SCHAEFFLER

Early Verification and Testing of a Mechatronic Active Roll Control

Dr. Hua Huang | Schaeffler Technologies AG & Co. KG
QTronic User Conference 2019, Berlin

SCHAEFFLER

Agenda

1 **Background and Motivation**

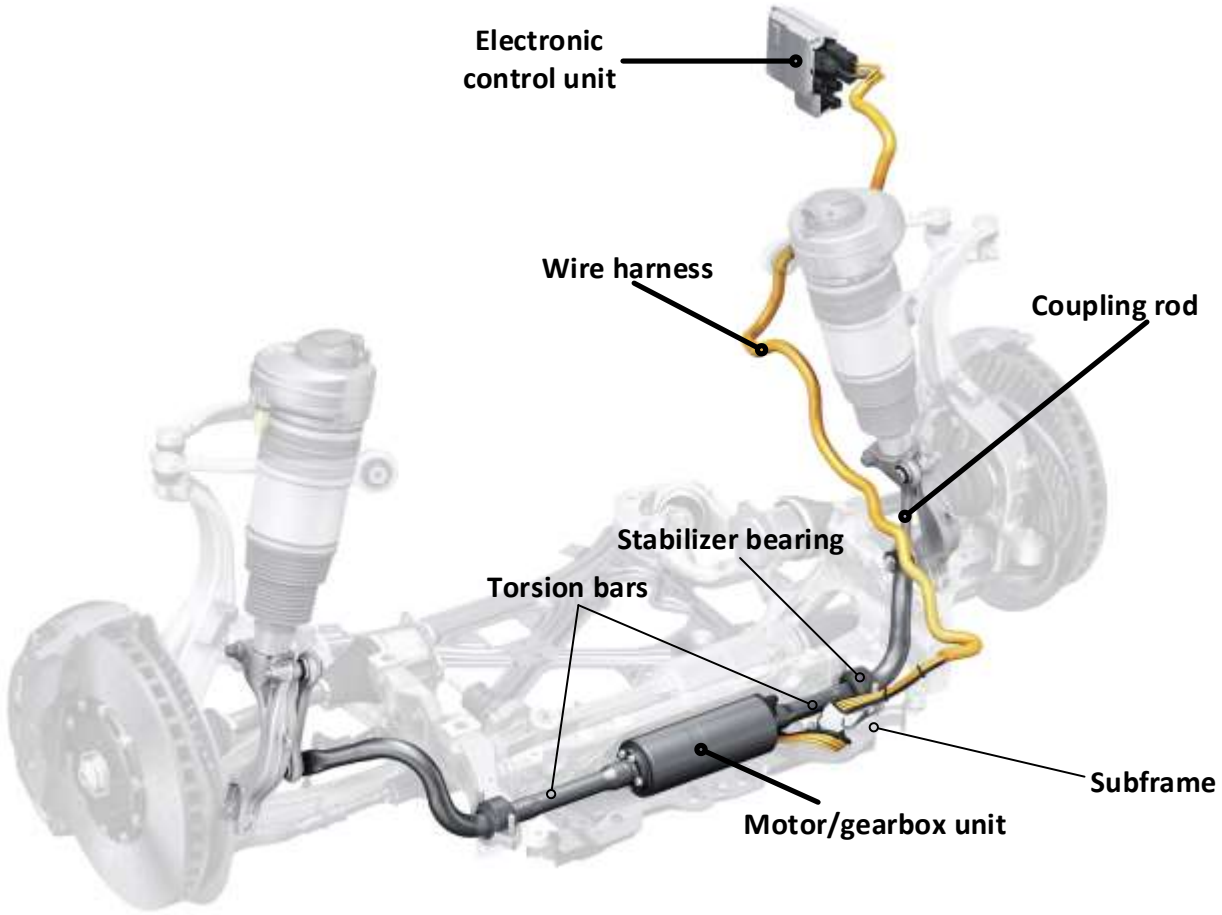
2 Virtual Testing with Silver

3 Use Case @Schaeffler

All rights reserved to Schaeffler Technologies AG & Co. KG, in particular in case of grant of an IP right.

