

The robot driver in a co-simulated test environment: Supporting integrated development processes in the field of Real Driving Emissions



IPG Apply & Innovate - TECH WEEKS 2020

Henning Nies, M.Sc., VKM - Technical University of Darmstadt, Otto-Berndt-Straße 2, 64289 Darmstadt

Tim Steinhaus, M.Sc., VKM - Technical University of Darmstadt, Otto-Berndt-Straße 2, 64289 Darmstadt

Dr.-Ing. Alexander Schwarz, Stähle GmbH, Maybachstraße 12, 71299 Wimsheim



Introduction



Institute for Internal Combustion
Engines and Powertrain Systems
Technical University of Darmstadt



vkm, Otto-Berndt-Straße 2, 64287 Darmstadt, Germany
+49 6151 1621270, info@vkm.tu-darmstadt.de



- Private company founded in 1983
- First products:
 - Valves for supra conductors:
pressure control of liquid helium at 8 K
 - Valves for exhaust emission analyser:
vacuum pressure regulator at 200 °C
- 1985: **1st AUTOPILOT system AP500** sold to BMW: Climatic chamber



- World-wide customer base
- More than 1000 robot systems sold world-wide
- **Wide product range of robot systems**



Stähle GmbH, 71299 Wimsheim, Germany
+49 7044 915610, info@stahle.com

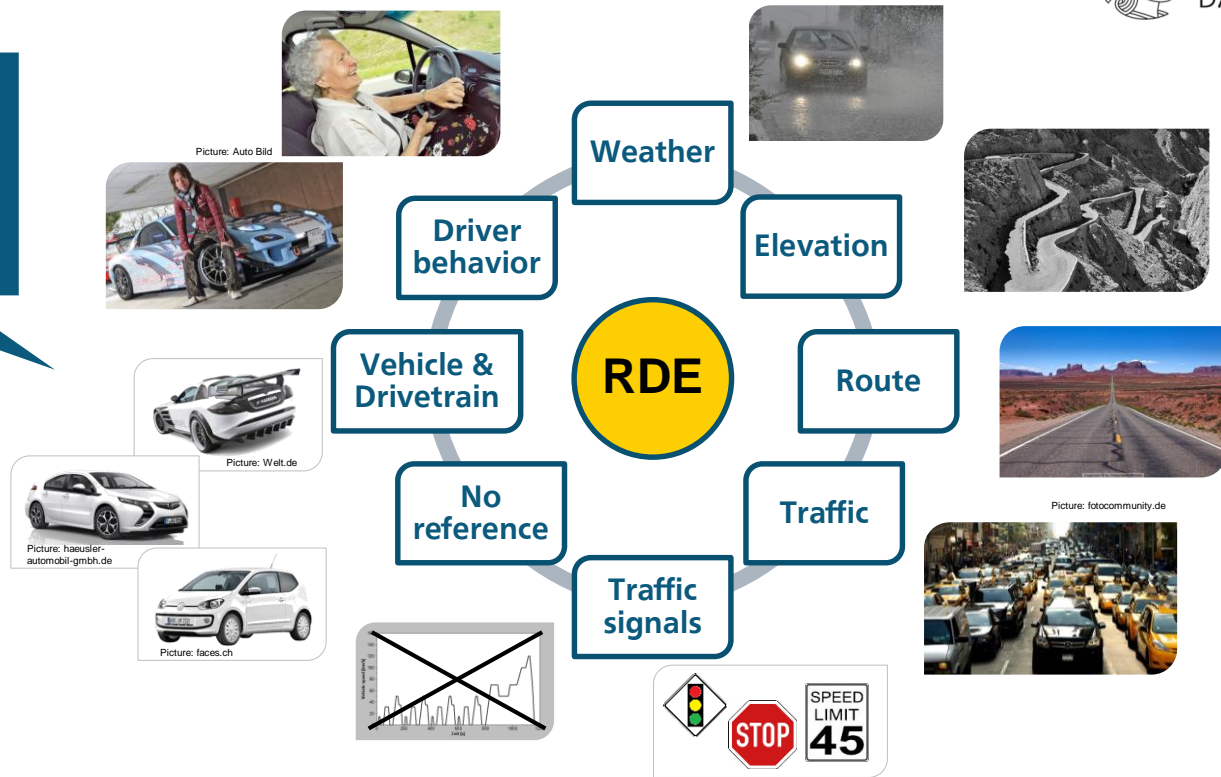
Content

- **Motivation**
- **Development Challenge: RDE**
- **Co-simulated test environment with CarMaker & Stähle DriverModule**
- **Conclusion**

