Continental
The Future in Motion

Test Automation and ISO-26262 Preparation for New Bus Product Line with Fully Electrified Powertrain

MathWorks Automotive Conference 2019

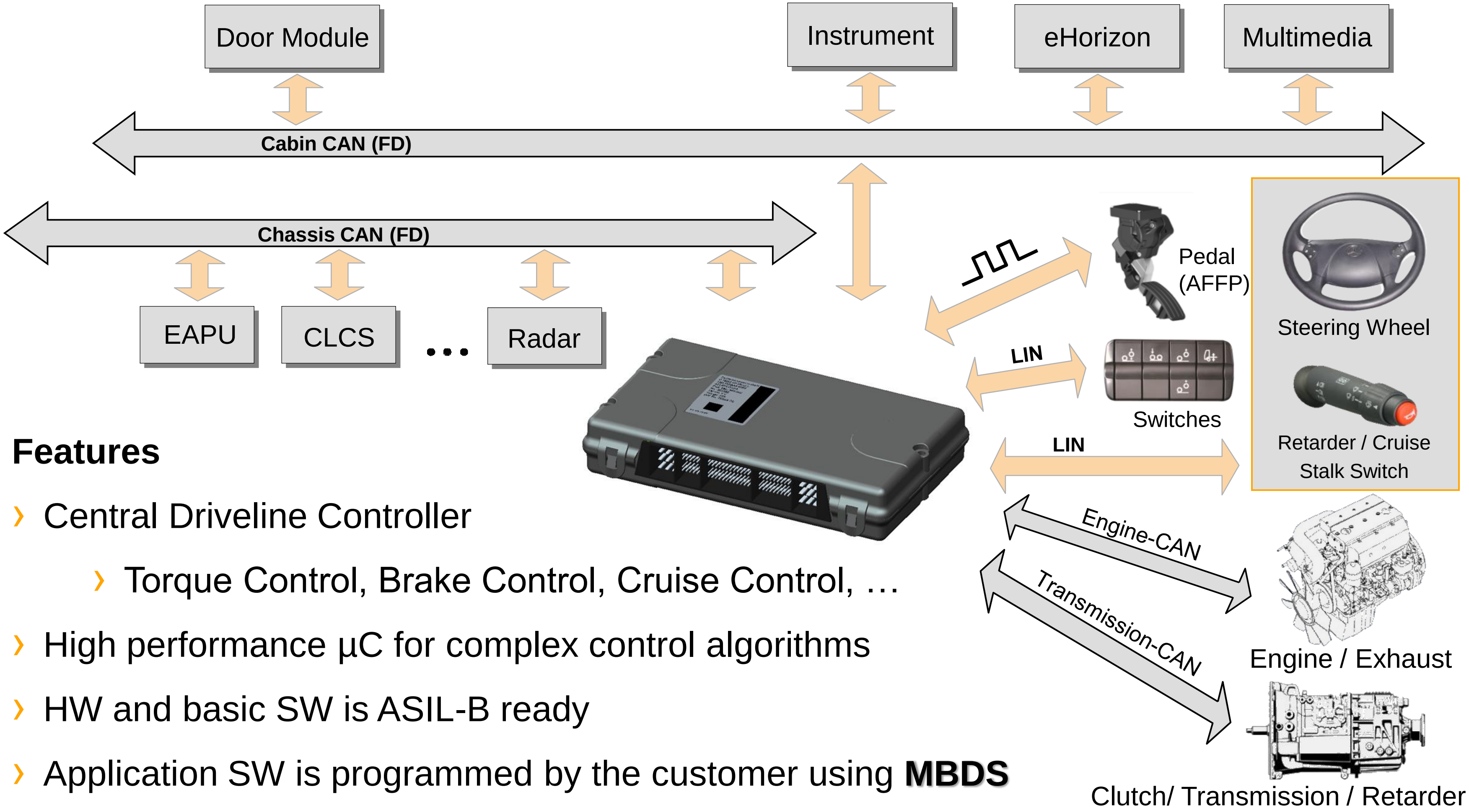
Scope
Continental Products used by VDL

- Next generation of public transportation busses
  - Fully electrified powertrain
  - **gVCU** implements high-level driveline controller functions

- Off-The-Shelf HW products
  - **g**eneric **V**ehicle **C**ontrol **U**nit
  - Body Controller
  - Multiplexer Nodes
  - Instrument Cluster

- Toolchain **M**odel **B**ased **D**evelopment **S**ystem
  - Based on MATLAB Simulink
  - **MBDS** IDE and modeling framework
  - Compliant to ISO-26262
  - CI/CT support