SCHAEFFLER

intelligent Active Roll Control (iARC)



- iARC system components, integrated in the front axle of an SUV (©Audi, Schaeffler)

Roll control

Active mechatronic roll control | Passive roll stabilization

Comfort

Decoupling: actuator torque front axle $T_{FA} \triangleq 0$

Agility and sportiness

Understeer $T_{FA} > T_{RA}$ | Neutral drivability $T_{FA} = T_{RA}$ | Oversteer $T_{FA} < T_{RA}$

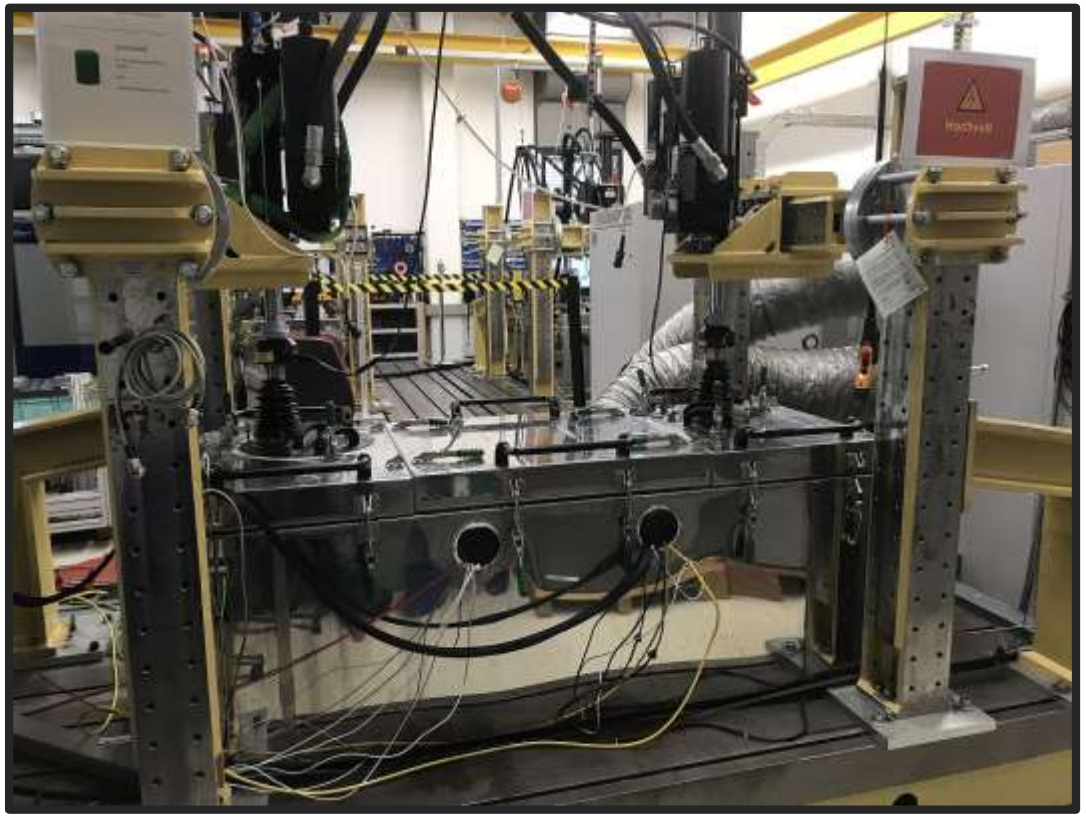
Safety

Active mechatronic roll control | Passive roll stabilization

All rights reserved to Schaeffler Technologies AG & Co. KG, in particular in case of grant of an IP right.

SCHAEFFLER

System Functional Test: Status and Challenges



Test Environment

- Target signals: Test profiles
- External disturbances at coupling rods: 2x hydraulic pulser system
- Vehicle/Chassis communication: Restbus simulation
- Supply voltage: 36V / 48V / 52V
- Ambient temperature: -30°C / 23°C / 80°C

Challenges

- Higher cost (compared with virtual testing)
- Bug-fix of unexpected errors brings more time consuming on test bench
- Test scheduling depends on the availability of the bench

Motivation

- Virtual testing on PC
  - Reduce cost on test bench
  - Increase the test coverage
  - Early verification and testing

All rights reserved to Schaeffler Technologies AG & Co. KG, in particular in case of grant of an IP right.