Motivation

RDE

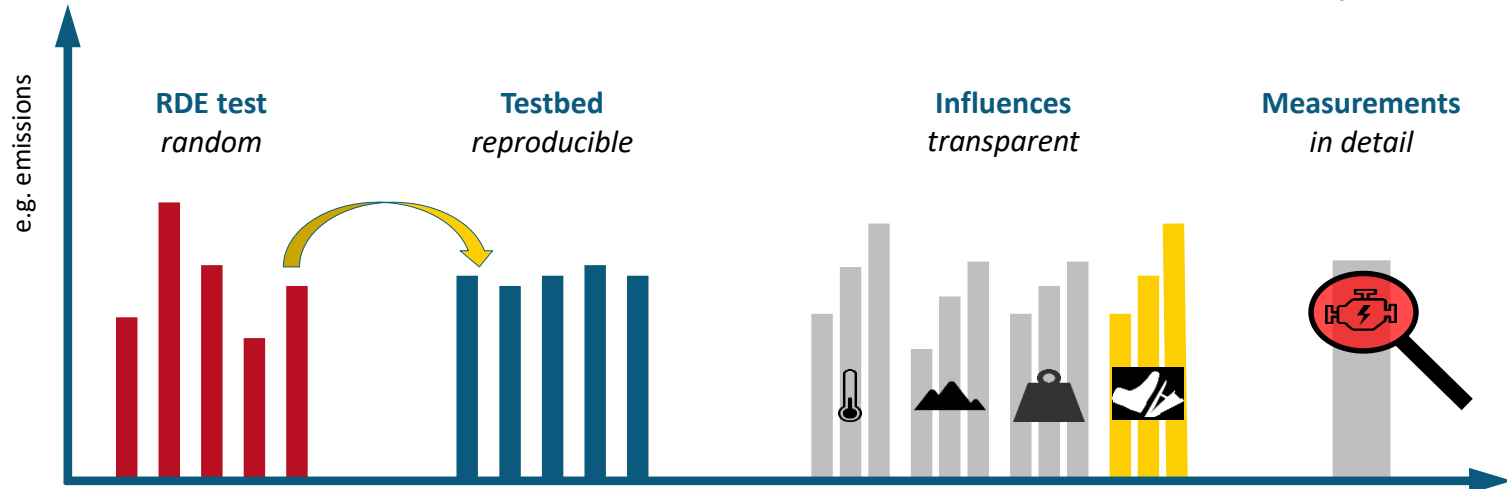
great variability –
many interactions



Motivation

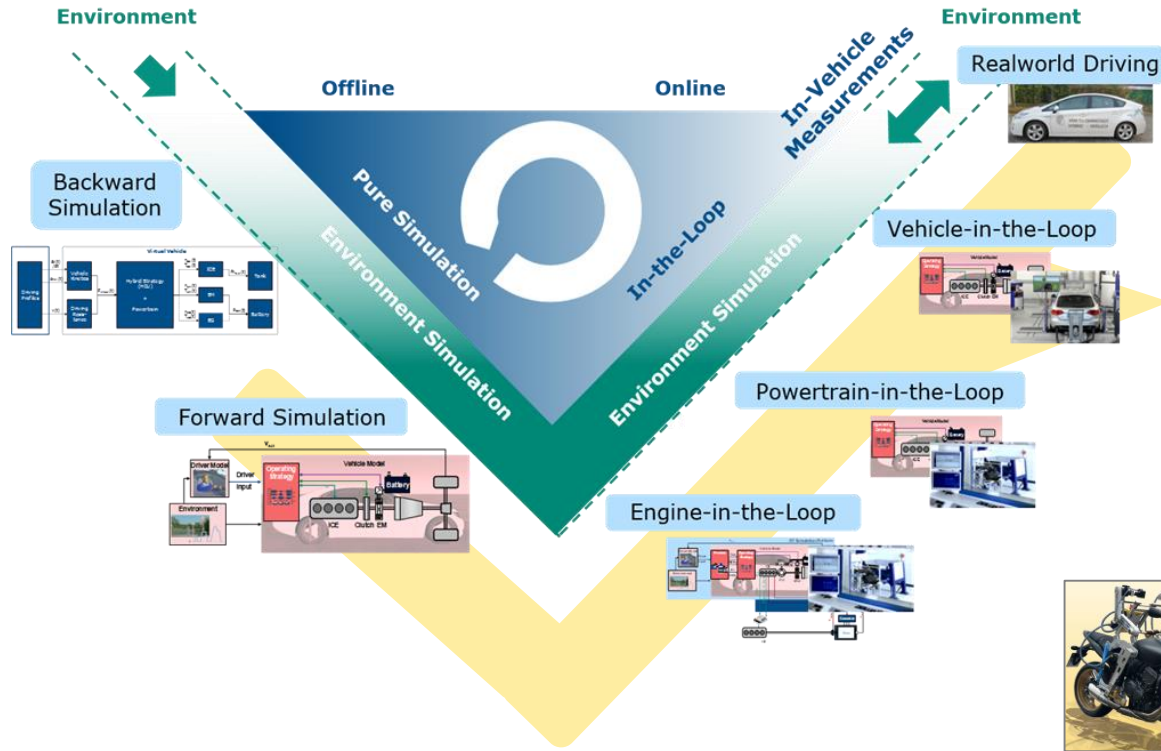
Detailed examination in
testbed environments

Enabling Frontloading by combining
hardware with simulation

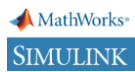


Source: AVL

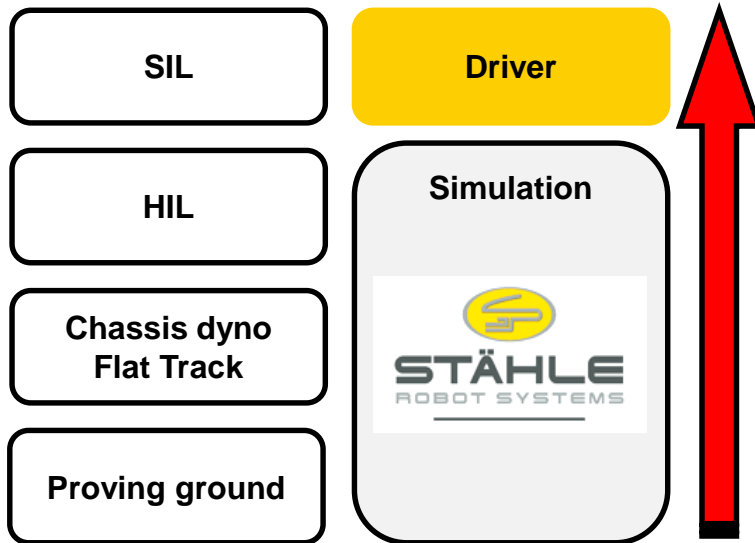
Development Challenge: RDE



Application of
Stähle DriverModule



Development Challenge: RDE



Application of Stähle DriverModule

- Same „vehicle input generator“
- Correlation between test bench configurations
- Same behaviour & performance & features
- Elimination of multiple and redundant development processes
- ***No incompatibilities from Vehicle to SIL***

