Real-time Software Systems Engineering (2IN70) Automotive Software Engineering Autumn 2022 WEEK7 – Testing and Integration

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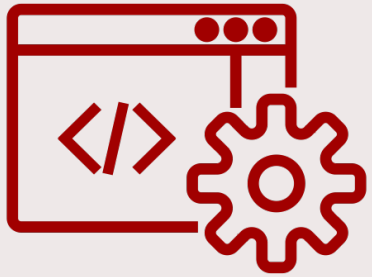

Automotive Software Development

1. Automotive Software Development Process
2. Variant Management
3. Integration Stages of Software Development
4. Testing Strategies
5. Construction Database in Automotive Software Engineering

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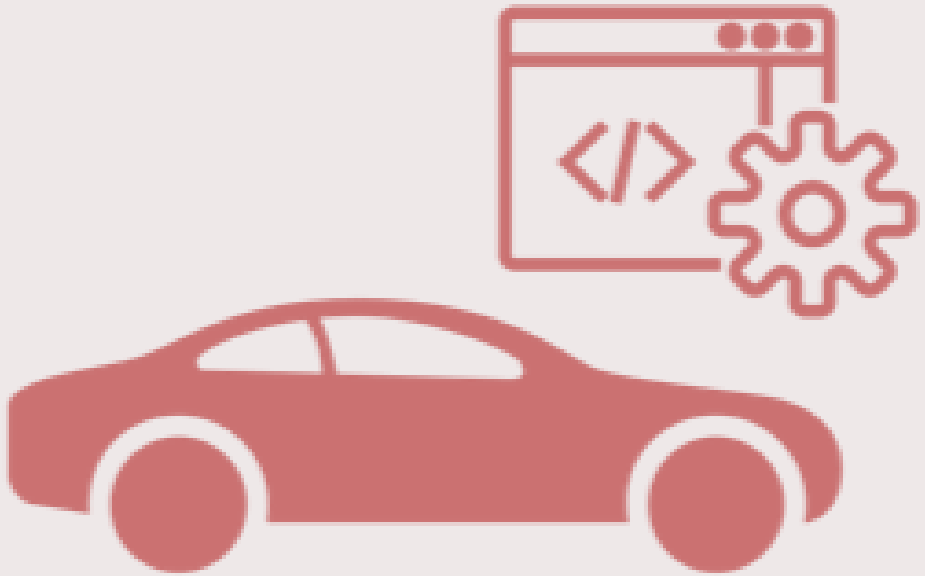
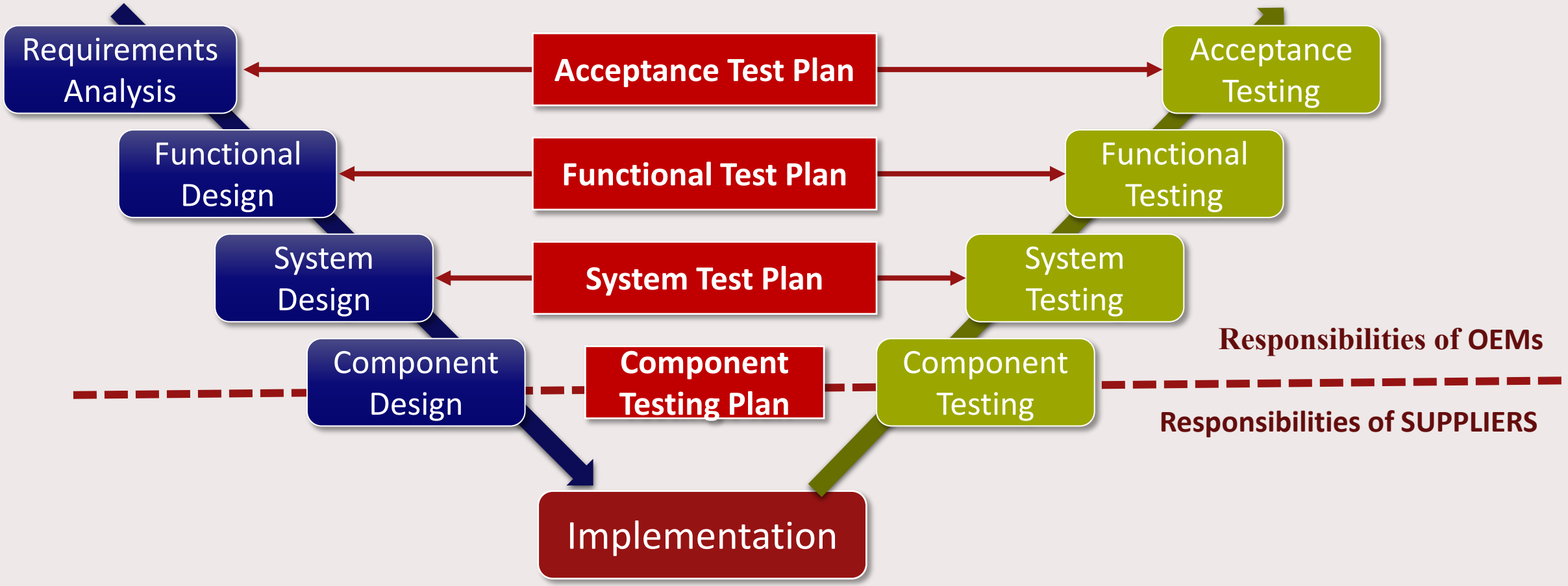


Automotive Software Development Process

V-shaped model of software development process in automotive software development



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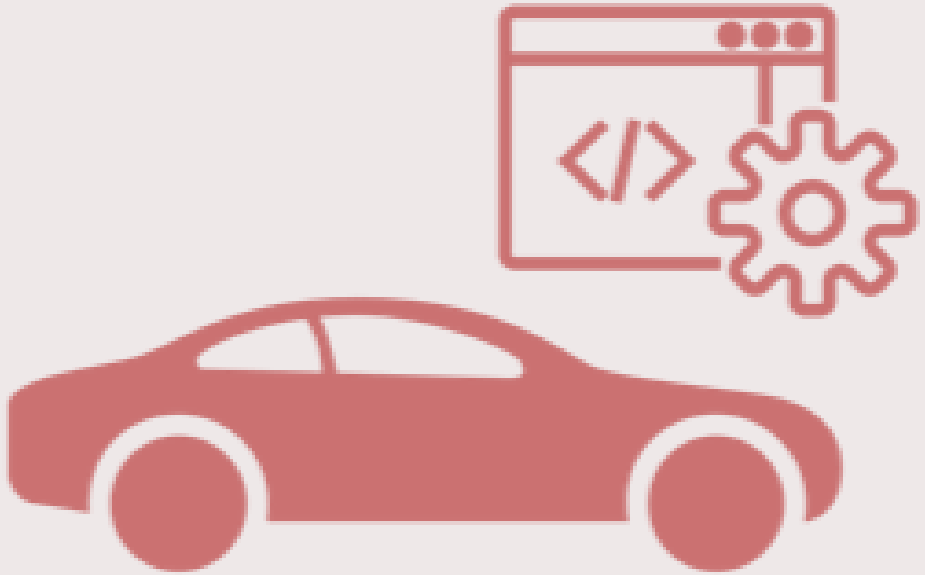