gVCU - generic Vehicle Control Unit
System Overview



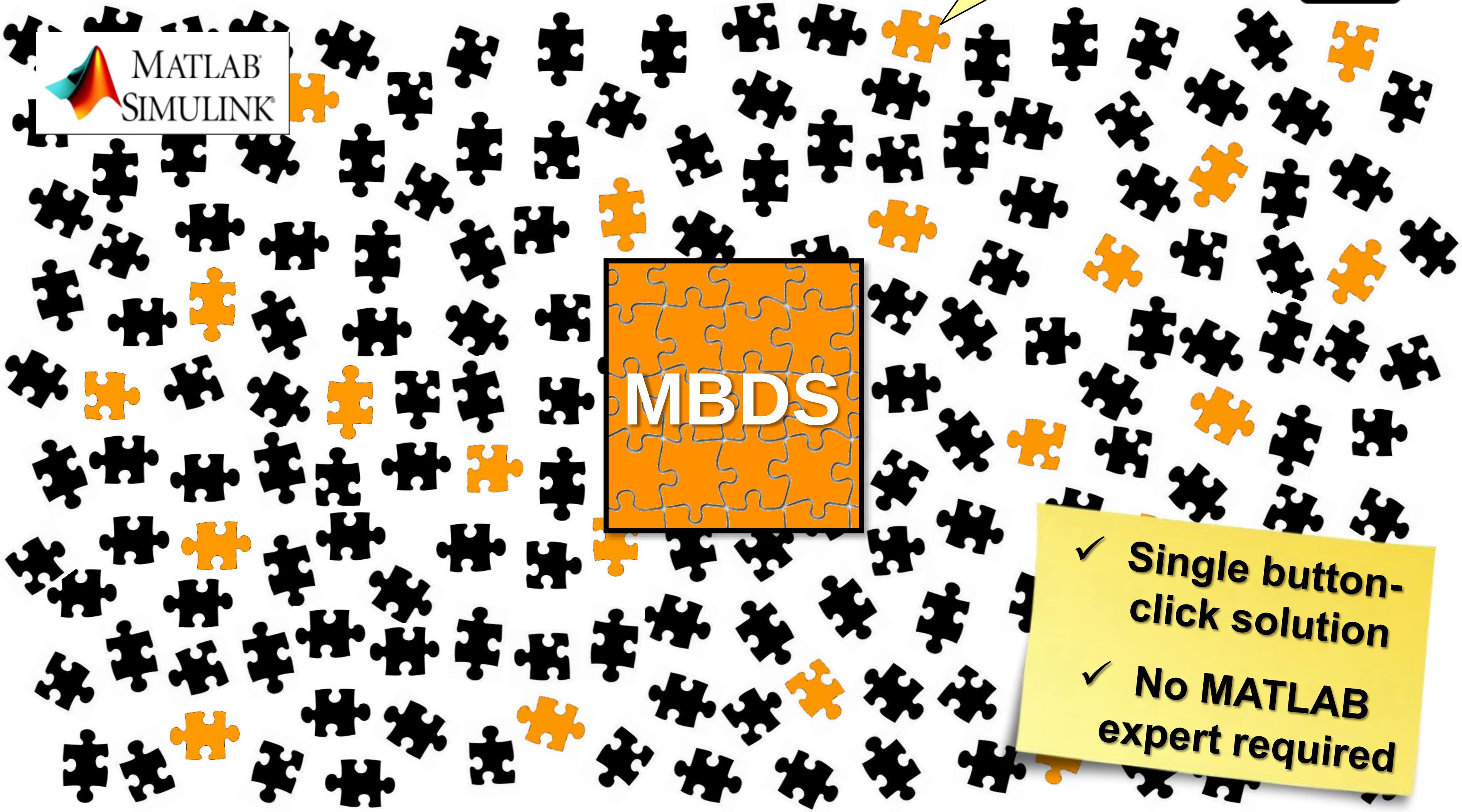
Features

- Central Driveline Controller
  - Torque Control, Brake Control, Cruise Control, …
- High performance µC for complex control algorithms
- HW and basic SW is ASIL-B ready
- Application SW is programmed by the customer using **MBDS**

