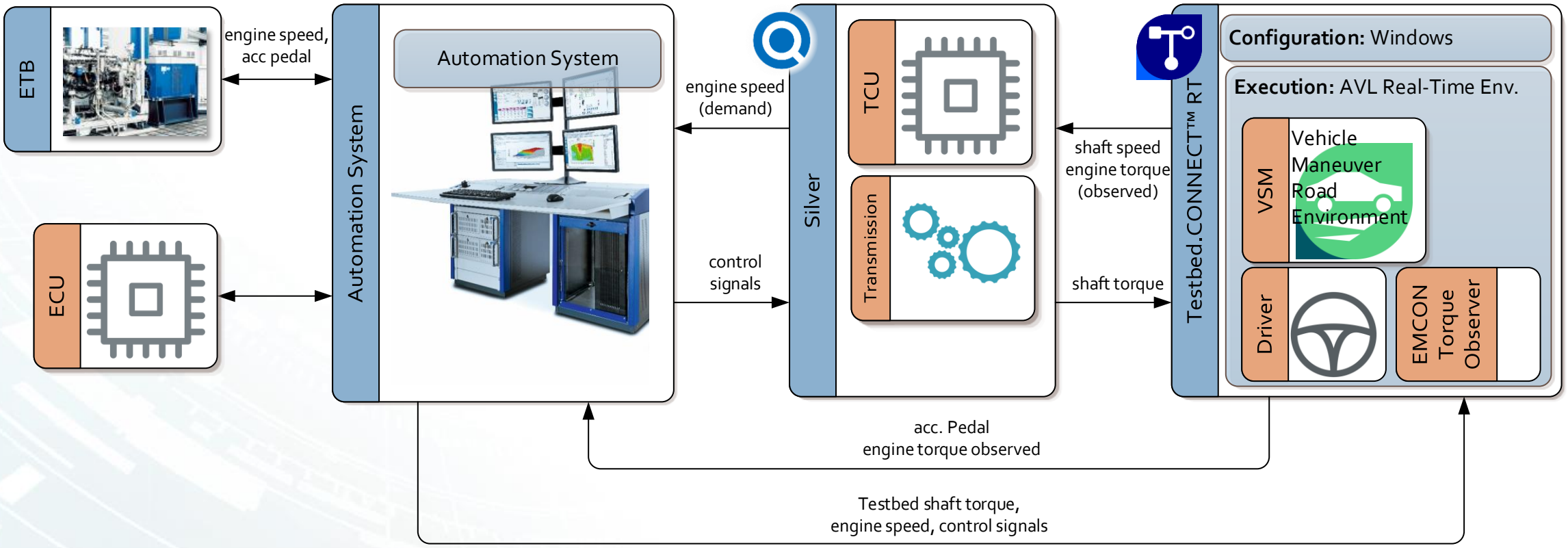
Convince Franck

Why? - **Franck must be able to rely on a new approach**

How? - **Reproduction of road measurements on an engine testbed**

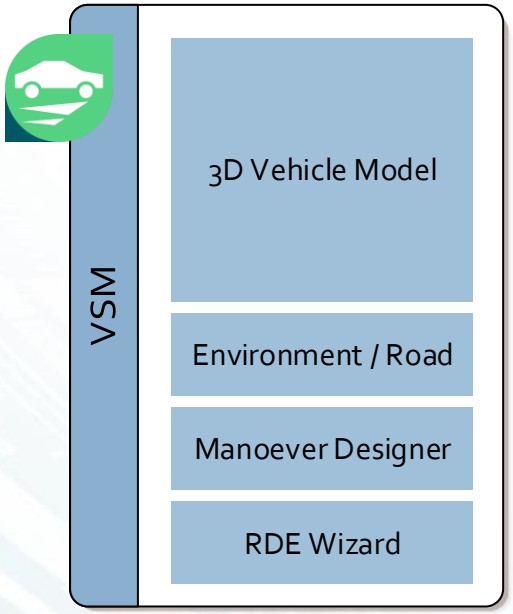
- Simulation models
  - Vehicle
  - Transmission & TCU
  - Driver
- Methodology
  - Import of the road measurement
  - Application on the testbed
  - Validation of the tool chain

