SIL standardization – the world driven by SIL

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Principle of Software-in-the-Loop (SIL)

**System under test (SUT): Software**

Test environment=vehicle

In-vehicle SW tests

**System under test (SUT): Software**

Test environment=labcar, lab equipment, Hardware-in-the-Loop (HIL)

HIL tests

**System under test (SUT): Software**

Test environment=virtual environment, PC, server or cloud

SIL tests

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**vehicle model / plant models**

(e.g. sensor models, actuator models)

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**ECU-model / vECU x**

ASW
(application Software, functions)

BSW
(Basis Software, e.g. operating system, HW driver)

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**ECU-model / vECU y**

ASW
(application Software, functions)

BSW
(Basis Software, e.g. operating system, HW driver)

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Virtual communication bus

Virtual control and data lines

Virtual power lines

Main SIL components / core topics:

- vECUs = virtual ECUs, ECU models
- Virtual HW driver
- Virtual communication busses (e.g. virtual CAN, virtual FlexRay, virtual Ethernet)
- Plant models (“Streckenmodelle”) suitable for SIL

SIL is an efficient approach for testing software
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Expectations towards SIL

**Function developer:**
user-friendly SIL&MIL-environment to develop & test their algorithms and functional models

**Software developer and tester:**
SIL environment integrated in existing tool chains & continuous testing strategy

**HIL tester:**
HIL test cases to be reused and run in SIL (but faster and with more input parameter combinations)

**Application engineers:**
usage of SIL environment for early SW and system application (efficiency increase)

**OEMs:**
SIL-tested software by suppliers, easily to be integrated into OEM-SIL-environments

**Everybody:**
- seamlessly usable SIL system
- SIL components are combinable between different use cases, roles and companies

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Several levels of SIL testing and release

**Release on Distributed Level**
- Requirement-based Testing
- Real-life condition Test
- Scenario Coverage
- Field-based Validation
- Security
- Network
- Virtual Release

... = In-vehicle tests

**Release on Component Level**
- Housekeeping, Middleware,
  Timing, Memory, Runtime,
  Concurrency, Fault-injection

... = tests in target HW

**Release on Functional Level**
- Back-to-back Test,
  Timing, Memory, Runtime,
  KPI Metrics, Robustness,
  Interface Tests,
  Component Tests,
  Model Verification,
  Model Verification,
  Static Code Analysis,
  Code Coverage,

= tests in virtual environment (SIL/simulation)

... = closed loop

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<th>Test Level</th>
<th>SIL</th>
<th>Description</th>
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<tbody>
<tr>
<td>Vehicle</td>
<td></td>
<td>In-vehicle tests</td>
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<tr>
<td>Virtual HIL / Vehicle in the loop</td>
<td></td>
<td>tests in target HW</td>
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<tr>
<td>vECU Release Test on SoS level (Multi-domain reference SIL)</td>
<td>SiL</td>
<td>tests in virtual environment (SIL/simulation)</td>
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<tr>
<td>Release Test on ECU level (Single ECU-HIL)</td>
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<td>closed loop</td>
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<td>Release Test on ECU level (Single ECU-SiL)</td>
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<td>open loop</td>
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<tr>
<td>Implementation Test on reference HW</td>
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<td>Implementation Test on complete function level</td>
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<tr>
<td>SW Integration + Interface Test (&quot;DLL / PC&quot;)</td>
<td>SiL</td>
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<td>Unit Test and SCA on Unit Level</td>
<td>SiL</td>
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</table>
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SIL: Target “SIL anytime”

SIL will be the continuous testing environment for the automotive industry
The need for standardization

- SIL components need to be compatible and therefore standardized, because
  - Functions being distributed across several nodes and domains need to be verified early in SIL environments (-> several vECUs to be combined in one SIL setup)
    **X-domain compatibility**
  - SIL components in projects are coming from different companies (e.g. OEMs / TIER1s / tool provider)
    **X-company compatibility**
  - Components need to be runnable in different execution platforms (e.g. PC, server, cloud)
    **X-platform compatibility**
Examples for topics of the required SIL standardization

1. Interfaces for (plant) models
2. Interfaces to the virtual communication busses
3. Integration of vECUs
4. Interfaces to the test system
5. Interfaces to the virtual control and data lines
6. Interfaces to the virtual power lines

Approach:
At least the same test cases as in HIL environment + network tests (e.g. replacement of “Brettaufbau”)
Example for interface standards – virtual networks

Target Configuration

Configuration with Bridge

○ = need for interface standards
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Status of the standardization in the industry

Selection of projects, initiatives and organizations contributing to the SIL standardization

Main players in the automotive industry say, we need to

• Strengthen these activities
• Increase the speed and scope of the SIL standardization

BOSCH supports the enforcement of SIL standardization
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BOSCH SILC ROAD spec

Approach for the specification
- Develop, implement and use the open SILC ROAD architecture
- Bosch specification document serves for discussions with
  - OEMs,
  - tool providers and
  - other 3rd parties
- Agile x-divisional and x-company working structure
- Existing standards are used (e.g. FMI/FMU, ASAM XiL, XCP)

Contents SILC ROAD specification
- Use cases
- SIL properties and architecture
- Requirements for
  - Network virtualization
  - Virtual power lines
  - Virtual control and data lines
  - SIL tool framework
  - Plant models
  - Virtual ECUs
  - Reference implementation
  - Process framework

* SILC = SW in the Loop Common Requirements
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Benefits of the SILC ROAD spec

The SILC ROAD specification can be the basis for

- Industry-wide SIL specification, standardized SIL tools and process frameworks
- Reference implementations
- Standardized SIL-capable products
- New efficient SW test environments and methods for the software, system and application engineers
- The OpenADx activities

Current status:

- discussion of the SILC ROAD spec between BOSCH and several different market players has started