SCHAEFFLER

Agenda

1 Background and Motivation

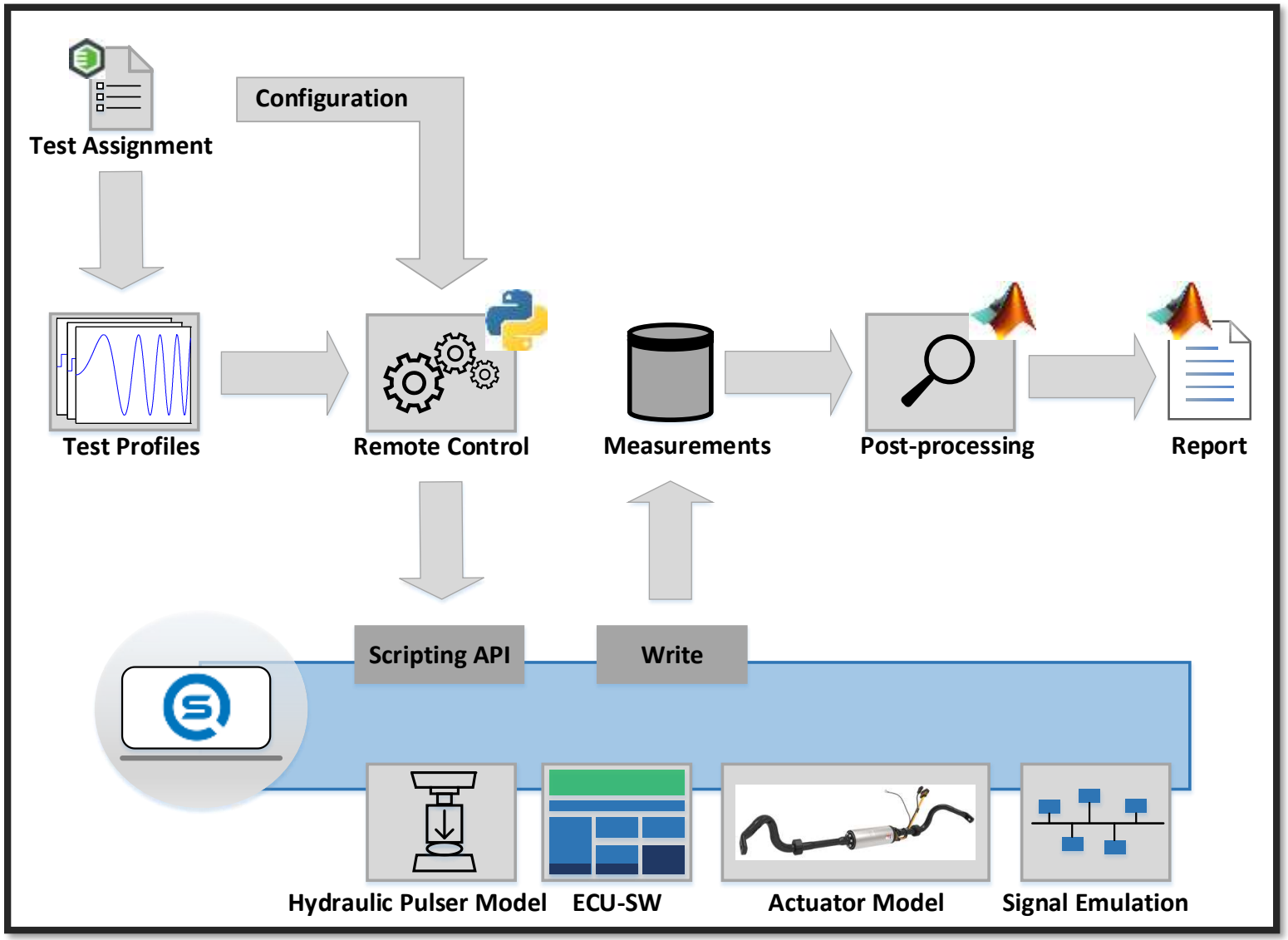
2 **Virtual Testing with Silver**

3 Use Case @Schaeffler

All rights reserved to Schaeffler Technologies AG & Co. KG, in particular in case of grant of an IP right.

SCHAEFFLER

Workflow of Virtual Testing



- Virtual simulation platform in Silver
- Test assignments are synchronized with database, i.e. PTC Integrity
- Virtual simulation platform is parameterized by software release, parameter container, actuator type and so on
- Post-processing: e.g. boundary values
- Test report shown in the end with “pass/fail“ results

All rights reserved to Schaeffler Technologies AG & Co. KG, in particular in case of grant of an IP right.