MATLAB/Simulink versus MBDS

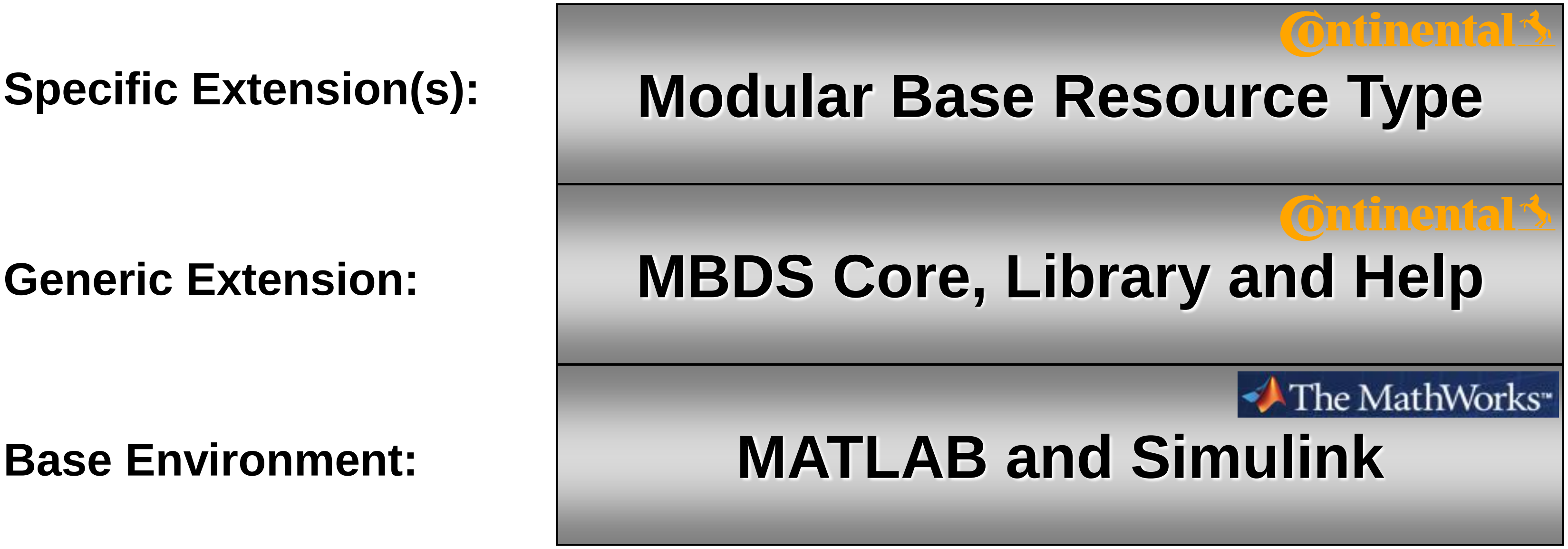
Non-Automotive SW Design

Automotive SW Design



- ✓ Single button-click solution
- ✓ No MATLAB expert required

MBDS Environment
Composition & Deployment


Specific Extension(s): Modular Base Resource Type

Generic Extension: MBDS Core, Library and Help

Base Environment: MATLAB and Simulink

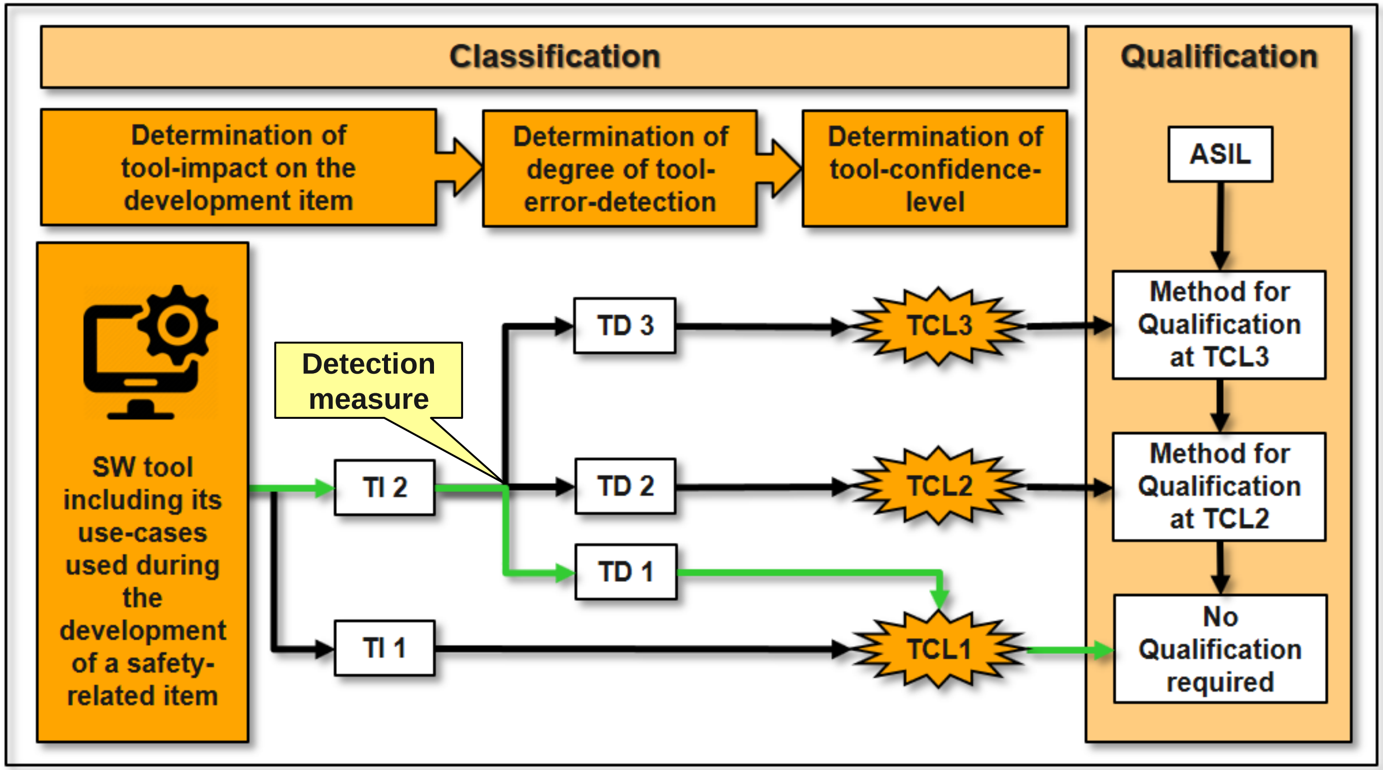
- Modeling: Simulink and Stateflow
- Code generation: Embedded Coder
- MBDS graphical user interface used as IDE
- Quality assurance measures, ACG, build & download
- Block library for design and integration
- Target HW and customer specific extension, e.g. BSW, compiler, …

✓ 100 % model based design

✓ Proven since many years

ISO-26262 Conformance
Tool Evaluation

- Hardware & Basic Software are ASIL-B ready
- **MBDS**: Evaluation of a software tool by analysis (ISO-26262, Part 8, Chapter 11.4.5)



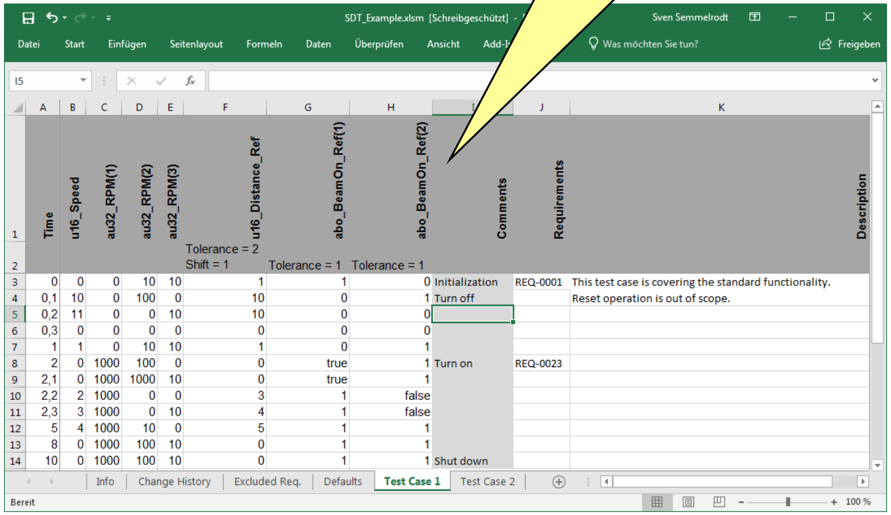
Classification
Qualification
Determination of tool-impact on the development item
Determination of degree of tool-error-detection
Determination of tool-confidence-level
ASIL
SW tool including its use-cases used during the development of a safety-related item
Detection measure
TI 2
TI 1
TD 3
TD 2
TD 1
TCL3
TCL2
TCL1
Method for Qualification at TCL3
Method for Qualification at TCL2
No Qualification required

MBDS Test Automation

3-Pillars of the Test Approach

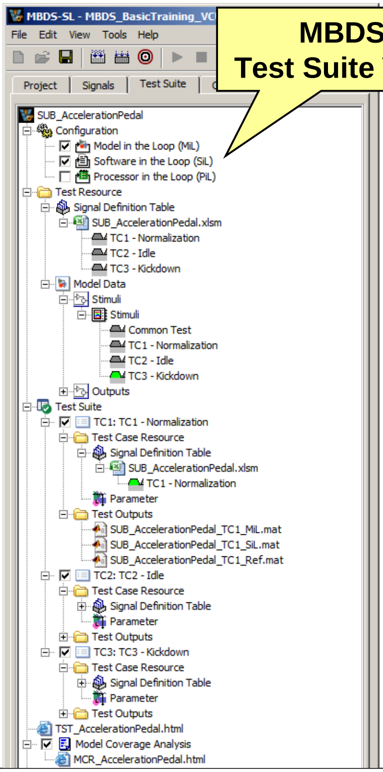
- Configuration, execution & evaluation: **Test Suite view in the MBDS IDE**
- Implementation of test stimuli & expected values: **Signal Definition Table**
- Test frame: **MBDS Model Template**