Automotive Software Development Process

Variant Management

Automotive Software Engineering
Variant Management

Automotive market is based on **Variability** - *i.e. the locations in the product (software) where it can be configured.*

A good database of requirements and construction elements is **key to success.**

The customers expect the **ability to configure** the car with the latest and greatest **features of hardware, electronics and software.**

Automotive Software Engineering
Variant Management

Configuration—*when we configure parameters of the software without modifying its internal structure*

Used

In the non-safety critical functions

Example – *the engine calibration or in configuring the availability of functions (e.g. rain sensors).*

Compilation—*when we change the internal structure of the software, compile it and then deploy on the target ECU*

Used

To ensure that the software always behaves in the same way

Example - *the availability of the function for collision avoidance by breaking.*

Automotive Software Engineering
Variant Management - Configuration

Configuration is often referred to as runtime variability

- Changing the software can be done after the software is compiled

The code for the software component is compiled once

- Two different configuration files are used when deploying the software

The software must be tested using multiple scenarios

- The software designers need to be able to prevent use of the software component with invalid configurations

Automotive Software Engineering
Variant Management - Configuration

Software component (e.g. windshield wipers controller)

Variability point: speed controller

Configuration 1: no rain sensor

Configuration 2: with rain sensor

Compile once the software component.

Use **two different** configuration files when deploying the software.

Automotive Software Engineering
Variant Management - Compilation

The Software Component cannot be modified (configured) after its compilation, during runtime.

Compilation

so- called *Design Time Variability*

The designers must decide during design which variant is being developed

Different code bases for the software component

The development of the variants can be decoupled from each other

The designers have to maintain different code bases at the same time

Advantages

The assurance that the code is not tampered with in any way after the compilation

The code can be tested, and once deployed there is no way that an incorrect configuration can break the quality of the component.

Disadvantage

High cost of maintenance of the code base—parallel maintenance.

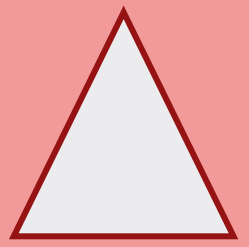
If there are defects in the common code, then all code bases need to be updated and tested

Automotive Software Engineering
Variant Management - Compilation

Software Component var 1 (e.g. windshield wipers controller)

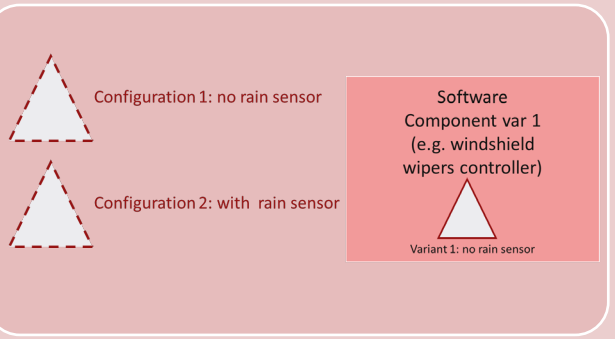
Variant 1: no rain sensor

Software Component var 2 (e.g. windshield wipers controller)

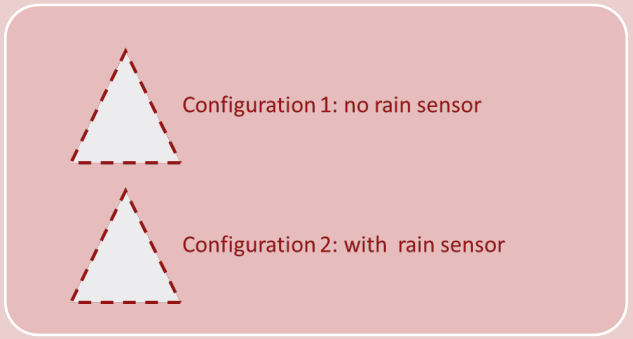


Variant 2: with rain sensor

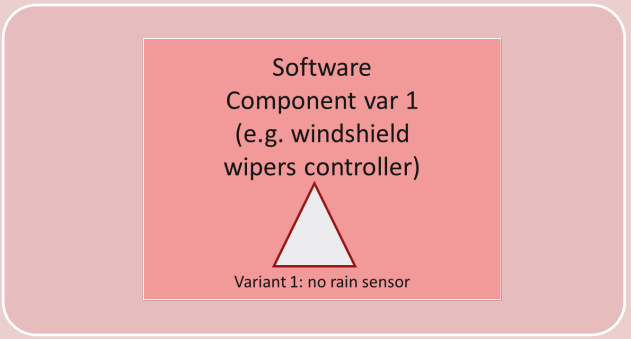
Practical Variability Management



Both variability management mechanisms are used in practice.



Compile time Variability - used when the software is **an integral part of an ECU**



Configuration Variability- used when the software **can be calibrated to different types of configurations during deployment**

Example: *configuration on the assembly line, calibration of the engine and gearbox depending on the powertrain*