SCHAEFFLER

Virtualization

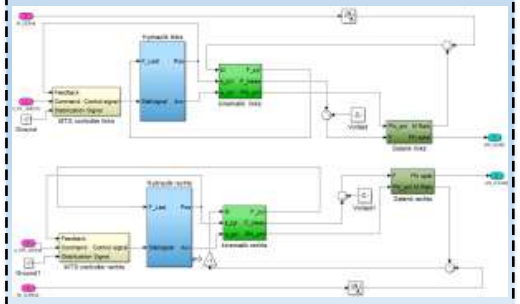
Real object

Hydraulic pulser system

iARC

virtualization **virtualization** **virtualization**

Modelling



Simulink

ECU functions

RTOS emulation

4GB virtual memory

A2L conve-rsion

XCP

flash

Simulation platform

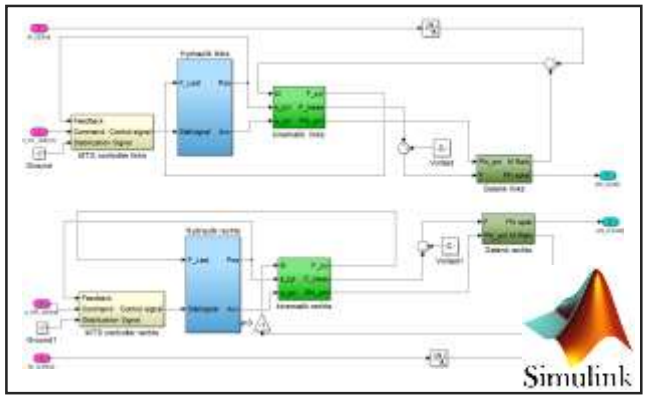
Silver

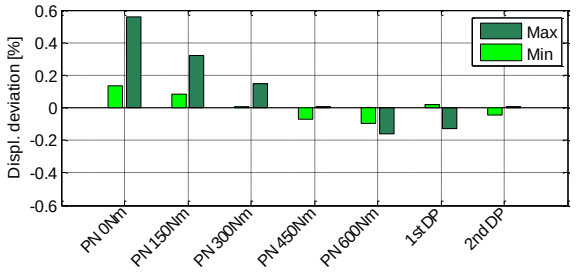
All rights reserved to Schaeffler Technologies AG & Co. KG, in particular in case of grant of an IP right.

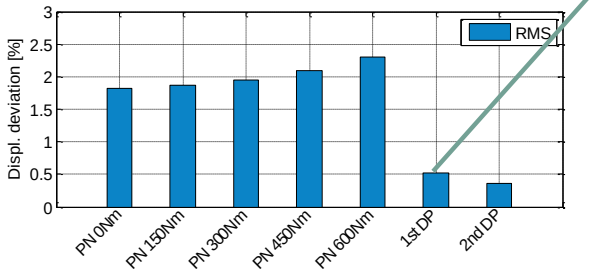
SCHAEFFLER

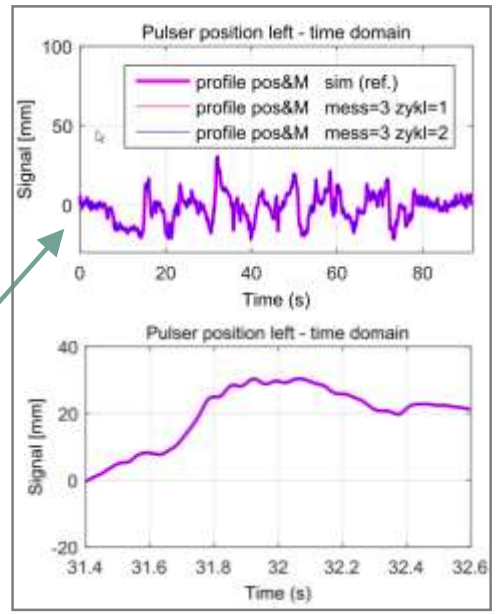
Virtualization of Physical Models

Hydraulic pulser system

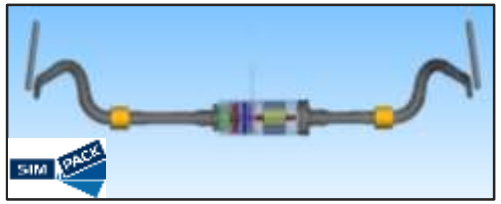


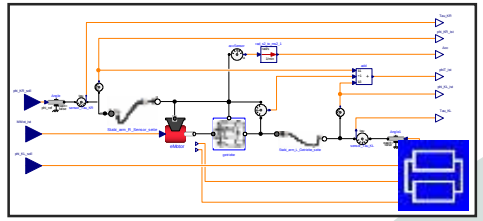






iARC (actuator component)

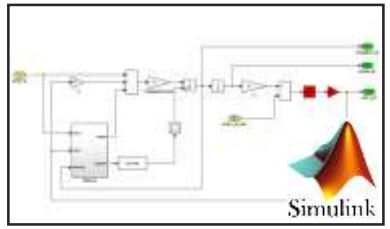




Advanced

Intermediate

Basic



All rights reserved to Schaeffler Technologies AG & Co. KG, in particular in case of grant of an IP right.