MBDS
Signal Definition Table



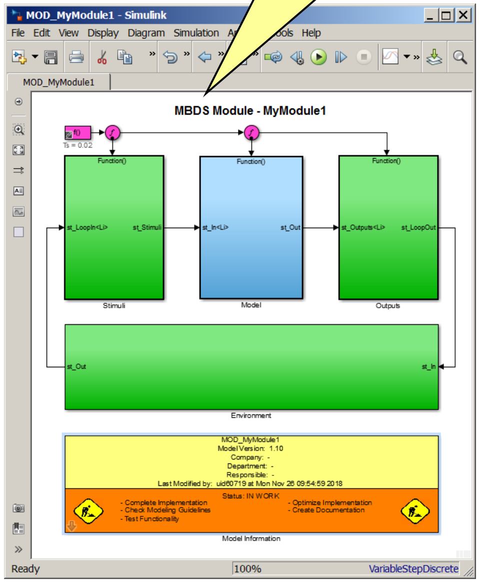
	A	B	C	D	E	F	G	H	I	J	K
1	Time	u16_Speed	au32_RPM(1)	au32_RPM(2)	au32_RPM(3)	u16_Distance_Ref	abo_BeamOn_Ref(1)	abo_BeamOn_Ref(2)	Comments	Requirements	Description
2						Tolerance = 2 Shift = 1	Tolerance = 1	Tolerance = 1			
3	0	0	0	10	10	1	1	0	Initialization	REQ-0001	This test case is covering the standard functionality.
4	0,1	10	0	100	0	10	0	1	Turn off		Reset operation is out of scope.
5	0,2	11	0	0	10	10	0	0			
6	0,3	0	0	0	0	0	0	0			
7	1	1	0	10	10	1	0	1			
8	2	0	1000	100	0	0	true	1	Turn on	REQ-0023	
9	2,1	0	1000	1000	10	0	true	1			
10	2,2	2	1000	0	0	3	1	false			
11	2,3	3	1000	0	10	4	1	false			
12	5	4	1000	10	0	5	1	1			
13	8	0	1000	100	10	0	1	1			
14	10	0	1000	100	10	0	1	1	Shut down		

MBDS
Test Suite View



- SUB_AccelerationPedal
  - Configuration
    - ☑ Model in the Loop (MiL)
    - ☑ Software in the Loop (SiL)
    - ☐ Processor in the Loop (PiL)
  - Test Resource
    - Signal Definition Table
      - SUB_AccelerationPedal.xlsm
        - TC1 - Normalization
        - TC2 - Idle
        - TC3 - Kickdown
    - Model Data
      - Stimuli
        - Stimuli
          - Common Test
          - TC1 - Normalization
          - TC2 - Idle
          - TC3 - Kickdown
      - Outputs
  - Test Suite
    - ☑ TC1: TC1 - Normalization
      - Test Case Resource
        - Signal Definition Table
          - SUB_AccelerationPedal.xlsm
            - TC1 - Normalization
        - Parameter
      - Test Outputs
        - SUB_AccelerationPedal_TC1_MiL.mat
        - SUB_AccelerationPedal_TC1_SiL.mat
        - SUB_AccelerationPedal_TC1_Ref.mat
    - ☑ TC2: TC2 - Idle
      - Test Case Resource
        - Signal Definition Table
        - Parameter
      - Test Outputs
    - ☑ TC3: TC3 - Kickdown
      - Test Case Resource
        - Signal Definition Table
        - Parameter
      - Test Outputs
  - TST_AccelerationPedal.html
  - ☑ Model Coverage Analysis
    - MCR_AccelerationPedal.html

MBDS
Model Template

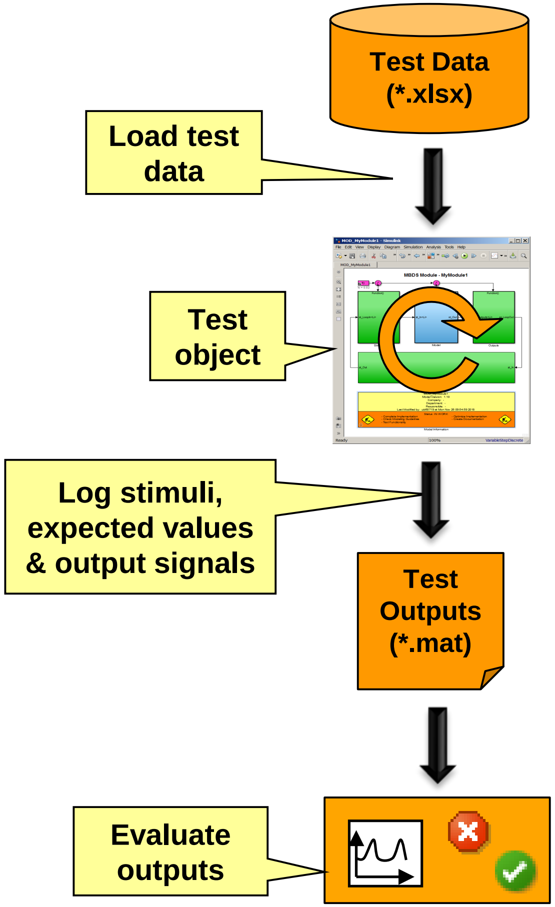


MOD_MyModule1
Model Version: 1.10
Company: -
Department: -
Responsible: -
Last Modified by: uid60719 at Mon Nov 26 09:54:59 2018

Status: IN WORK
- Complete Implementation
- Check Modeling Guidelines
- Test Functionality
- Optimize Implementation
- Create Documentation

MBDS Test Automation

Test Implementation, Execution & Evaluation



Test Data (*.xlsx)

Load test data

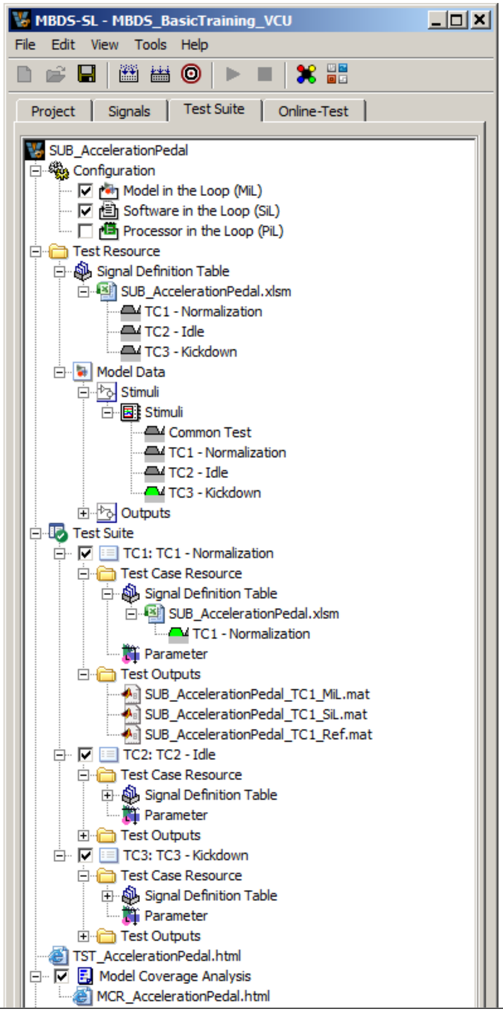
Test object

Log stimuli, expected values & output signals

Test Outputs (*.mat)