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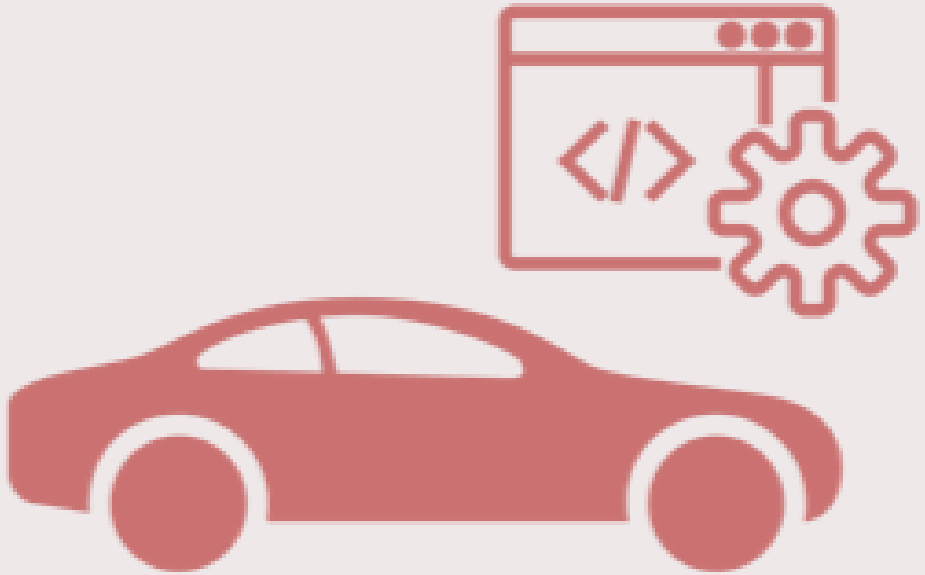
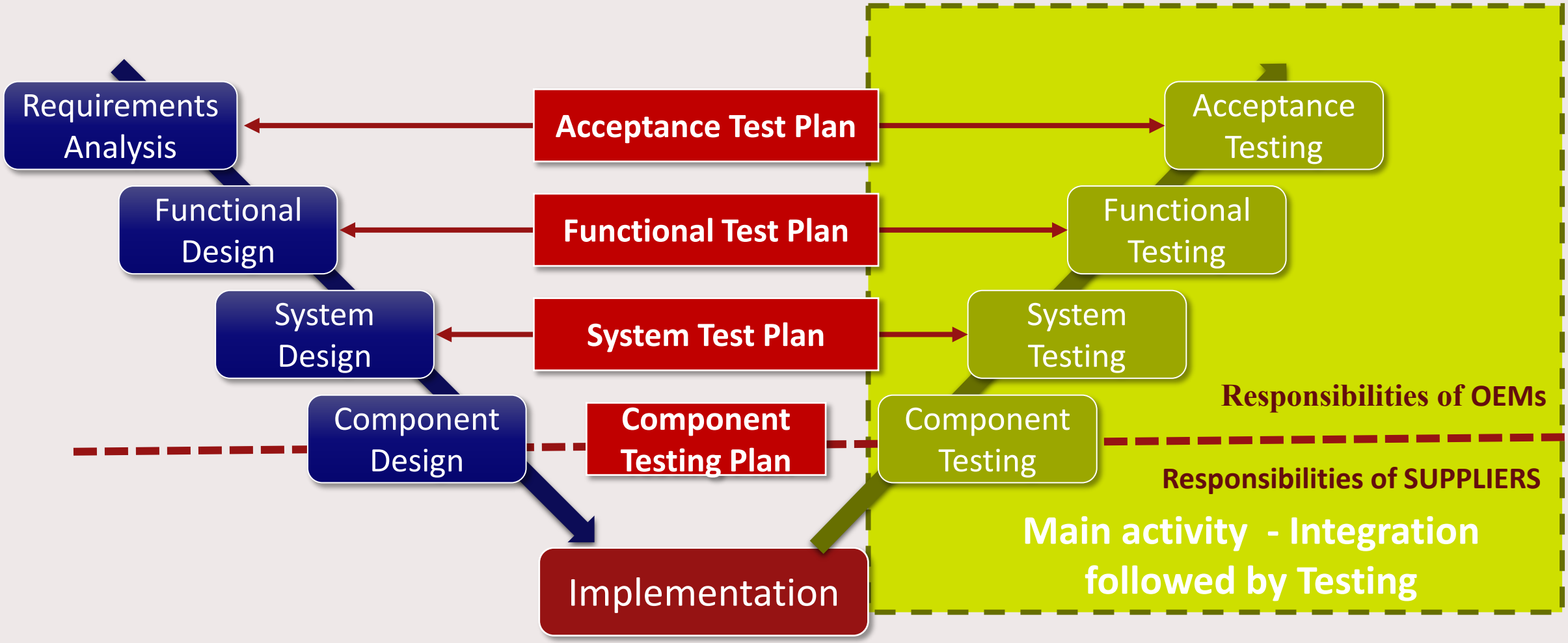


Automotive Software Development Process

Integration Stages of Software Development

Integration Stages of Software Development



Integration Stages of Software Development

Integration

The activity where software construction engineers integrate their code with the code of other components and with the hardware

First integration stages

To allow unit and component testing, the hardware is usually simulated – **DT, MIL,SIL**

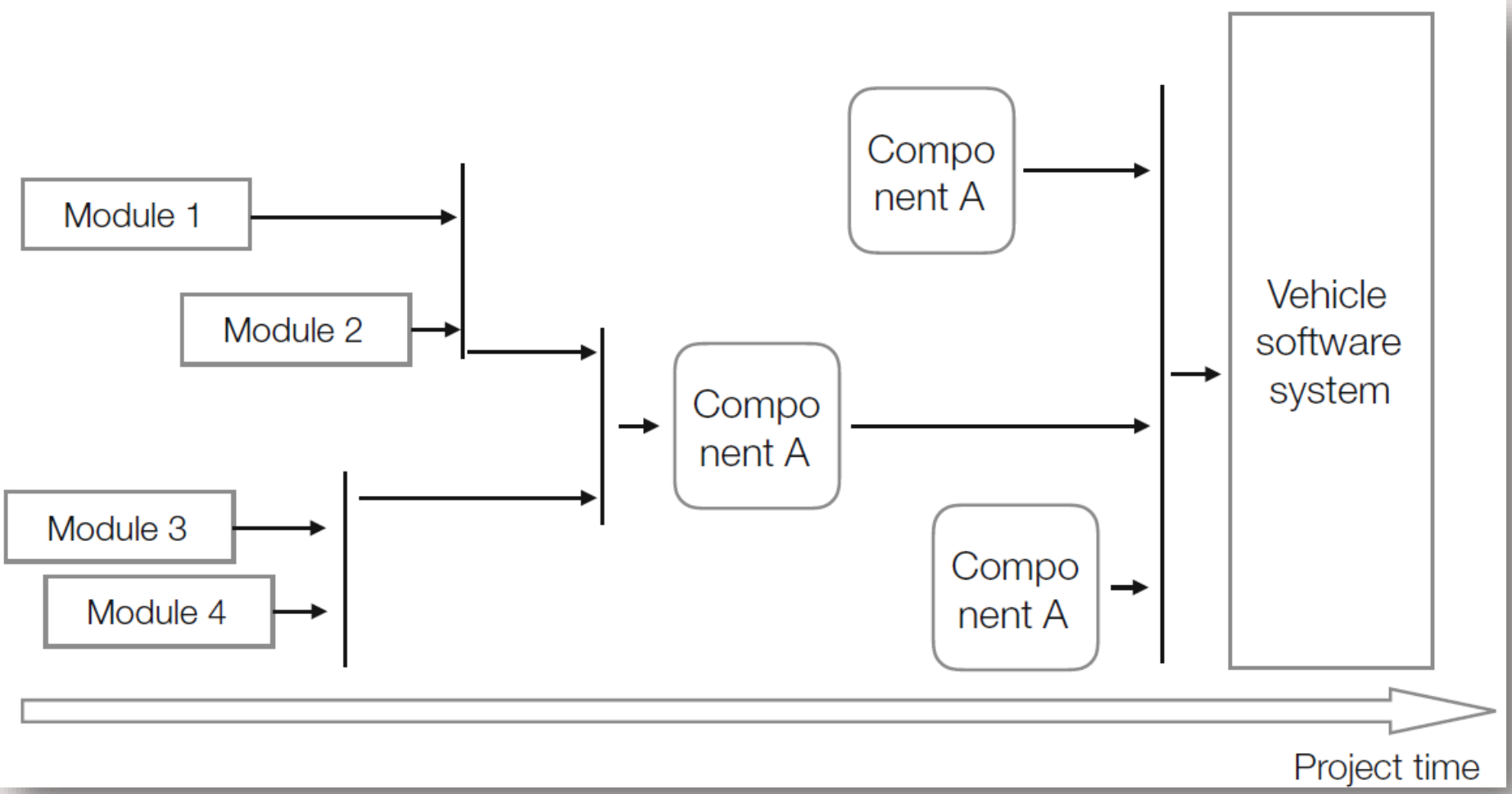
Later integration stages

The software code is integrated together with the target hardware, which is then integrated into a complete electrical/electronic system of the car – **HIL**