Overall System Scheme

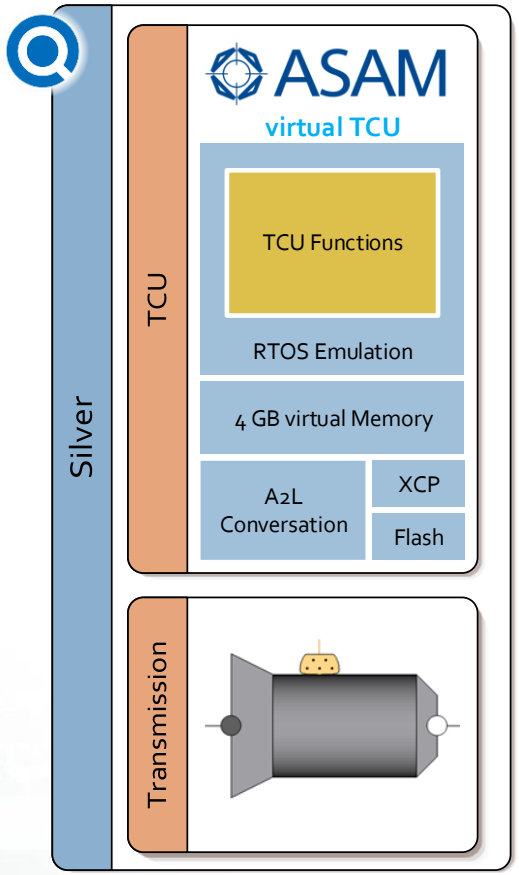


Simulation Models

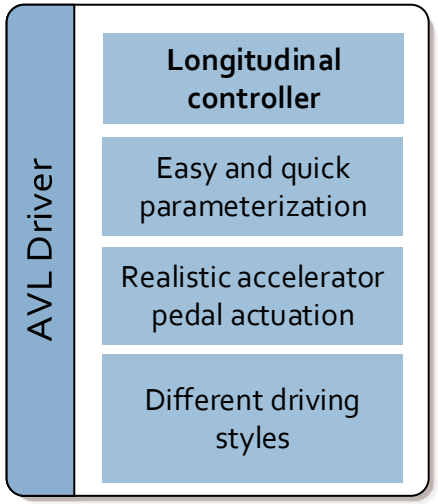
AVL VSM – **V**ehicle **S**imulation **M**odel



Qtronic Silver – Transmission and TCU Model



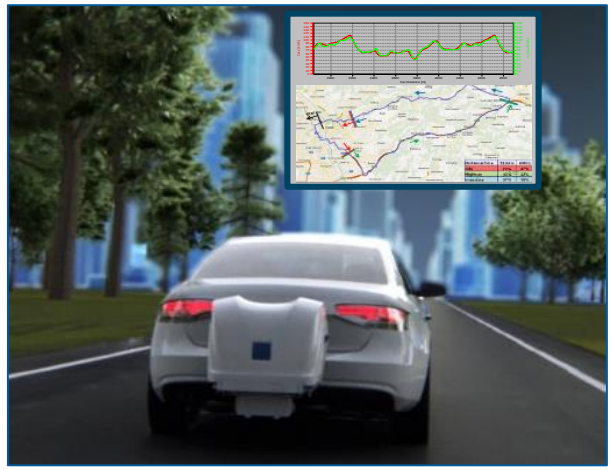
AVL Driver



Methodology

STEP 1

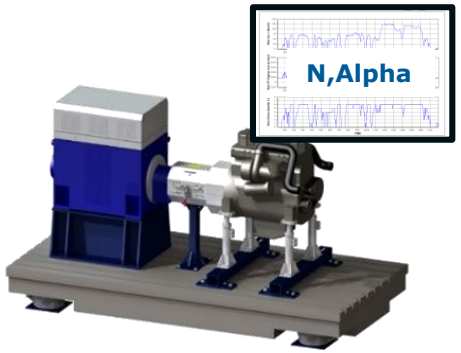
Road measurements & AVL Simulation model parametrization