***Human drivestyles
Repeatable
Precise***

Development Challenge: RDE

Repeatability and Analysis

Virtual Integration

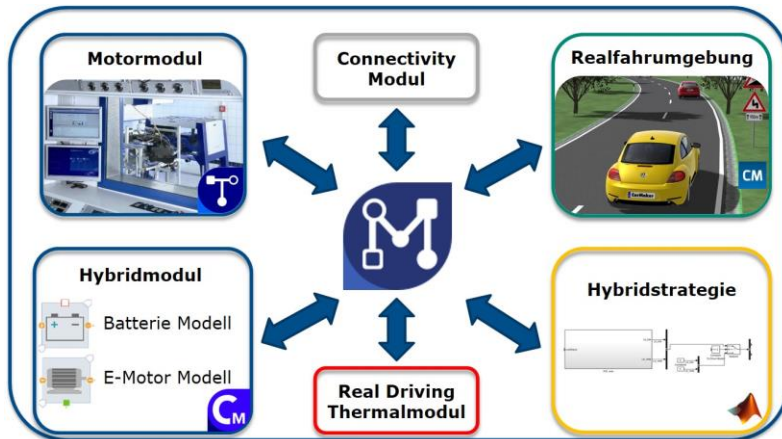
RDE Reference-Cycle

VKM RDE Methodology Toolbox

Methodical adjustments to existing development procedures are necessary

Addressing RDE in early development phases with Co-Simulation Toolchain in the office & at the testbed

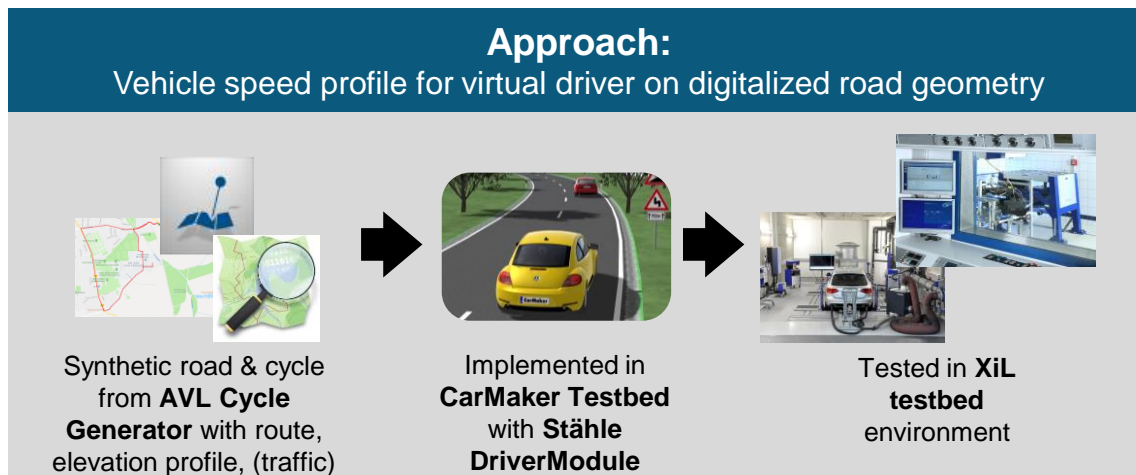
Modular Methodology Toolbox for various RDE Use Cases