SCHAEFFLER

Virtualization of ECU-SW

Options

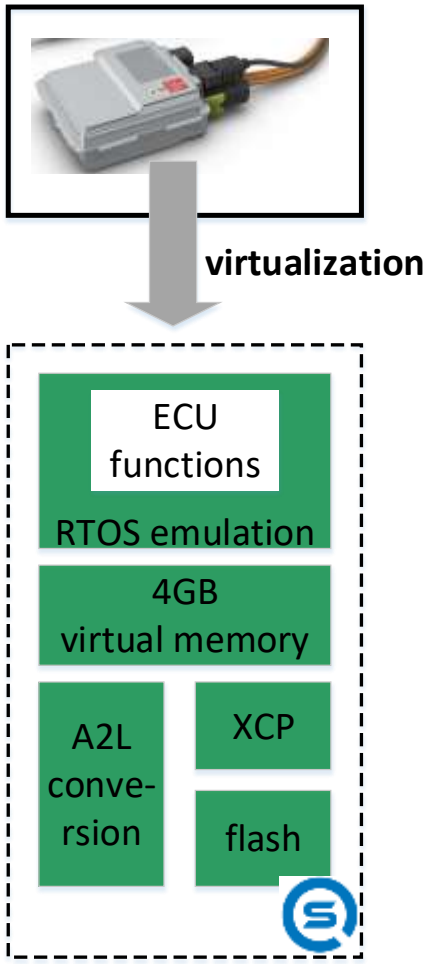
- MATLAB/Simulink modules in MiL (Model-in-the-Loop)
- C code in SiL (Software-in-the-Loop)
- Delivered Hex file (binary containing data and program code)

Status

- SW is developed together with another supplier
- Hex file is delivered from SW department and verified against specification
- Use the identical SW as the one on test bench

Virtualization

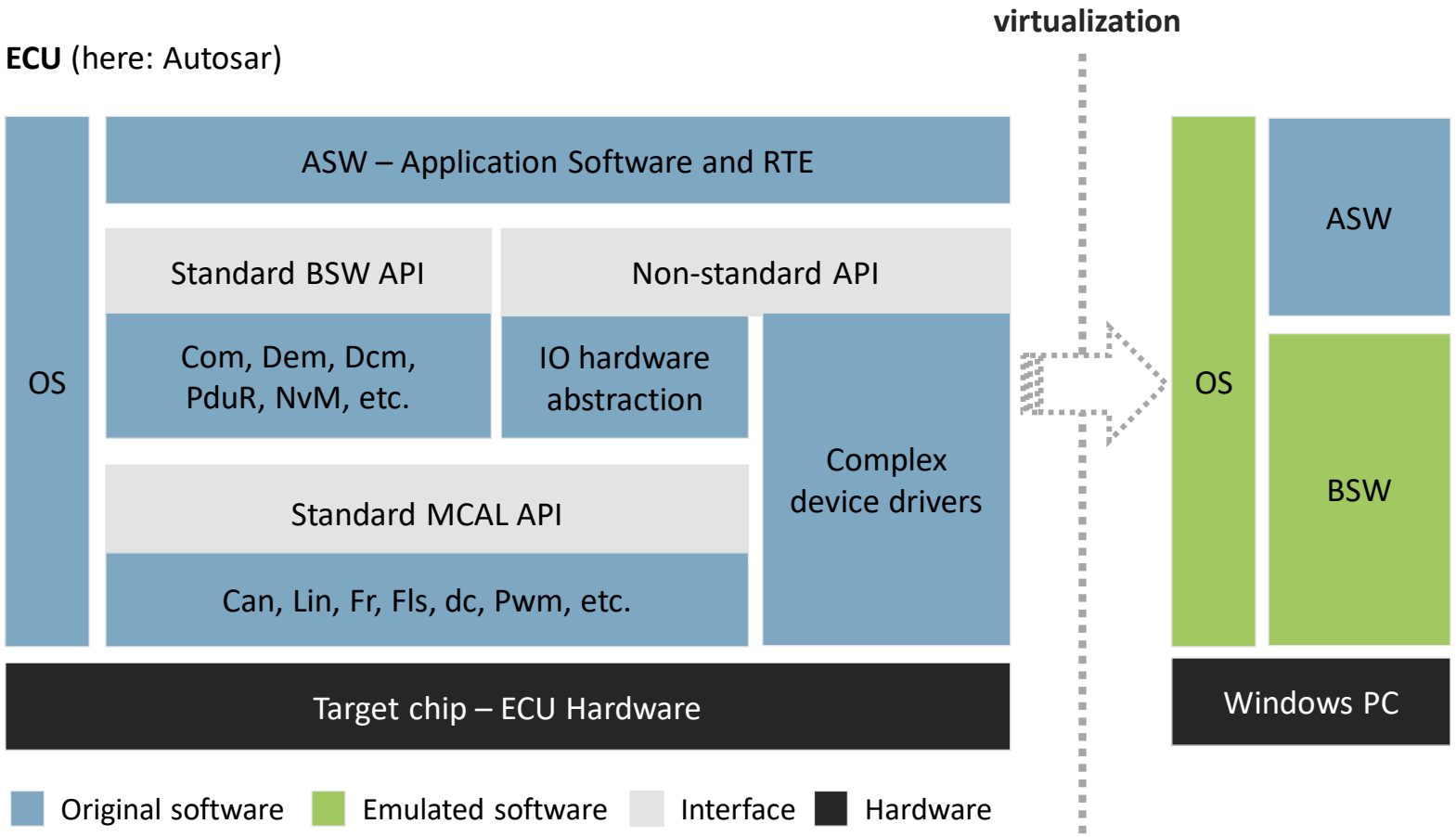
- Chip simulation



All rights reserved to Schaeffler Technologies AG & Co. KG, in particular in case of grant of an IP right.