Evaluate outputs

Test Management



```
SUB_AccelerationPedal
⊟ Configuration
    ☑ Model in the Loop (MiL)
    ☑ Software in the Loop (SiL)
    □ Processor in the Loop (PiL)
⊟ Test Resource
    ⊟ Signal Definition Table
        ⊟ SUB_AccelerationPedal.xlsm
            TC1 - Normalization
            TC2 - Idle
            TC3 - Kickdown
    ⊟ Model Data
        ⊟ Stimuli
            ⊟ Stimuli
                Common Test
                TC1 - Normalization
                TC2 - Idle
                TC3 - Kickdown
        ⊞ Outputs
⊟ Test Suite
    ⊟ ☑ TC1: TC1 - Normalization
        ⊟ Test Case Resource
            ⊟ Signal Definition Table
                ⊟ SUB_AccelerationPedal.xlsm
                    TC1 - Normalization
            Parameter
        ⊟ Test Outputs
            SUB_AccelerationPedal_TC1_MiL.mat
            SUB_AccelerationPedal_TC1_SiL.mat
            SUB_AccelerationPedal_TC1_Ref.mat
    ⊟ ☑ TC2: TC2 - Idle
        ⊟ Test Case Resource
            ⊞ Signal Definition Table
            Parameter
        ⊞ Test Outputs
    ⊟ ☑ TC3: TC3 - Kickdown
        ⊟ Test Case Resource
            ⊞ Signal Definition Table
            Parameter
        ⊞ Test Outputs
    TST_AccelerationPedal.html
⊟ ☑ Model Coverage Analysis
    MCR_AccelerationPedal.html
```

Test Configuration

Test Suite (*.xml)

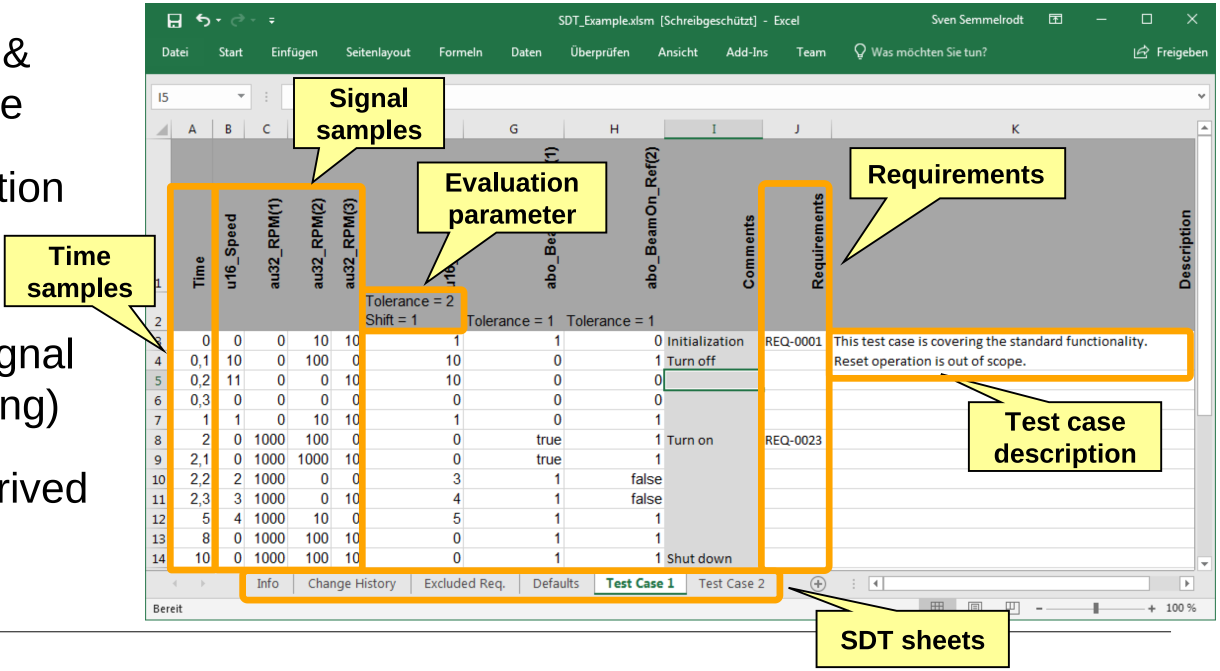
- One or multiple test levels
- One or multiple test cases
- With or without model coverage
- Manual inspection using Simulation Data Inspector
- Stimuli, expected values, outputs and configuration can be archived

MBDS Test Automation

Test Implementation using Signal Definition Table

- Test data editor for Stimuli & Expected Values: **MS Excel**
  - Our customers are MS Excel but no MATLAB experts
- Each test case is specified by a separate sheet in the SDT
  - Using defaults, a test case may contain signal subsets only
  - Simple test data specification using transition based time/value pairs
- Evaluation parameters (Shift & Tolerance) per expected value
- Test case & test step description
- Requirements for traceability
- Implementation of SDT by Signal Builder blocks (Q&D debugging)
- SDT can be automatically derived from existing models