Co-simulated test environment

Use Case

- RDE Testing on **EiL-testbed** with **CarMaker & Stähle DriverModule**



- Detailed focus on **Repeatability & Analysis** of virtual driver behaviour

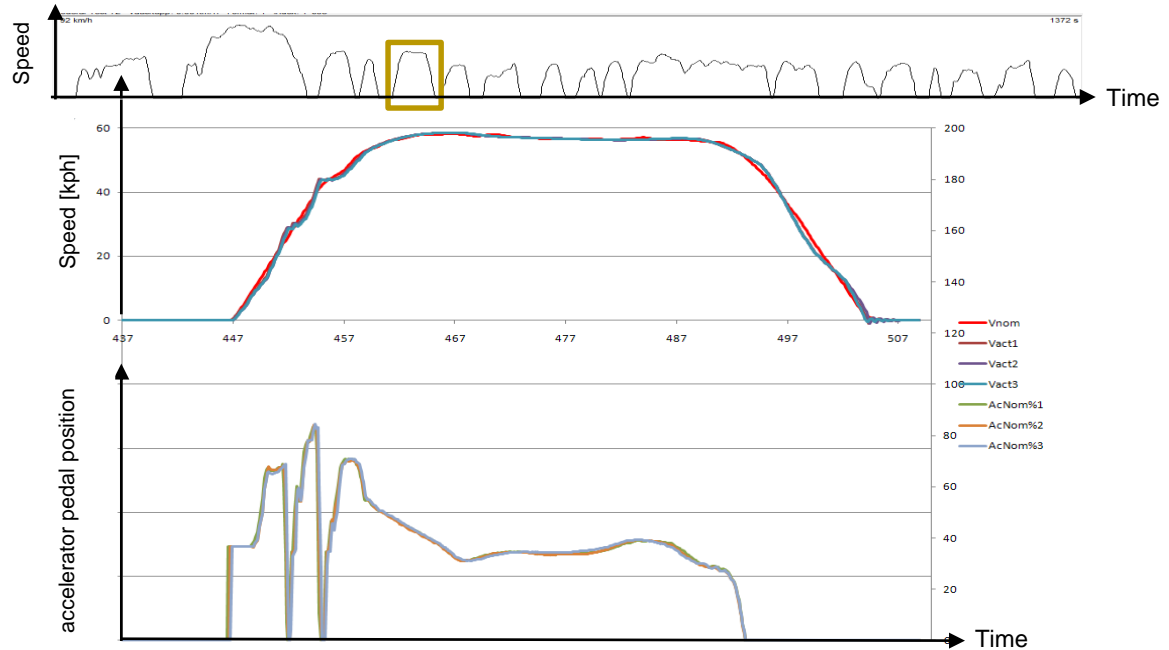
Different drive style settings & strategies

Different shifting behaviour & strategies

Test repeatability

Co-simulated test environment

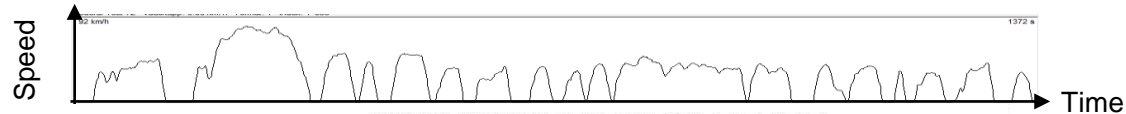
Repeatability – 3 ROBOT runs on chassis dyno