SCHAEFFLER

Virtual ECU with Chip Simulation



Principle of chip simulation

- Mapping the instruction set of the target processor to the instruction set of the host processor on PC

Use case of chip simulation

- Only application SW
- Basic SW is verified in HiL (Hardware-in-the-Loop)

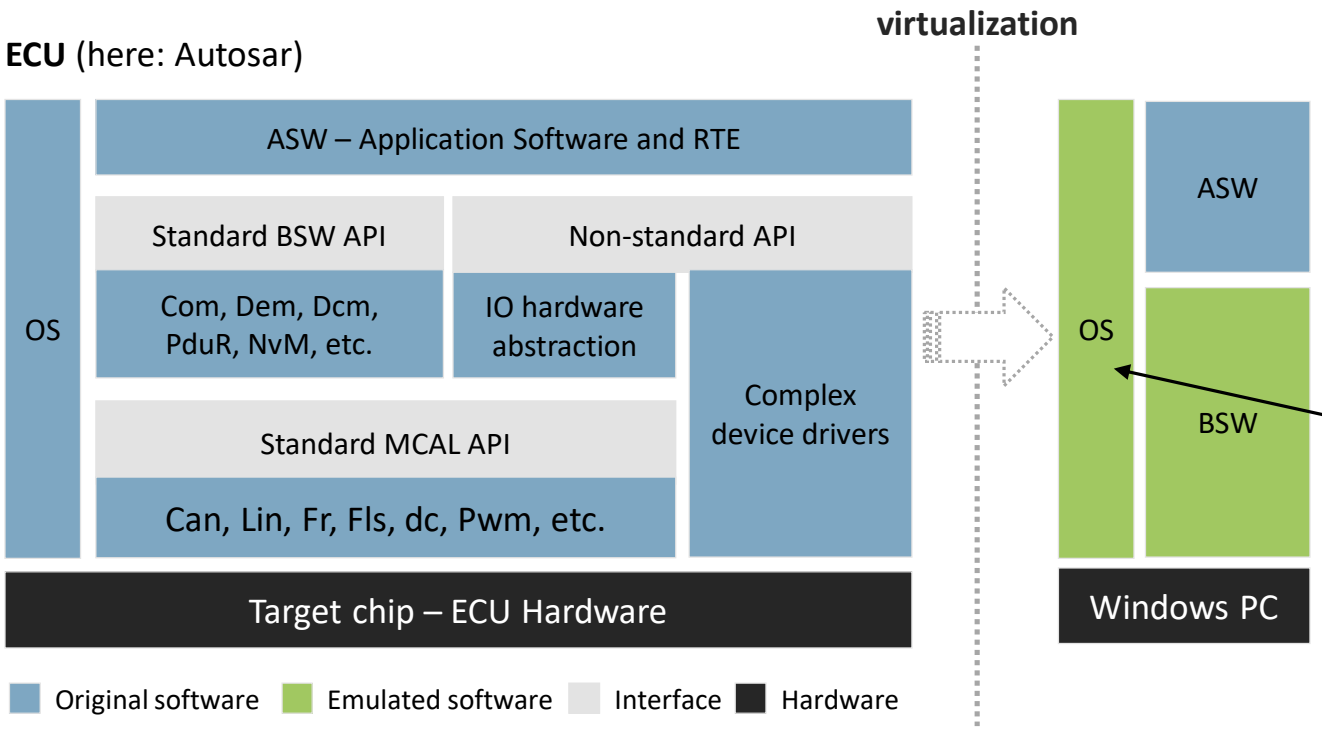
All rights reserved to Schaeffler Technologies AG & Co. KG, in particular in case of grant of an IP right.