Types of integration

Software Integration	Software-Hardware Integration	Hardware Integration
Two (or more) software components are put together and their joint functionality is tested. Integration depend on the what is integrated: 1. *Merging of the source code if the integration is on the source code level* 2. *Linking of two binary code bases together* 3. *Parallel execution to test interoperability.*	**The software is integrated (deployed) to the target hardware platform.** The focus is on the ability of the complete ECU to be executed and the main testing type is **component testing**.	**The focus is on the integration of the ECUs with the electrical system.** The focus is on the interoperability of the nodes and basic functionality, such as communication. The testing related to this type of integration is **system testing**.

Software integration with integration steps



The integration steps (vertical solid black lines) are not synchronized as the development of different software modules is done at different pace.
Each integration cycle is done several times during the project.

Automotive Software Architectures
Miroslav Staron

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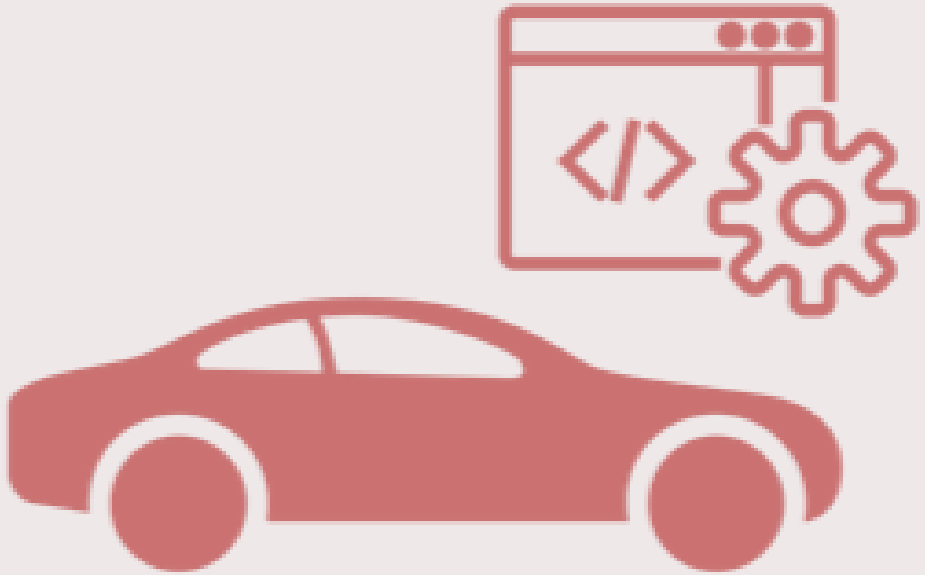


Automotive Software Development Process

Testing Strategies

Overview of Software Testing

"Testing shows the presence, not the absence of bugs." —Edsger W. Dijkstra

A fault, also called "defect" or "bug," is an erroneous hardware or software element of a system that can cause the system to fail!

Test-Driven Development (TDD)

- Every step in the development process must start with a plan of how to verify that the result meets a goal
- The developer should not create a software artifact (a system requirement, a UML diagram, or source code) unless they know how it will be tested
- A test case is a particular choice of input data to be used in testing a program
- A test is a finite collection of test cases

Why Testing is Hard

A key tradeoff of testing

Testing as many potential cases as possible while keeping the economic costs limited

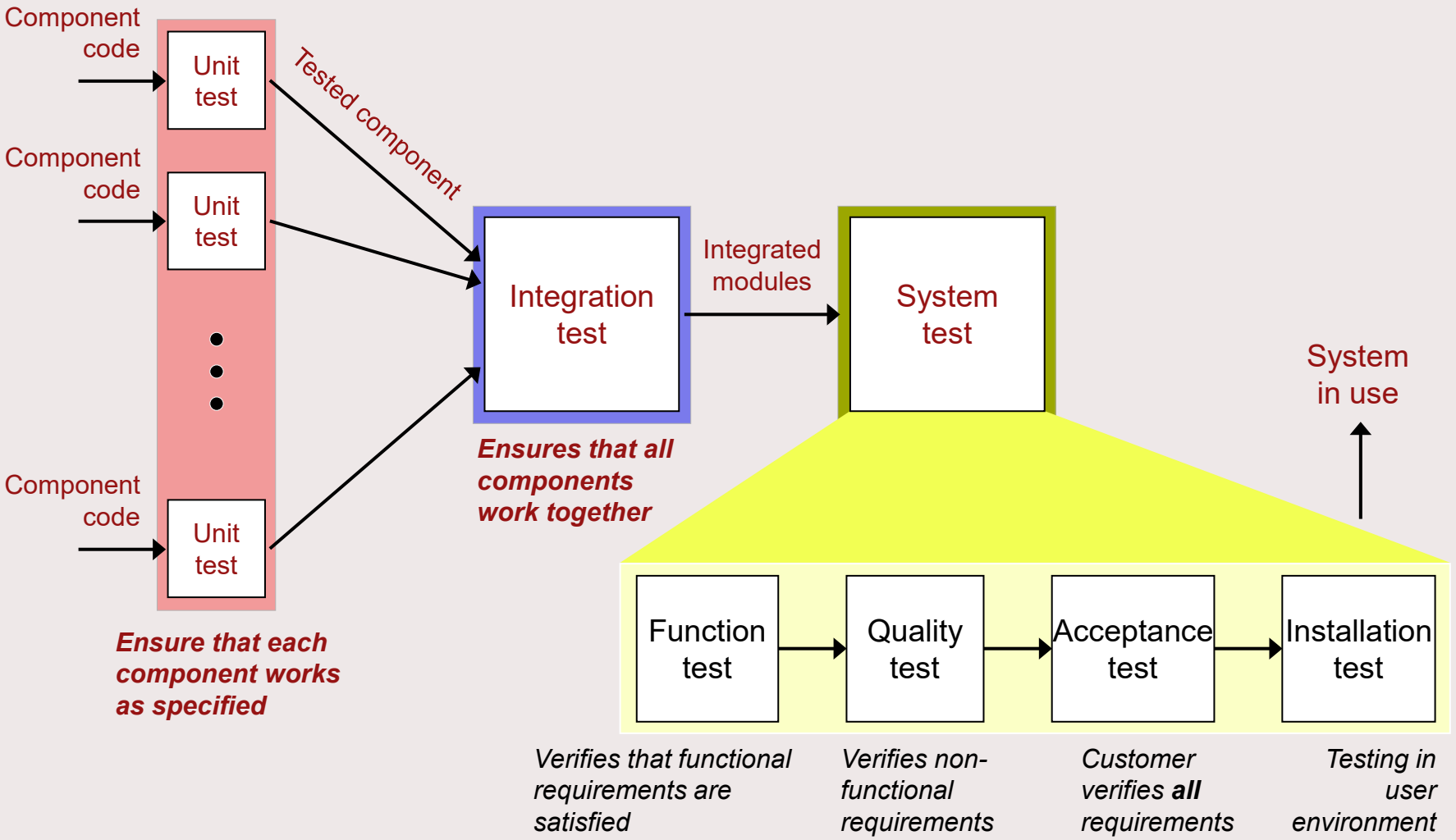
Our goal is to find faults as cheaply and quickly as possible.