1. Outdoor Road Measurement with PEMS system
2. Configuration of vehicle model
3. Automated digitalization of road data

STEP 2

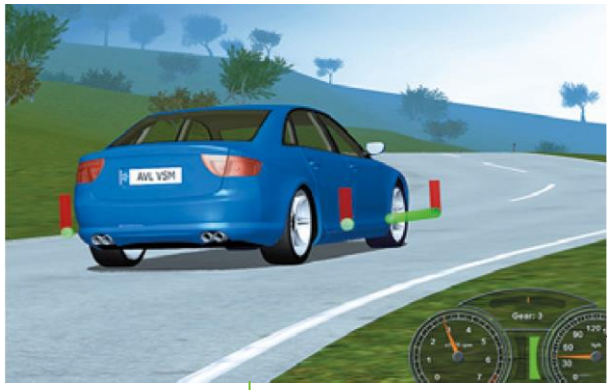
Open Loop Tests



1. 1:1 reproduction of engine speed and load from the road measurement
2. Driver in reproduction mode to verify vehicle and transmission

STEP 3

Closed loop simulation

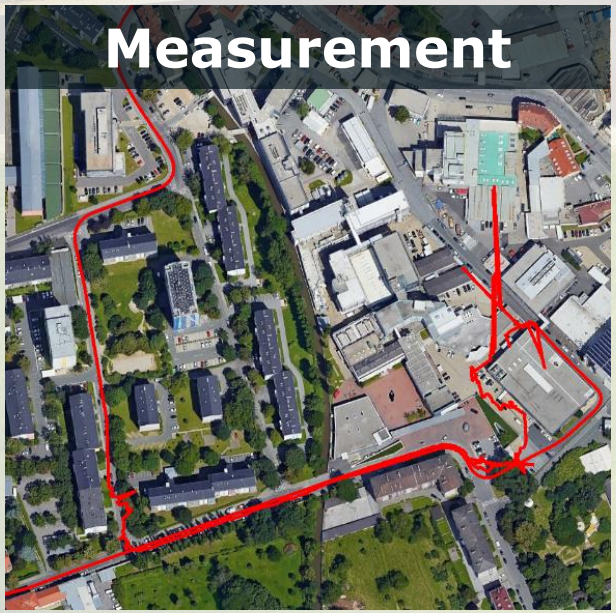


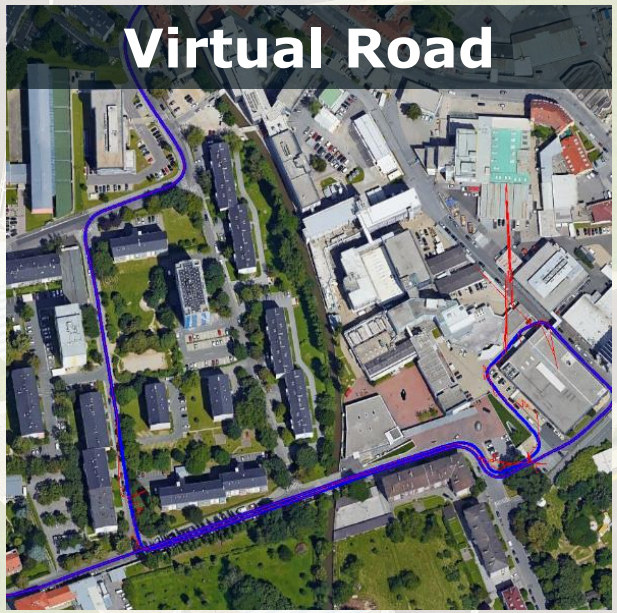
AND/OR CUSTMERS MODELS

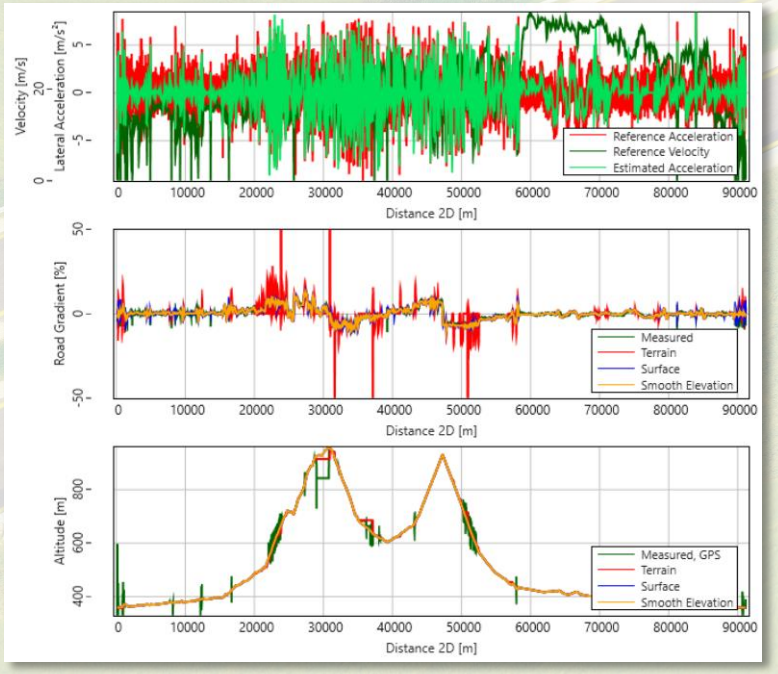
1. Full simulation of vehicle, transmission, driver

Generation of the virtual 3D Road

Generation of virtual 3D road from combination of noisy **vehicle measurement data** (GPS, IMU, Vehicle CAN) and **digital map data** (e.g. Google Earth).