SCHAEFFLER

Virtual ECU with Chip Simulation

Needed files

- **Hex file**: Program code and data of the functions to run
- **A2L file**: Describes the inputs, outputs (MEASUREMENT elements) and parameters (CHARACTERISTIC and shared AXIS_PTS elements)
- **MAP file**: Maps function names to ECU memory addresses
- **DCM file** (for calibration): Calibration data to be flashed




```
01  # ============================================
02  # Spec file for tcbuild.exe and Silver module tcdebug.dll
03  #============================================
04
05  # Used files
06  hex_file(iARC_SW_H03.A.V01_R0.2.0.167.hex, TriCore_1.6.1)
07  map_file(iARC_SW_H03.A.V01_R0.2.0.167.map)
08  a2l_file(iARC_SW_H03.A.V01_R0.2.0.167_rear.a2l)
09
10  # Specification of startup code
11  chip_config(STEP_SIZE, 0.001)          # base clock tick in milli seconds
12  chip_config(TEXT_START, 0xa0000000)  # 4 bytes for Silver internal use
13
14  # List of functions to run, in order of execution
15  task_initial(ATC_TaskInit, 0)
16  task_periodic(ATC_step, 2, 0)
17
18  a2l_function_inputs(ATC_Gen)
19  a2l_function_outputs(ATC_Gen)
```


All rights reserved to Schaeffler Technologies AG & Co. KG, in particular in case of grant of an IP right.

SCHAEFFLER

Agenda

1 Background and Motivation

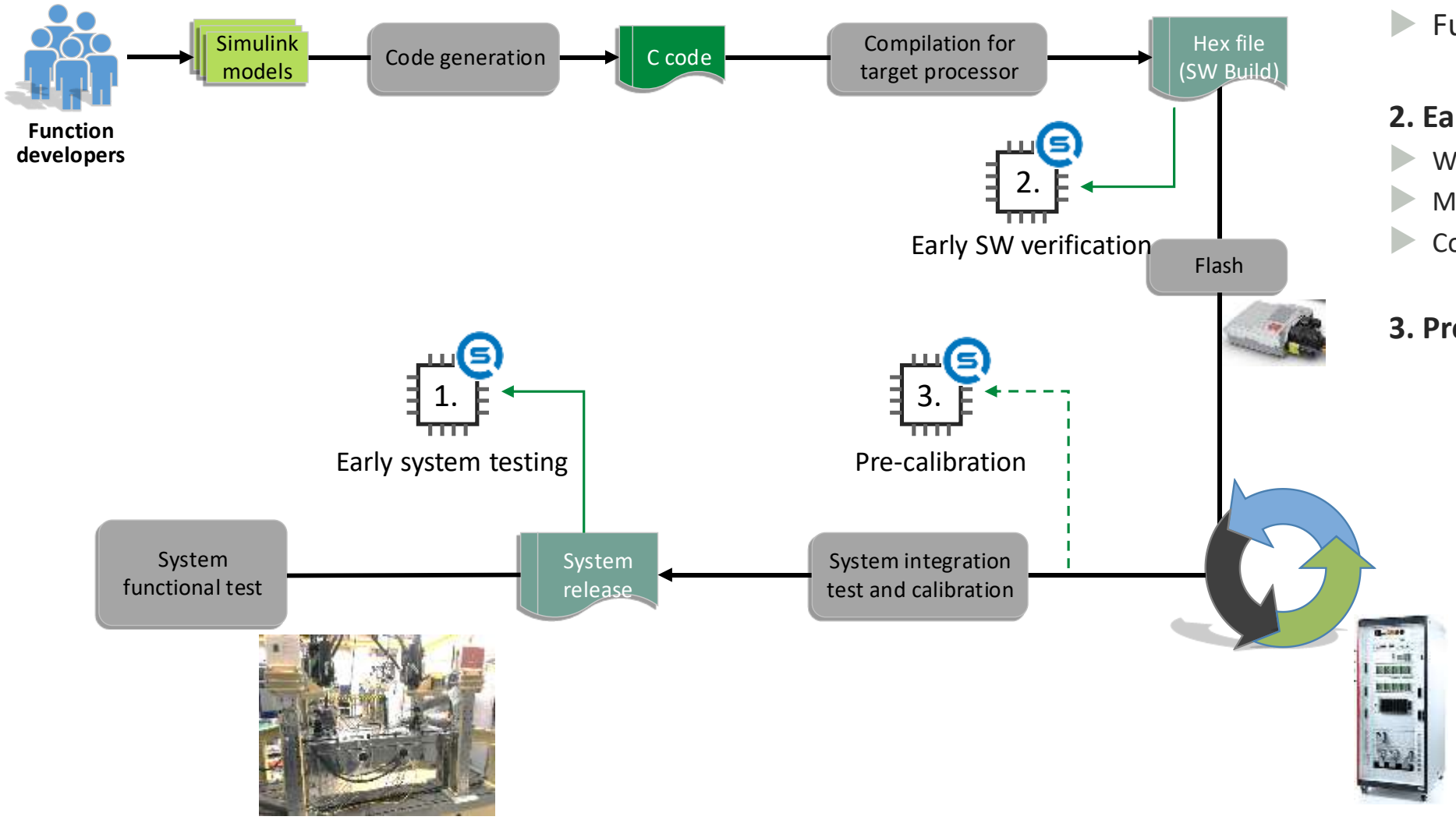
2 Virtual Testing with Silver

3 **Use Case @Schaeffler**

All rights reserved to Schaeffler Technologies AG & Co. KG, in particular in case of grant of an IP right.