✓ **Simplicity**
✓ **Readability**
✓ **Maintainability**
✓ **Completeness**

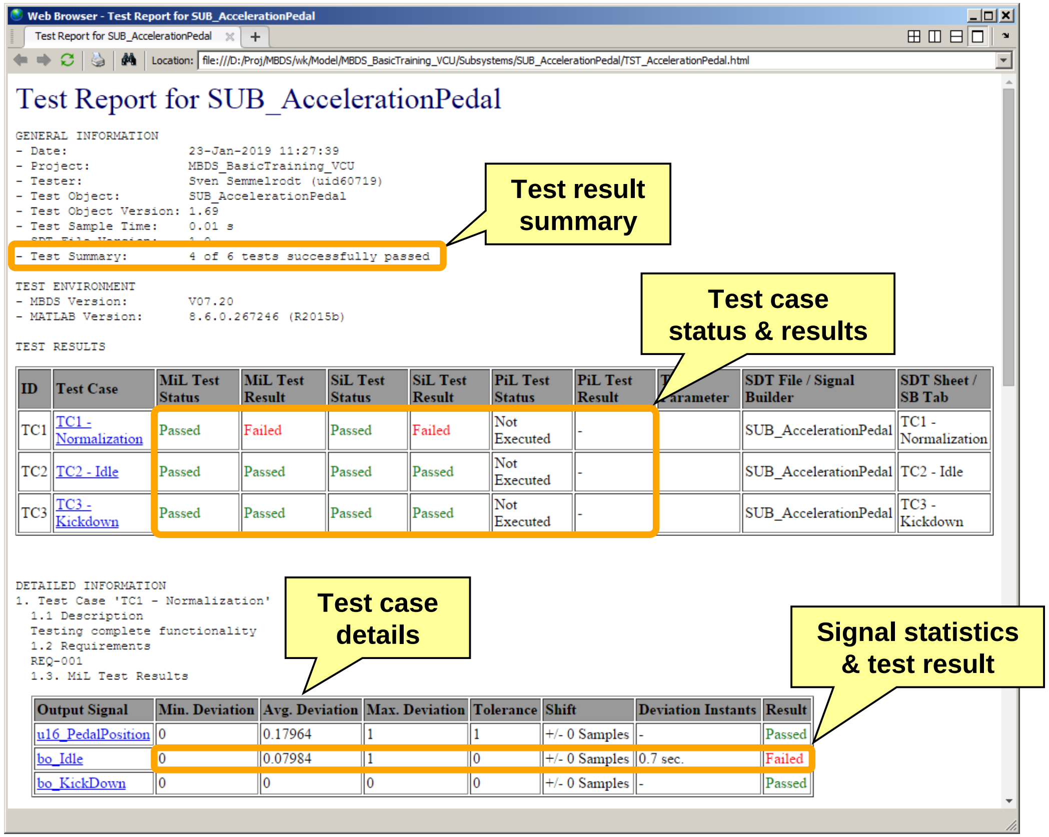


SDT_Example.xlsm [Schreibgeschützt] - Excel

	A	B	C				G	H	I	J	K
1	Time	u16_Speed	au32_RPM(1)	au32_RPM(2)	au32_RPM(3)	u16	abo_Be…(1)	abo_BeamOn_Ref(2)	Comments	Requirements	Description
2						Tolerance = 2 Shift = 1	Tolerance = 1	Tolerance = 1			
3	0	0	0	10	10	1	1	0	Initialization	REQ-0001	This test case is covering the standard functionality.
4	0,1	10	0	100	0	10	0	1	Turn off		Reset operation is out of scope.
5	0,2	11	0	0	10	10	0	0			
6	0,3	0	0	0	0	0	0	0			
7	1	1	0	10	10	1	0	1			
8	2	0	1000	100	0	0	true	1	Turn on	REQ-0023	
9	2,1	0	1000	1000	10	0	true	1			
10	2,2	2	1000	0	0	3	1	false			
11	2,3	3	1000	0	10	4	1	false			
12	5	4	1000	10	0	5	1	1			
13	8	0	1000	100	10	0	1	1			
14	10	0	1000	100	10	0	1	1	Shut down		

MBDS Test Automation
Automated Test Evaluation & Test Report

- Test report is generated based on the test levels & test cases selected for a test session
- Logged test outputs are compared to the expected values (considering Tolerance & Shift)
- Test information overview with test result summary
- Test description & requirements
- Signal test results & deviation statistics are displayed
- Test results are tagged in HTML report for simple CT result extraction jobs
- Fully automated via API


Web Browser - Test Report for SUB_AccelerationPedal

Test Report for SUB_AccelerationPedal
+
Location: file:///D:/Proj/MBDS/wk/Model/MBDS_BasicTraining_VCU/Subsystems/SUB_AccelerationPedal/TST_AccelerationPedal.html

Test Report for SUB_AccelerationPedal

```
GENERAL INFORMATION
- Date:                23-Jan-2019 11:27:39
- Project:             MBDS_BasicTraining_VCU
- Tester:              Sven Semmelrodt (uid60719)
- Test Object:         SUB_AccelerationPedal
- Test Object Version: 1.69
- Test Sample Time:    0.01 s
- SDT File Version:    1.0
- Test Summary:        4 of 6 tests successfully passed

TEST ENVIRONMENT
- MBDS Version:        V07.20
- MATLAB Version:      8.6.0.267246 (R2015b)

TEST RESULTS
```

ID	Test Case	MiL Test Status	MiL Test Result	SiL Test Status	SiL Test Result	PiL Test Status	PiL Test Result	T arameter	SDT File / Signal Builder	SDT Sheet / SB Tab
TC1	TC1 - Normalization	Passed	Failed	Passed	Failed	Not Executed	-		SUB_AccelerationPedal	TC1 - Normalization
TC2	TC2 - Idle	Passed	Passed	Passed	Passed	Not Executed	-		SUB_AccelerationPedal	TC2 - Idle
TC3	TC3 - Kickdown	Passed	Passed	Passed	Passed	Not Executed	-		SUB_AccelerationPedal	TC3 - Kickdown

```
DETAILED INFORMATION
1. Test Case 'TC1 - Normalization'
  1.1 Description
  Testing complete functionality
  1.2 Requirements
  REQ-001
  1.3. MiL Test Results
```

Output Signal	Min. Deviation	Avg. Deviation	Max. Deviation	Tolerance	Shift	Deviation Instants	Result
u16_PedalPosition	0	0.17964	1	1	+/- 0 Samples	-	Passed
bo_Idle	0	0.07984	1	0	+/- 0 Samples	0.7 sec.	Failed
bo_KickDown	0	0	0	0	+/- 0 Samples	-	Passed