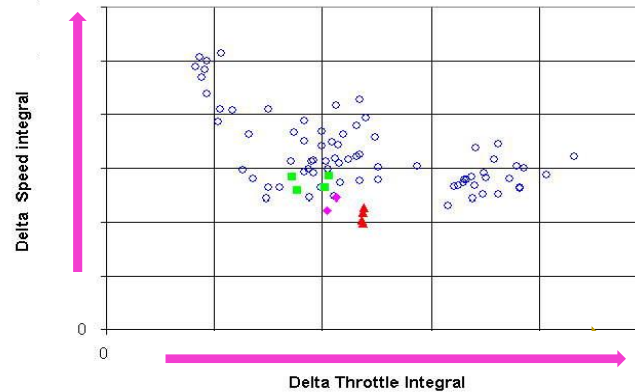
Pictures: Courtesy of IPEK, AUDI

Co-simulated test environment

Comparability – human drivers + Autopilot



DRIVER CHARACTERISTICS FOR FTP TEST



- Various Drivers
- Single Driver



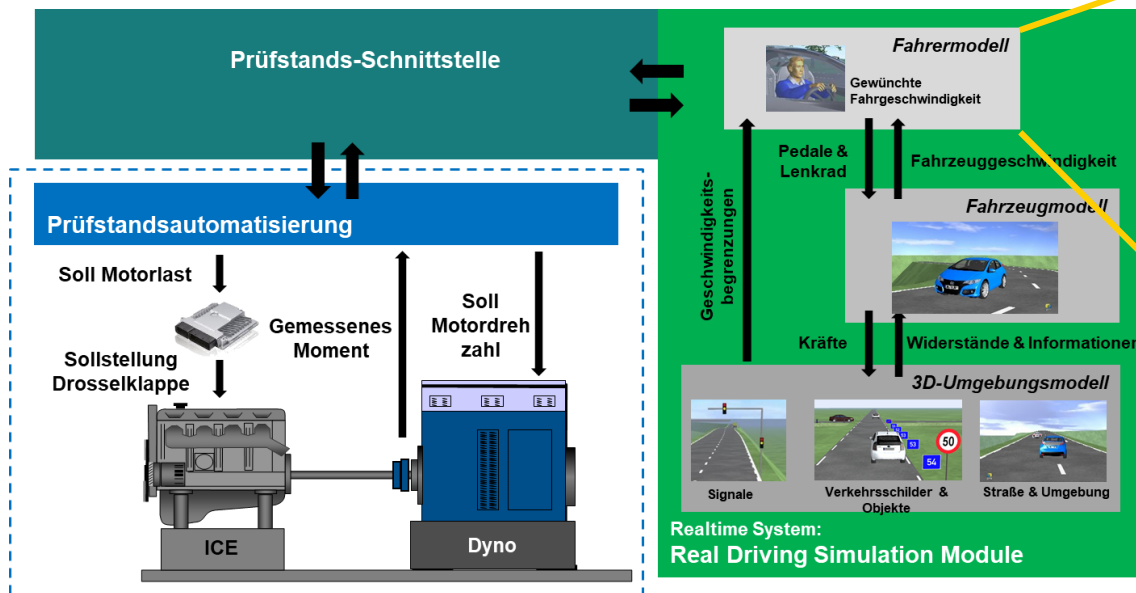
- ▲ AP500S (high accurate drive mode)
- ◆ AP500S (smooth drive mode)



Pictures: Courtesy of IPEK, AUDI

Co-simulated test environment

Testbed setup & Scenario



IPG CM CarMaker Testbed with
Stähle DriverModule



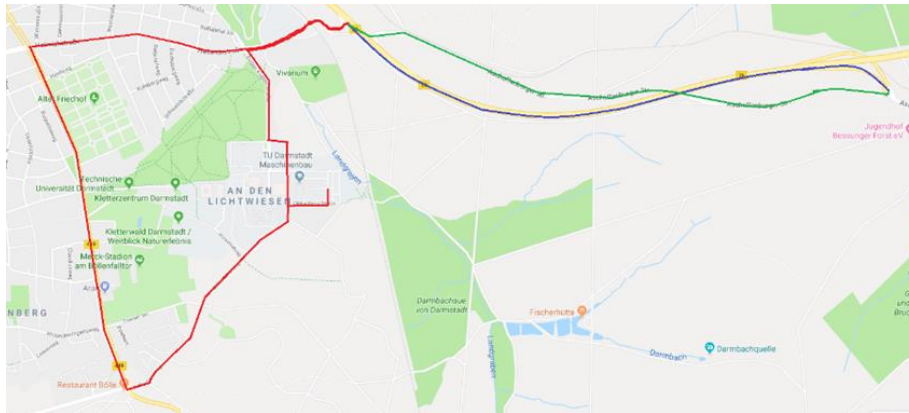
Input Driverparameter with
Autopilot GUI