Ideally, we would design a single "right" test case to expose each fault and run it

In practice, we have to run many "unsuccessful" test cases

Tests which do not expose any faults

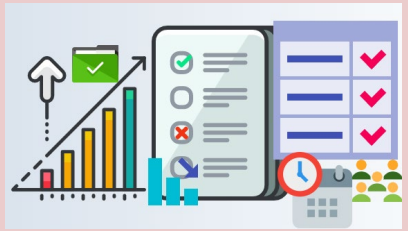
Logical Organization of Testing



Test Coverage

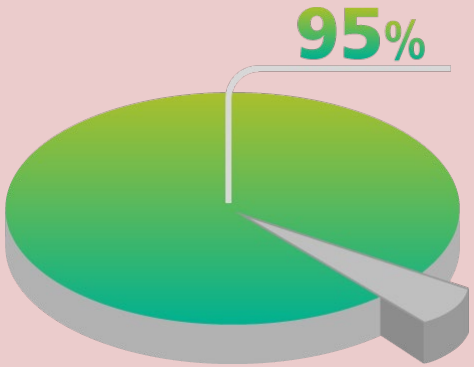
Test Coverage

measures the degree to which the *specification or code* of a software program has been exercised by tests



Code Coverage

measures the degree to which *the source code of a program has been tested*

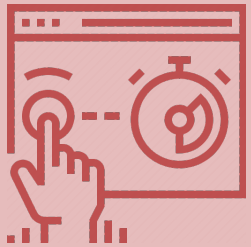


Code Coverage Criteria

- equivalence testing
- boundary testing
- control-flow testing
- state-based testing

Automotive Software Testing Strategies

Requirements engineering progresses from higher abstraction levels towards more detailed, lower abstraction levels



Testing the software starts from the most atomic type of testing—unit testing—where they test each function and each line of code

Testing gradually progress by testing **entire components** (i.e. multiple units linked together), then the **entire system** and finally each function.

Testing phases in automotive software development

Responsibilities of OEMs

Acceptance Testing

Customer Test

Functional Testing

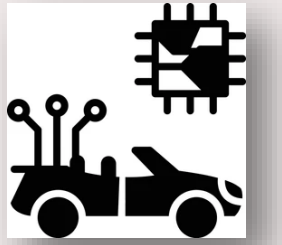
System Testing

Component Testing

Implementation & Unit Testing

done by supplier

Responsibilities of SUPPLIERS

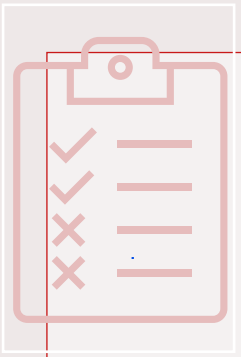


TU/e

Unit Testing

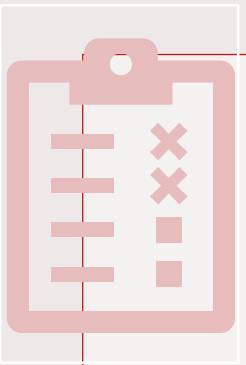
Unit test is the basic test

Is performed on individual entities of software such as classes, source code modules and functions.



The goal of unit testing

To find defects related to the implementation of atomic functions/methods in the source code.



The basic scheme of unit testing

1. Create automated test cases which combine individual methods with the data that is needed to achieve the needed quality.
2. The result is then compared to the expected result, usually with the help of assertions.

Unit Testing

Example unit test for testing the status of windshield wiper module

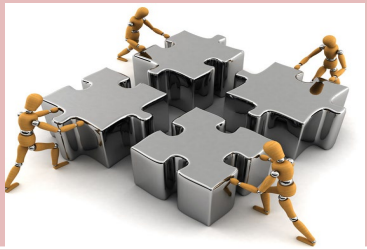
```
1  using System;
2  using Microsoft.VisualStudio.TestTools.UnitTesting;
3  using WindshieldSimulator;
4
5  namespace WindshieldTest
6  {
7      [TestClass]
8      public class BasicSuite
9      {
10         // unit test method
11         [TestMethod]
12         public void TestCreationInitialState()
13         {
14             // arrange
15             WindshieldWiper pWiper;
16
17             // act
18             pWiper = new WindshieldWiper();
19
20             // assert
21             Assert.AreEqual(pWiper.Status,
22                             position.closed,
23                             "Initial status should be /closed/");
24         }
25     }
26 }
```

The most interesting are lines 21–23 since they contain the so-called assertion.
The assertion is a condition which should be fulfilled after the execution of the test code. In our example the assertion is that the status of the newly created object (line 21) is "closed" (line 22). If it is not the case, then the error message is logged in the testing environment (line 32) and the execution of the new test cases continues.

Unit testing is most often automated. Frameworks like CppUnit, JUnit or Google test framework can orchestrate the execution of unit tests, allowing us to quickly execute the entire set of tests (called test suites) without the need for manual intervention.

Component Testing

Put component together at a larger components.
Test → in environment → simulate this environment



Called integration testing, as the goal of this type of testing is to test the integrations, i.e. links, between units of code within one of many components.

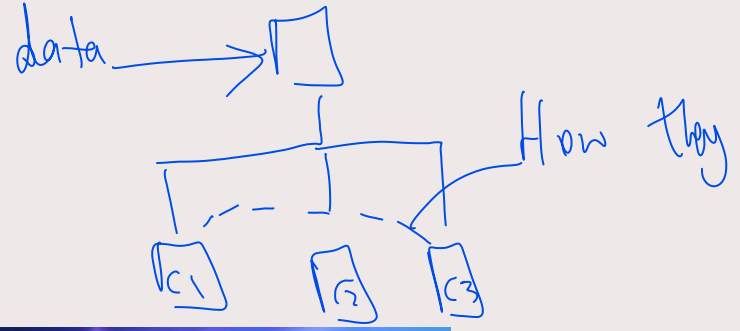
We use stubs to simulate the environment of the tested component or the group of the components

Component tests focus on the interaction between the stubs and the component under test.

The goal of this type of testing is to verify that the structure and behavior of the interfaces is implemented correctly.