Test result summary

Test case status & results

Test case details

Signal statistics & test result

MBDS Test Automation

Automated Test Evaluation & Test Report

- Test report is generated based on the test levels & test cases selected for a test session
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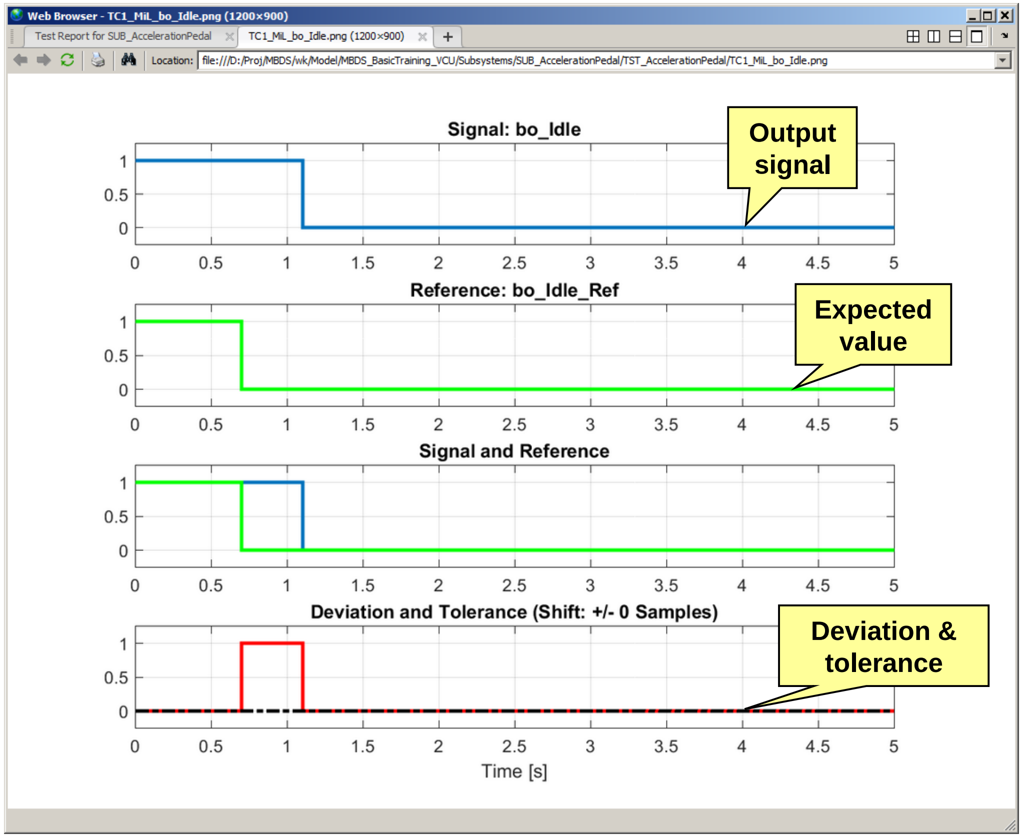
- Test information overview with test result summary
- Test description & requirements
- Signal test results & deviation statistics are displayed
- Test results are tagged in HTML report for simple CT result extraction jobs
- Fully automated via API
- Signal plots for fast visual inspection



Web Browser - TC1_MiL_bo_Idle.png (1200×900)

Location: file:///D:/Proj/MBDS/wk/Model/MBDS_BasicTraining_VCU/Subsystems/SUB_AccelerationPedal/TST_AccelerationPedal/TC1_MiL_bo_Idle.png

Test Report for SUB_AccelerationPedal
TC1_MiL_bo_Idle.png (1200×900)
Signal: bo_Idle
Reference: bo_Idle_Ref
Signal and Reference
Deviation and Tolerance (Shift: +/- 0 Samples)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time [s]

Output signal

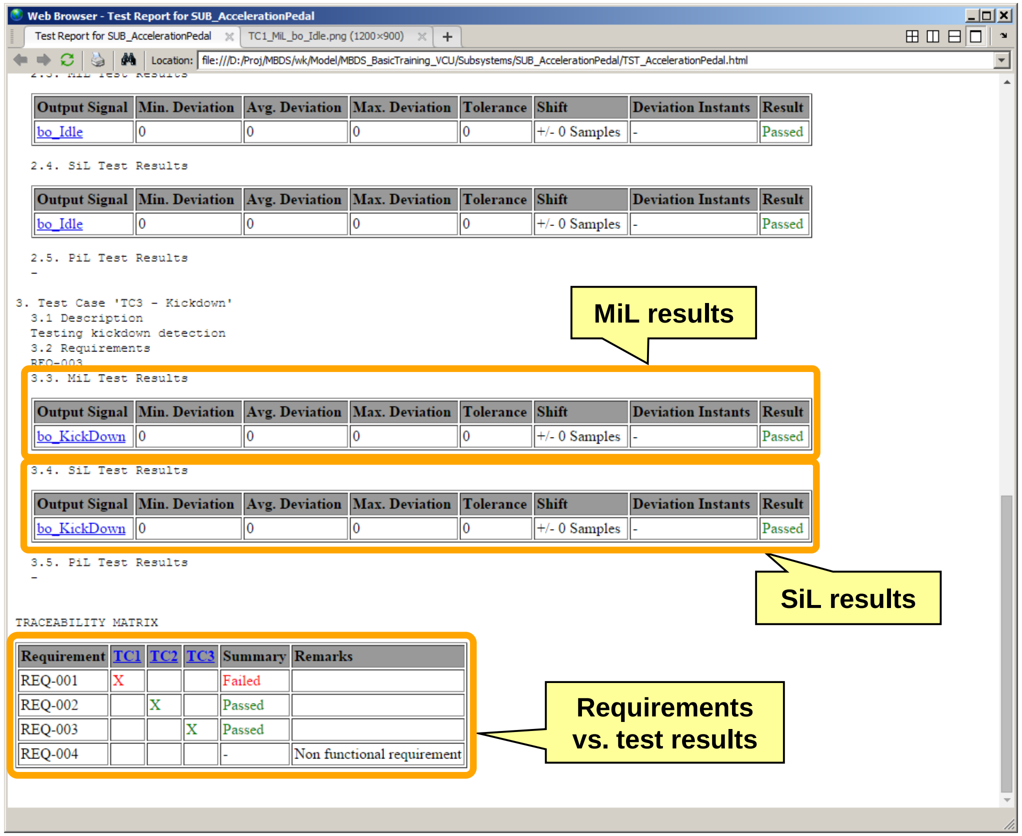
Expected value

Deviation & tolerance

MBDS Test Automation

Automated Test Evaluation & Test Report

- Test report is generated based on the test levels & test cases selected for a test session
- Logged test outputs are compared to the expected values (considering Tolerance & Shift)
- Test information overview with test result summary
- Test description & requirements
- Signal test results & deviation statistics are displayed
- Test results are tagged in HTML report for simple CT result extraction jobs
- Fully automated via API
- Signal plots for fast visual inspection
- Reqirements to test results matrix



Web Browser - Test Report for SUB_AccelerationPedal
Test Report for SUB_AccelerationPedal
TC1_MiL_bo_Idle.png (1200×900)
Location: file:///D:/Proj/MBDS/wk/Model/MBDS_BasicTraining_VCU/Subsystems/SUB_AccelerationPedal/TST_AccelerationPedal.html

```
  2.3. MiL Test Results
```

Output Signal	Min. Deviation	Avg. Deviation	Max. Deviation	Tolerance	Shift	Deviation Instants	Result
bo_Idle	0	0	0	0	+/- 0 Samples	-	Passed

```
  2.4. SiL Test Results
```

Output Signal	Min. Deviation	Avg. Deviation	Max. Deviation	Tolerance	Shift	Deviation Instants	Result
bo_Idle	0	0	0	0	+/- 0 Samples	-	Passed

```
  2.5. PiL Test Results
  -

3. Test Case 'TC3 - Kickdown'
  3.1 Description
  Testing kickdown detection
  3.2 Requirements
  REQ-003
  3.3. MiL Test Results
```