Testbed-Setup

CarMaker Testbed
Stähle DriverModule
AVL PUMA Automation System

Co-simulated test environment

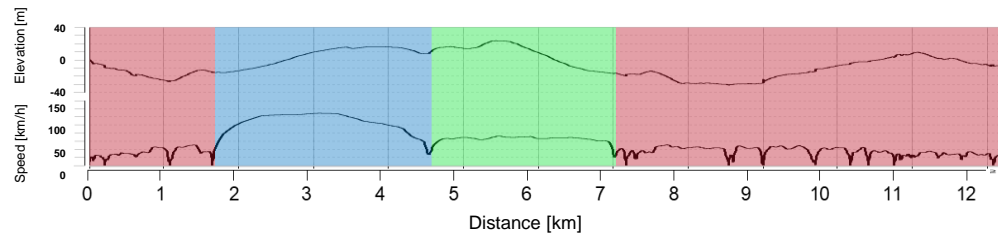
Testbed setup & Scenario



VKM commuter route profile

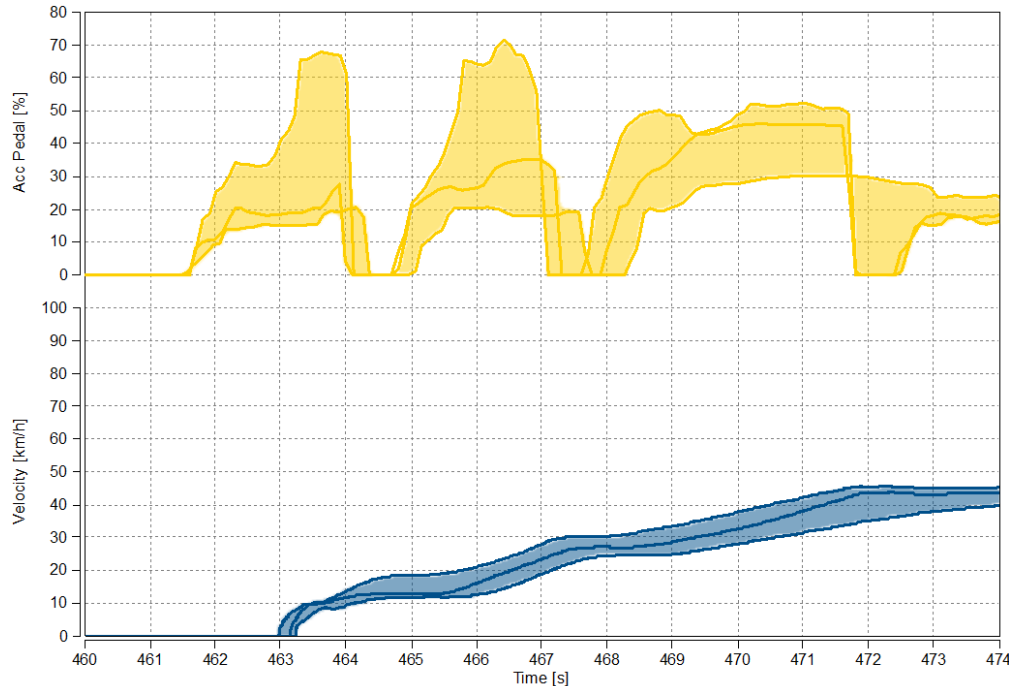
- Driving profile representative for ordinary commuter driving
- Consisting of all speed types regarding RDE

	<i>Urban</i>	<i>Rural</i>	<i>Motorway</i>	<i>Total</i>
Ø Speed (km/h)	23,1	67,7	113,1	32,4
Trip share (%)	59,87	22,21	17,92	100
Distance (km)	7,24	2,69	2,17	12,1