- interaction between the environment
- hardware simulator
- digital twins

Component Testing



Automotive systems component testing

- **Simulation Environment** using models (the so-called Model-In-the-Loop or MIL testing)
- **Hardware simulators** (the so-called Hardware-In-the-Loop or HIL testing).
- **Digital Twins**

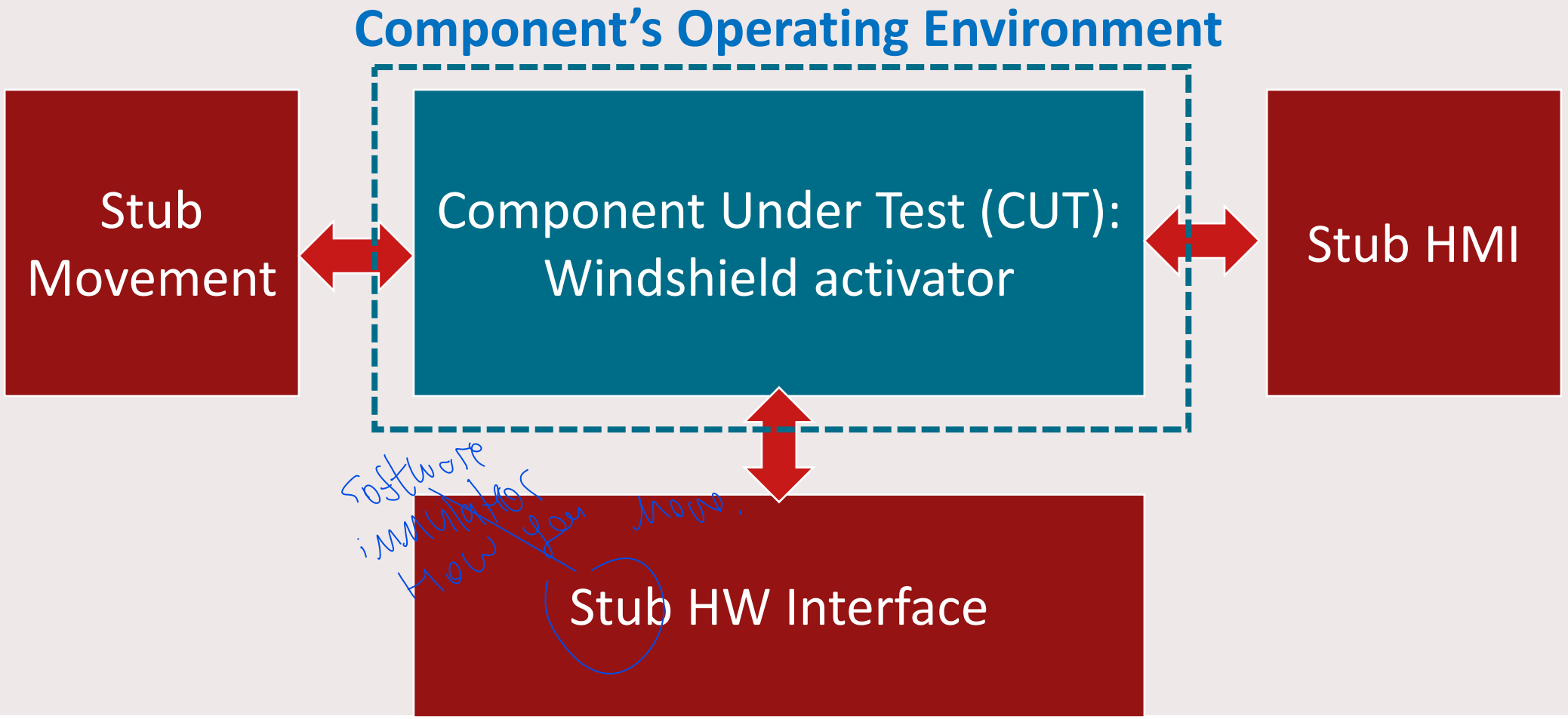
simulate in hold time

the physical component of the car & virtual environment.

Simulation Models

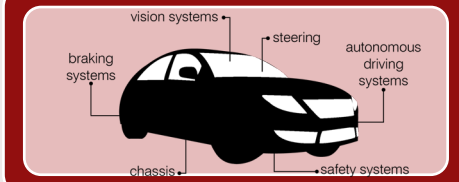
Hardware

Component under test with the simulated environment



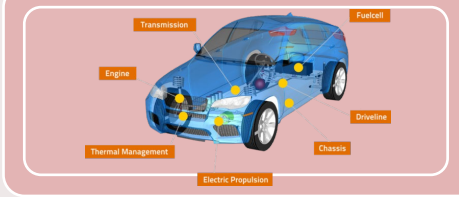
have to place the system into the operating environment.

System Testing

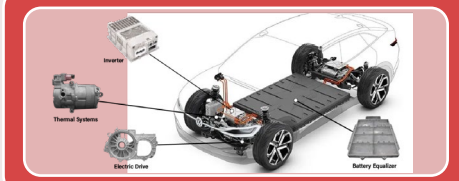


The entire system is assembled and tested as a whole

The focus of system testing is on checking whether the system fulfills its specifications in several ways



System Testing is a very costly way of testing and very inefficient, as fixing the defects found in this phase requires frequent changes in multiple components.



In the automotive software this type of testing is often done using the so-called “box cars”—the entire electrical system being set up on tables without the chassis and the hardware components.

System Testing – Verifying aspects

Functionality

Testing whether the system has the functionality as specified in the requirements specification

Interoperability

Testing whether the system can connect to the other systems which are designed to interact with the system under test

Performance

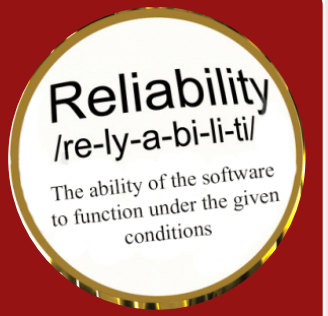
Testing whether the system under test performs within the specified limits (e.g. timing limits, capacity limits)

Scalability

Testing whether the system's operation scales up and down (e.g. whether the communication buses operate with 80 and 120 ECUs connected)

Stress

Testing whether the system operates correctly under high load (e.g. when the maximum capacity of the communication buses is reached)



Reliability

Testing whether the system operates correctly during a specific period

Regulatory and compliance

Testing whether the system fulfills legal and regulatory requirements (e.g. carbon dioxide emissions)

Functional Testing

Verifies that the functions of the system work according to their specification

Tests correspond to the functional requirements in the form of use cases and are quite often specified according to the use cases

Tests recreate the situations when the system could be activated

In case of functional test fails, it is difficult to find the defect; many components that take part in the interaction