Output Signal	Min. Deviation	Avg. Deviation	Max. Deviation	Tolerance	Shift	Deviation Instants	Result
bo_KickDown	0	0	0	0	+/- 0 Samples	-	Passed

```
  3.4. SiL Test Results
```

Output Signal	Min. Deviation	Avg. Deviation	Max. Deviation	Tolerance	Shift	Deviation Instants	Result
bo_KickDown	0	0	0	0	+/- 0 Samples	-	Passed

```
  3.5. PiL Test Results
  -

TRACEABILITY MATRIX
```

Requirement	TC1	TC2	TC3	Summary	Remarks
REQ-001	X			Failed	
REQ-002		X		Passed	
REQ-003			X	Passed	
REQ-004				-	Non functional requirement

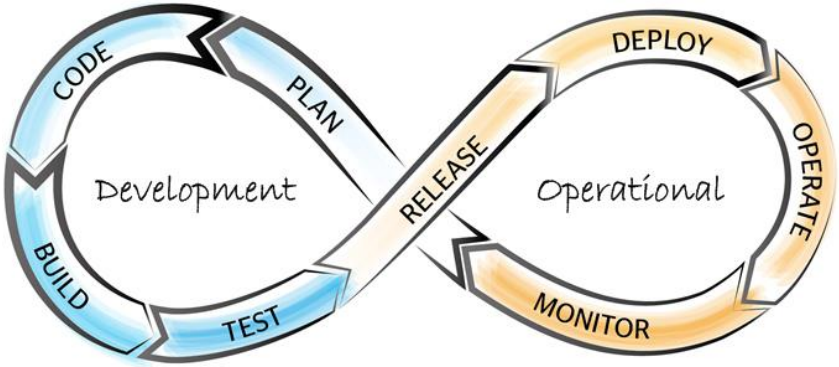
MiL results

SiL results

Requirements vs. test results

Continuous Integration / Continuous Testing
Why?

- Continuous Integration & Testing
  - Improvement of the SW quality by continuously integration of the SW (**agile** development process)
  - Automated Activities

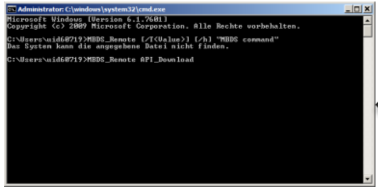


    - Static model analysis using automated model rule checks
    - Calculate model metrics (e.g. subsystem depth, cyclomatic complexity, …)
    - Automatically execute test sessions and summarize test results
    - Determine model test coverage
    - Automatically generate code, model documentation & run the build process
- Running above listed activities of a complex SW project is a time consuming activity
  - A fully automated ‘nightly’ build & test feature is required

Continuous Integration / Continuous Testing
MBDS API

- MBDS API
  - All major MBDS features are available via simple API scripts
  - Applicable for single or all project items
  - All arguments are strongly checked on plausibility
- MBDS Remote Tool
  - Call MBDS API functions to automate MBDS features from batch jobs or OS command line.
  - MATLAB is started via COM-Interface with MBDS in silent mode

Features
Project Item Handling
Code & Document Generation
Model Rule Checking
Execute Test Suite
Build & Download

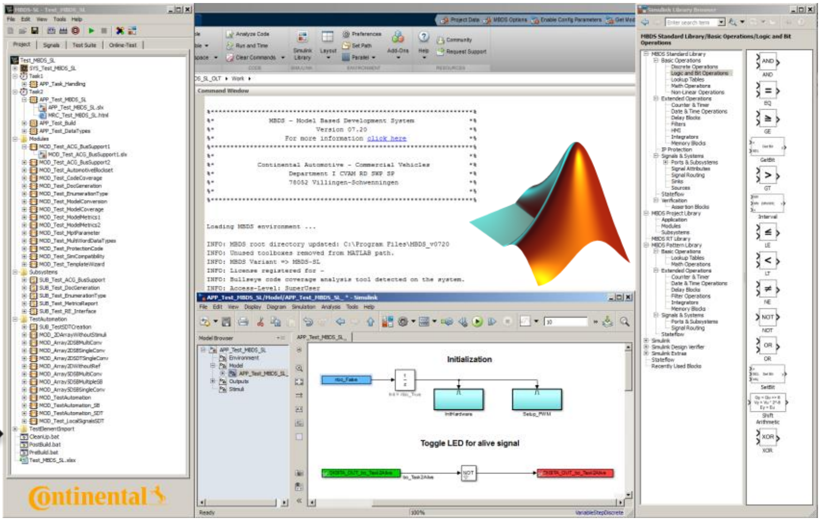

Administrator: C:\windows\system32\cmd.exe

```
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation. Alle Rechte vorbehalten.

C:\Users\uid60719>MBDS_Remote [/T<Value>] [/h] "MBDS command"
Das System kann die angegebene Datei nicht finden.

C:\Users\uid60719>MBDS_Remote API_Download
```

COM Interface


Command Window

```
%**************************************************************************%
%*              MBDS - Model Based Development System                     *%
%*                          Version 07.20                                 *%
%*                 For more information click here                        *%
%**************************************************************************%
%*                                                                        *%
%*         Continental Automotive - Commercial Vehicles                   *%
%*                  Department I CVAM RD SWP SP                           *%
%*                  78052 Villingen-Schwenningen                          *%
%*                                                                        *%
%**************************************************************************%


Loading MBDS environment ...

INFO: MBDS root directory updated: C:\Program Files\MBDS_v0720
INFO: Unused toolboxes removed from MATLAB path.
INFO: MBDS Variant => MBDS-SL
INFO: License registered for -
INFO: Bullseye code coverage analysis tool detected on the system.
INFO: Access-Level: SuperUser
```

APP_Test_MBDS_SL/Model/APP_Test_MBDS_SL_ * - Simulink
Initialization
Toggle LED for alive signal
Simulink Library Browser
Continental

Conclusions

- With the KIBES system platform Continental provides
  - Vehicle Control Hardware & Development Environment
    - ASIL B ready according ISO-26262
    - Fully automated quality assurance measures
    - Integration into CI/CT activities is supported
- VDL Activities
  - Currently quality assurance measures are applied on models implementing QM and ASIL rated features
  - Continuous integration & testing will be applied using the MBDS API and MBDS Remote
  - Statement VDL: We are working together on making the VDL software architecture future-proof with Continentals **M**odel **B**ased **D**evelopment **S**ystem

Thank you
for your attention!