SCHAEFFLER

Early Software Verification and System Testing



1. Early system testing

- Functional testing in system context

2. Early software verification

- When SW-Build is deployed
- Move selected tests from HiL
- Component testing

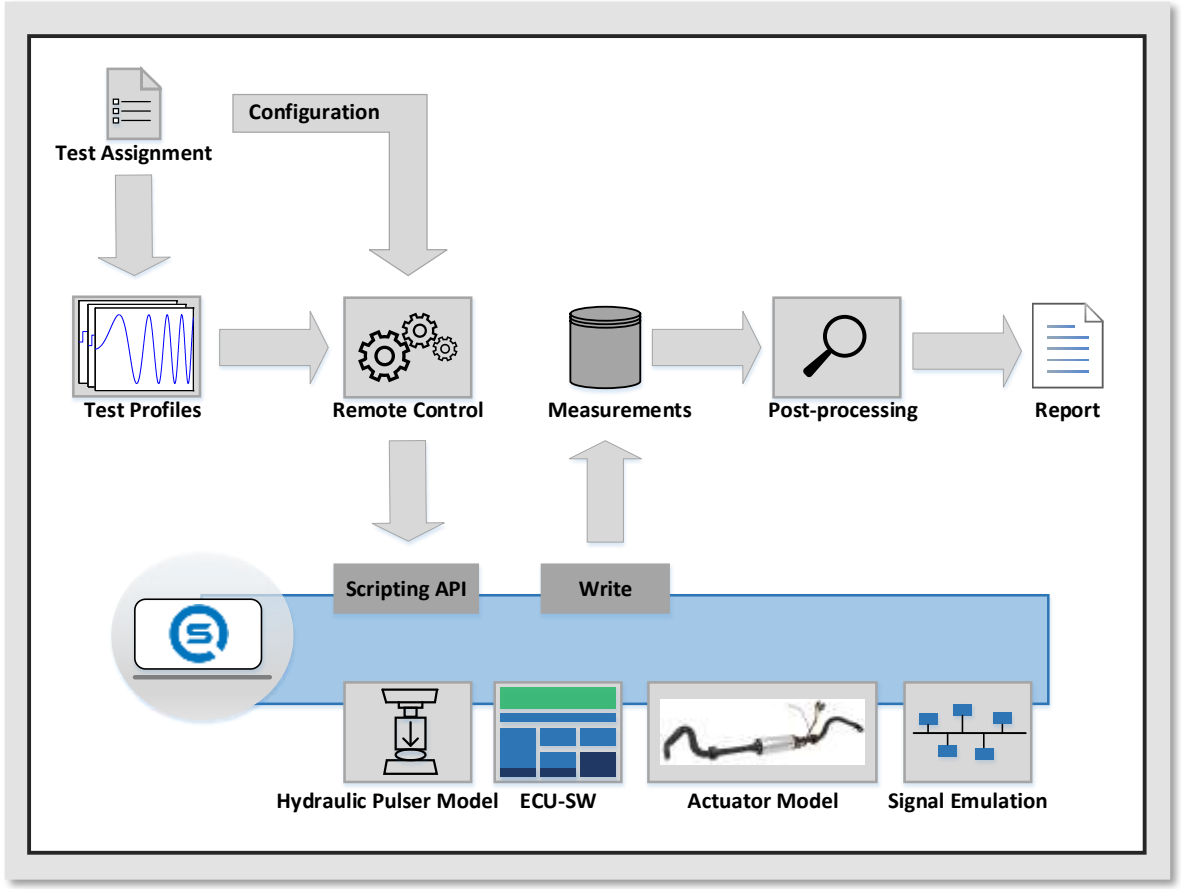
3. Pre-calibration

All rights reserved to Schaeffler Technologies AG & Co. KG, in particular in case of grant of an IP right.

SCHAEFFLER

Status Quo

1. 46 % IDs of system functional test can be verified in virtual environment
2. Virtual testing has a good correlation with measurements
3. Enlarge test strategy in a cost-effective way
4. Has been established for more than one project, and is also planned for other chassis mechatronic systems
5. Continuing improvement of physical models to increase test scenarios



All rights reserved to Schaeffler Technologies AG & Co. KG, in particular in case of grant of an IP right.

Dr. Hua Huang

Schaeffler Technologies AG & Co. KG

All rights reserved to Schaeffler Technologies AG & Co. KG, in particular in case of grant of an IP right.