Road curvature and **gradient** are calculated by **optimization**

→ **realistic lateral acceleration and gradient**

Validation on the Engine Test Bed

STEP 2.1:
Engine Testbed:
Reproduction n/alpha

STEP 2.2:
Vehicle Model:
Driving Resistance

STEP 2.3:
Transmission & TCU Model:
Reproduction v/alpha

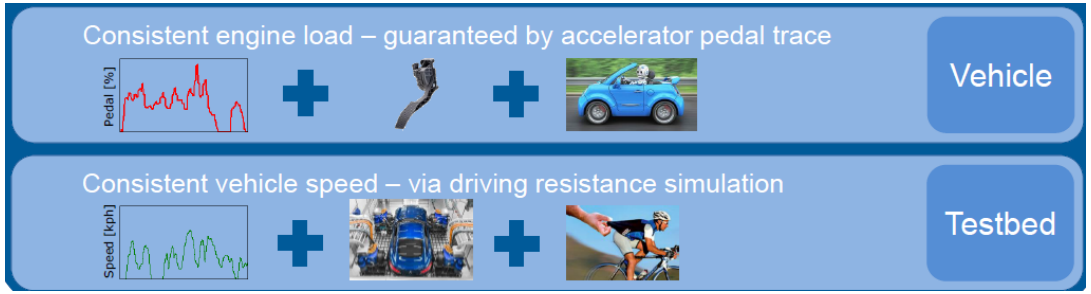
Measured throttle pedal and engine speed are run in open-loop control.

Restbus simulation also originates from the measurement

Final adjustment of road load

Measured throttle pedal is run in open-loop mode.

Vehicle speed is controlled by the driver via an additional road load.