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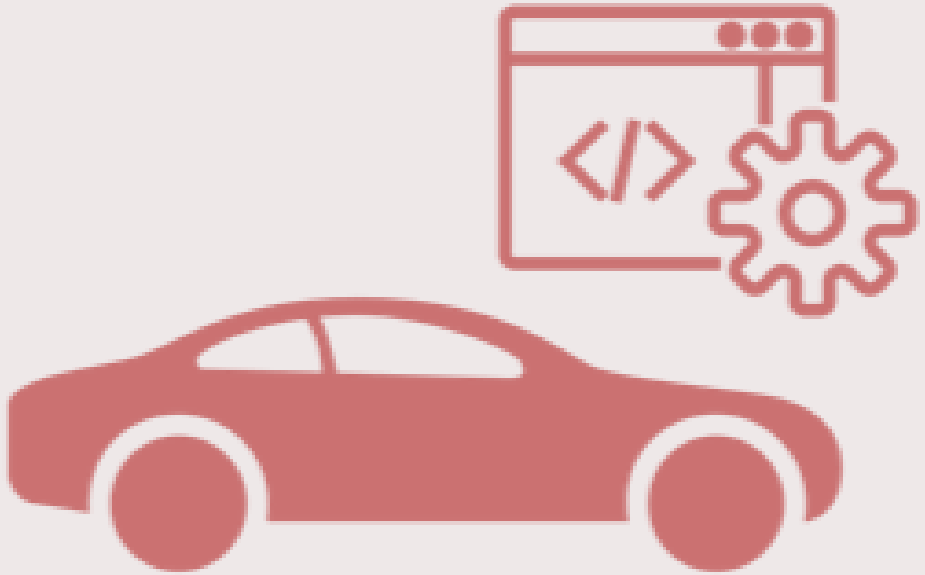


Construction Database and Its Role in Automotive Software Engineering

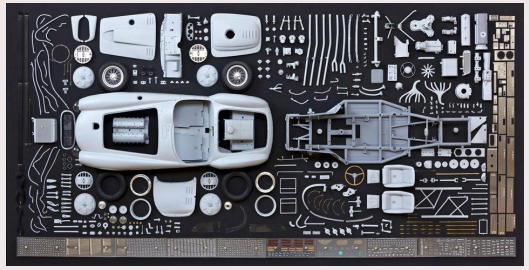
Construction Database and Its Role in Automotive Software Engineering

The requirements need to come together somehow and that's why we have the process and the infrastructure for requirements engineering.

The Construction Database

- Contains all elements of the design of the electrical system of the vehicle— components, electronic control units, systems, controllers, etc. The structure of such a database is hierarchical and reflects the structure of the vehicle.
- Grows over time and is version-controlled as different versions of the same elements can be used in different vehicles (e.g. different year models of the same car or different cars).
- Each of the elements in the database has a set of requirements linked to it.
- The requirements are also linked to one another to show how they are broken down.