Results

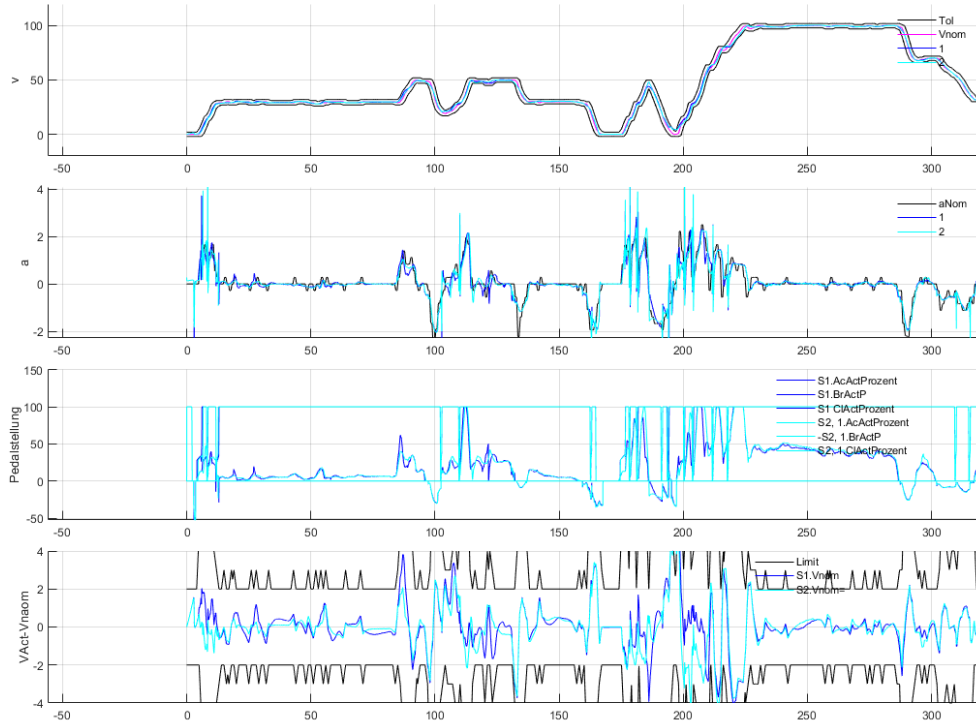
Observed behavior in RDE tests: Acceleration to ~ 50 km/h



- Different drivers, same maneuver
- Characteristic, pulsative increase in pedal activity
- Interrupted by shifting which leads to variances
- Two types of behavior
 - Quasi-constant pedal position after increase
 - Continuous increase in pedal position

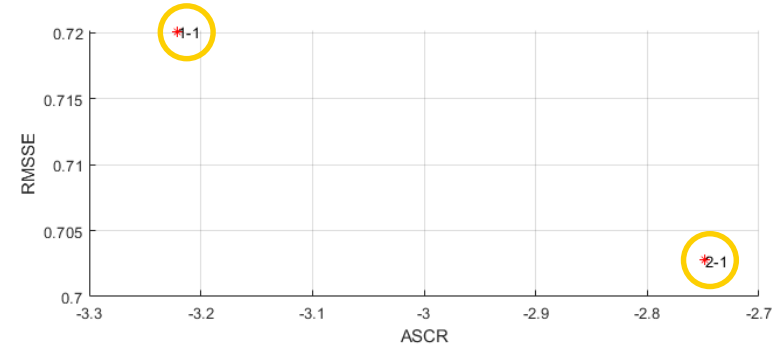
Results

Stähle DriverModule integration with CarMaker Testbed



➤ Investigation of 2 different drive style settings (Driver 1 & Driver 2) at EIL-testbed

	RMSSE	ASCR
Driver 1	0.72	-3.22
Driver 2	0.70	-2.75



Conclusion

- **RDE**: great variability – many interactions
- **Frontloading** with automatable and reproducible tests on **XiL-Testbeds** with **RDE Methodology Toolbox**
- Successful implementation of **CarMaker Testbed** with **Stähle DriverModule** on **PUMA EiL-Testbed**
- Testbed setup shows **great potential regarding RDE testing**
 - Detailed focus on **Driver Influence**:
 - Repeatable driver behavior on testbed
 - Precise driver behavior
 - Different strategies in driving style realizable

Thank you for your kind attention!