Results

Compare Road, Chassis Dyno and Engine Testbed

Investigated Vehicle

MERCEDES-AMG C 43

3,0-Liter-V6-Biturbo Engine

Comparison

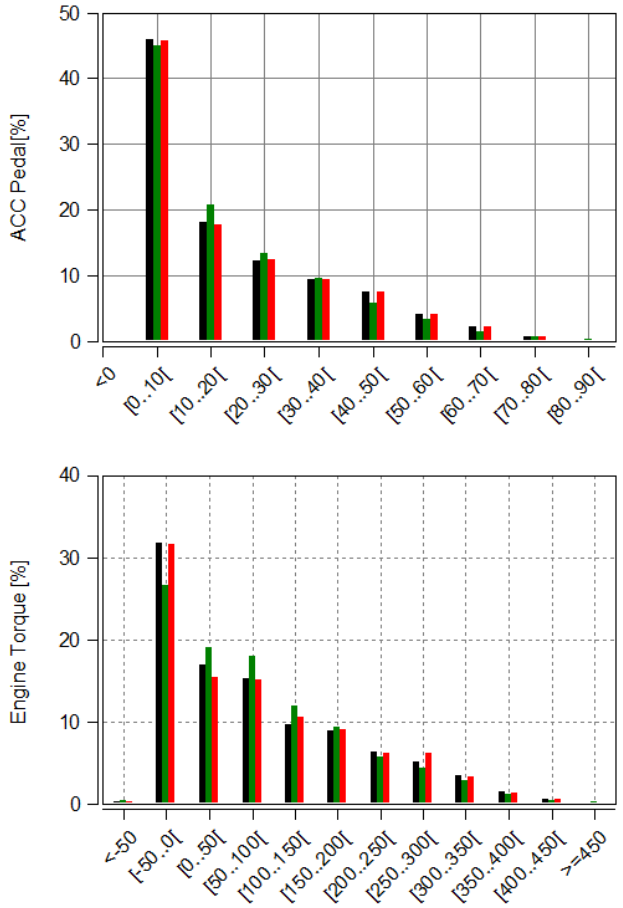
- Road
- Engine Test Bed
- Chassis Dyno

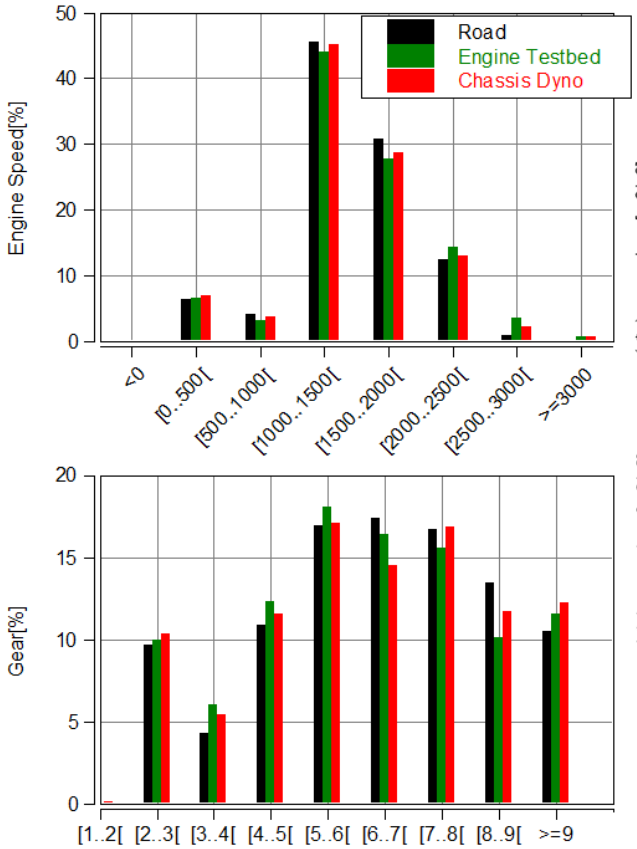
Details

Time course of gear, acceleration pedal, engine speed, engine torque and vehicle speed show good correlation.

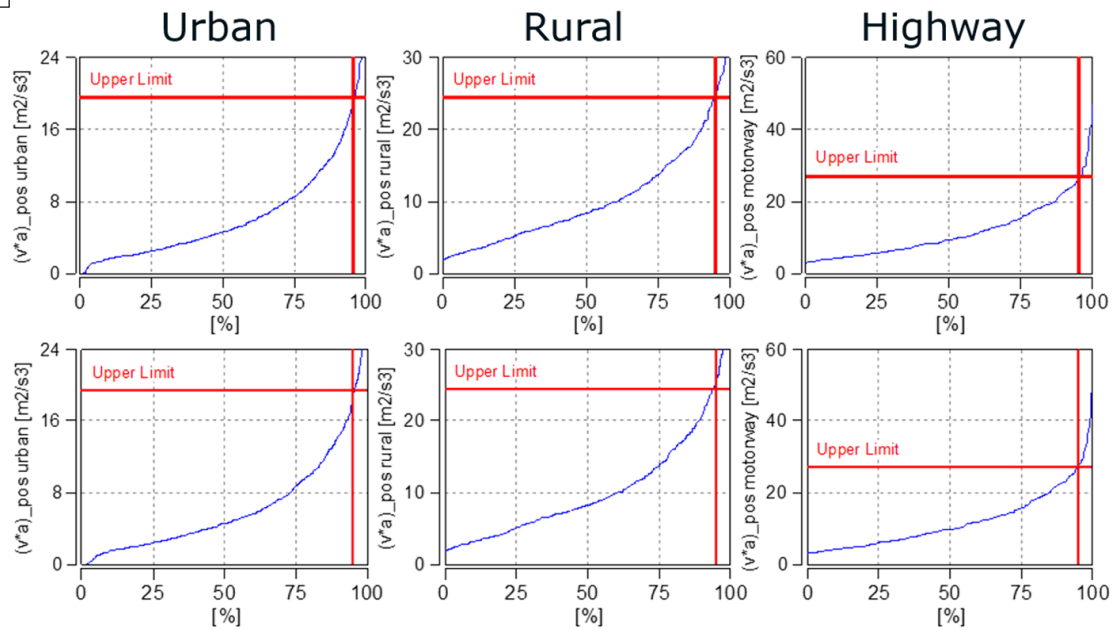
Statistic Analysis

Operating Point

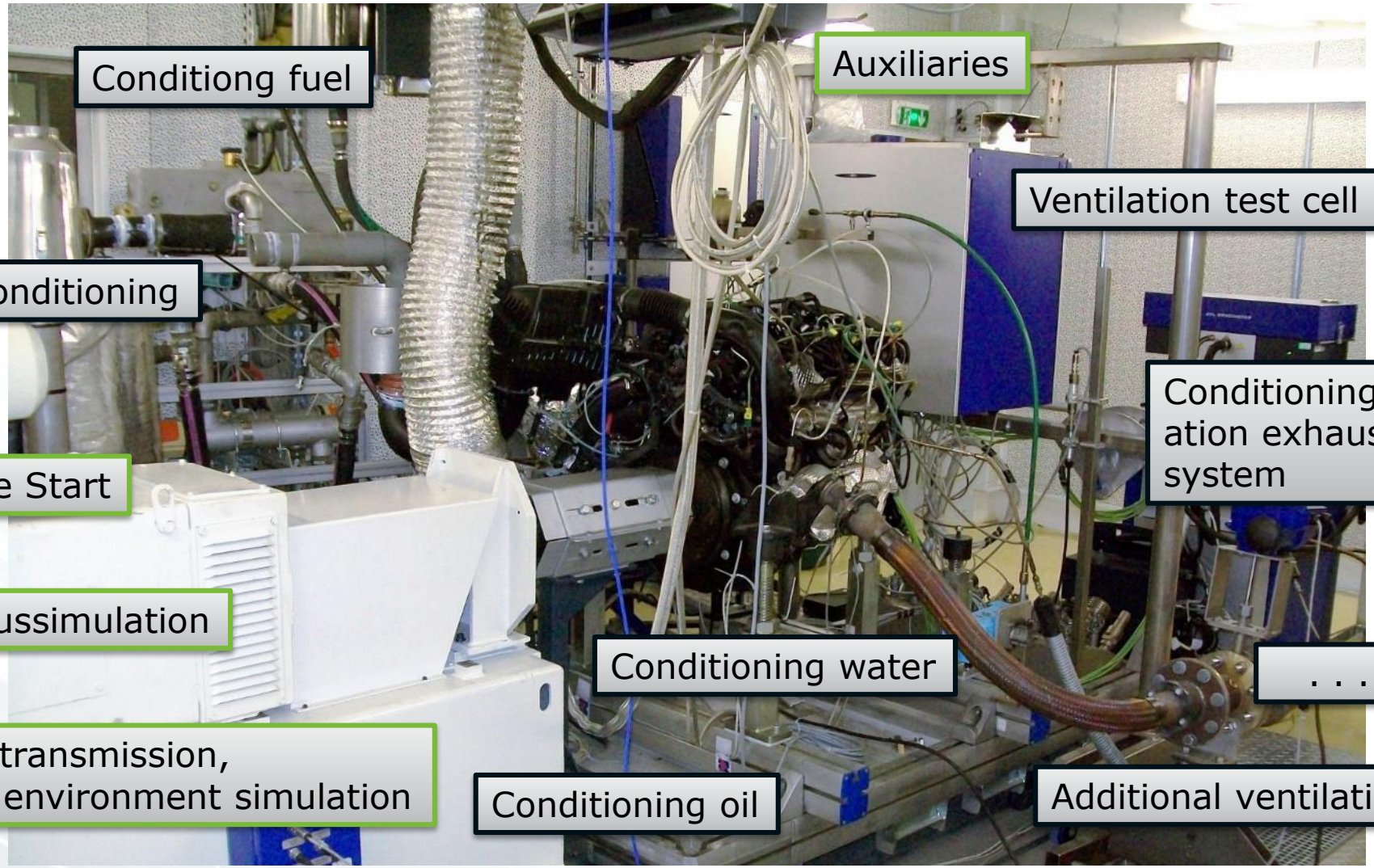




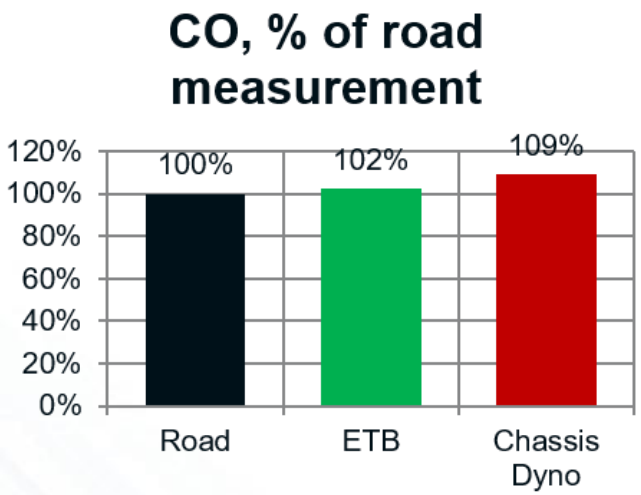
RDE Dynamic Criteria

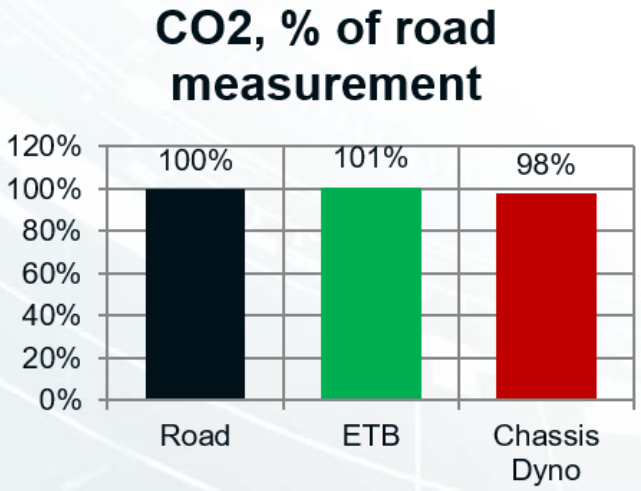


Factors Influencing Emission Results



Emission Result - Overall





- CO2 and CO show a good match

Conclusion

- Result quality of the engine test bed and the chassis dyno are equal
- Franck can shift development tasks from the road and chassis dyno to the engine test bed
- Know-How about the influence of boundary conditions on emission results must be considered

- **earlier**

- **faster**

- **better**


Thank You
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