Architectural Models



Detailed design models

Test specifications

Requirements

Design and Construction Database

Implementation Plan

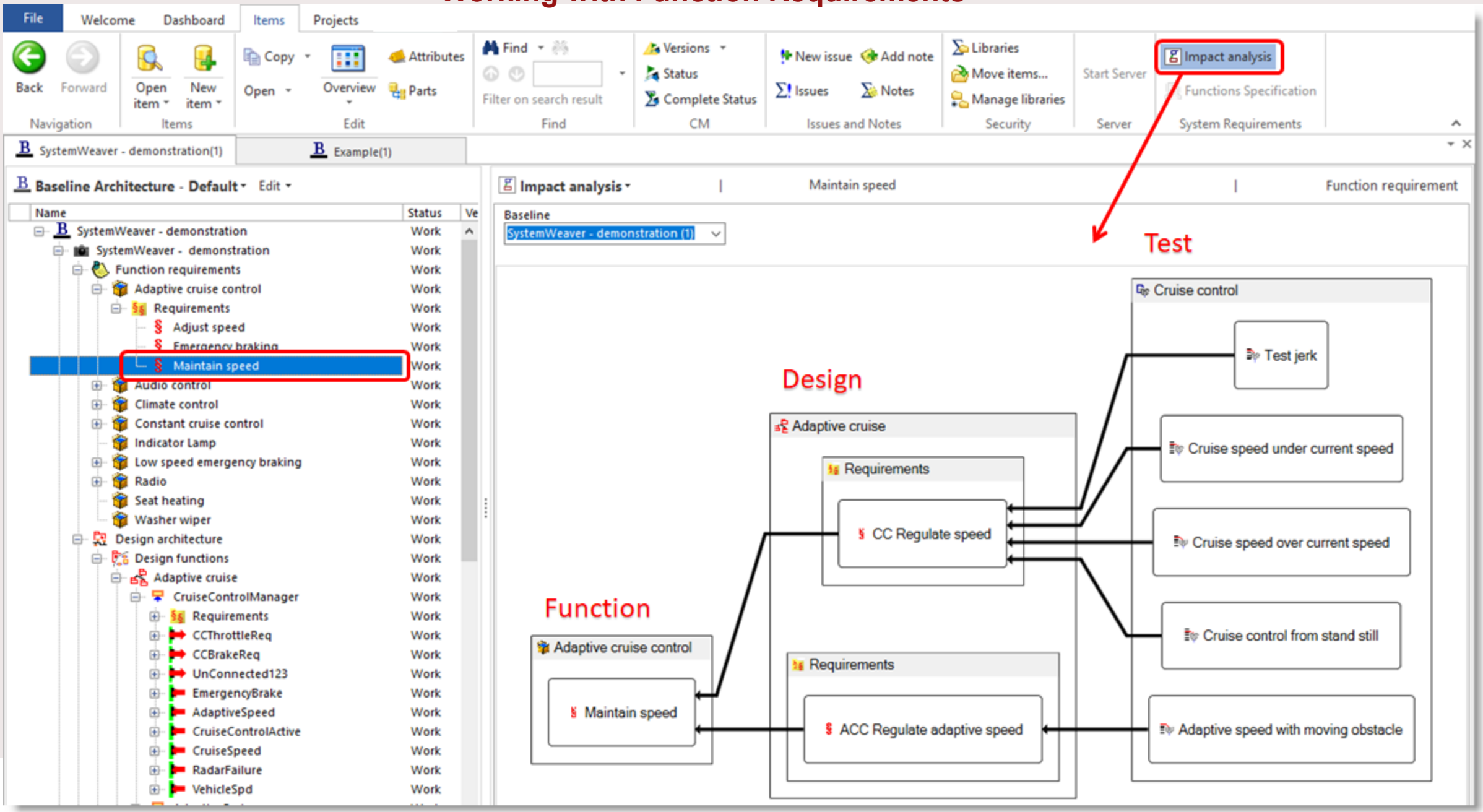
Component Specification

Test Plan

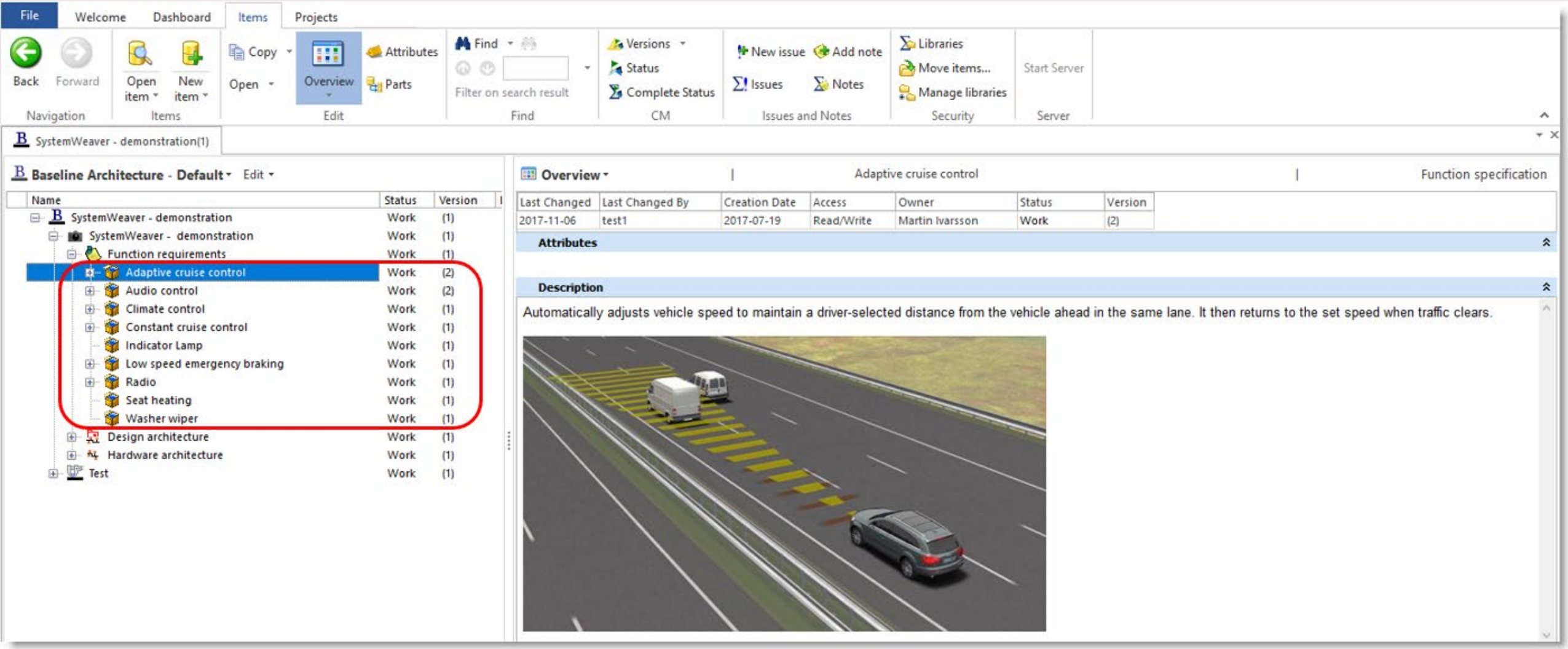
Tools

- Doors + IBM Rhapsody
- SystemWeaver - Systemite

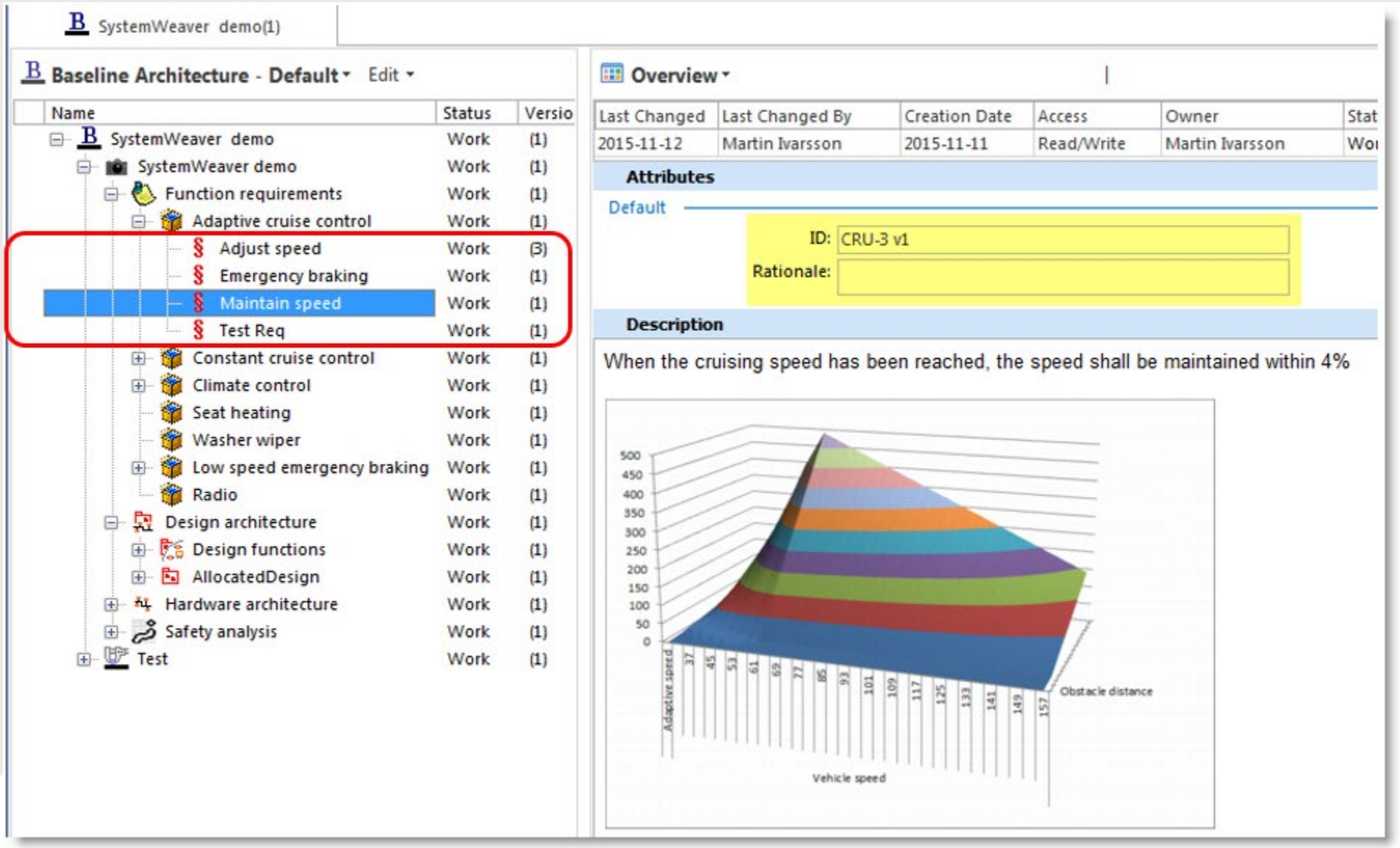
Working with Function Requirements



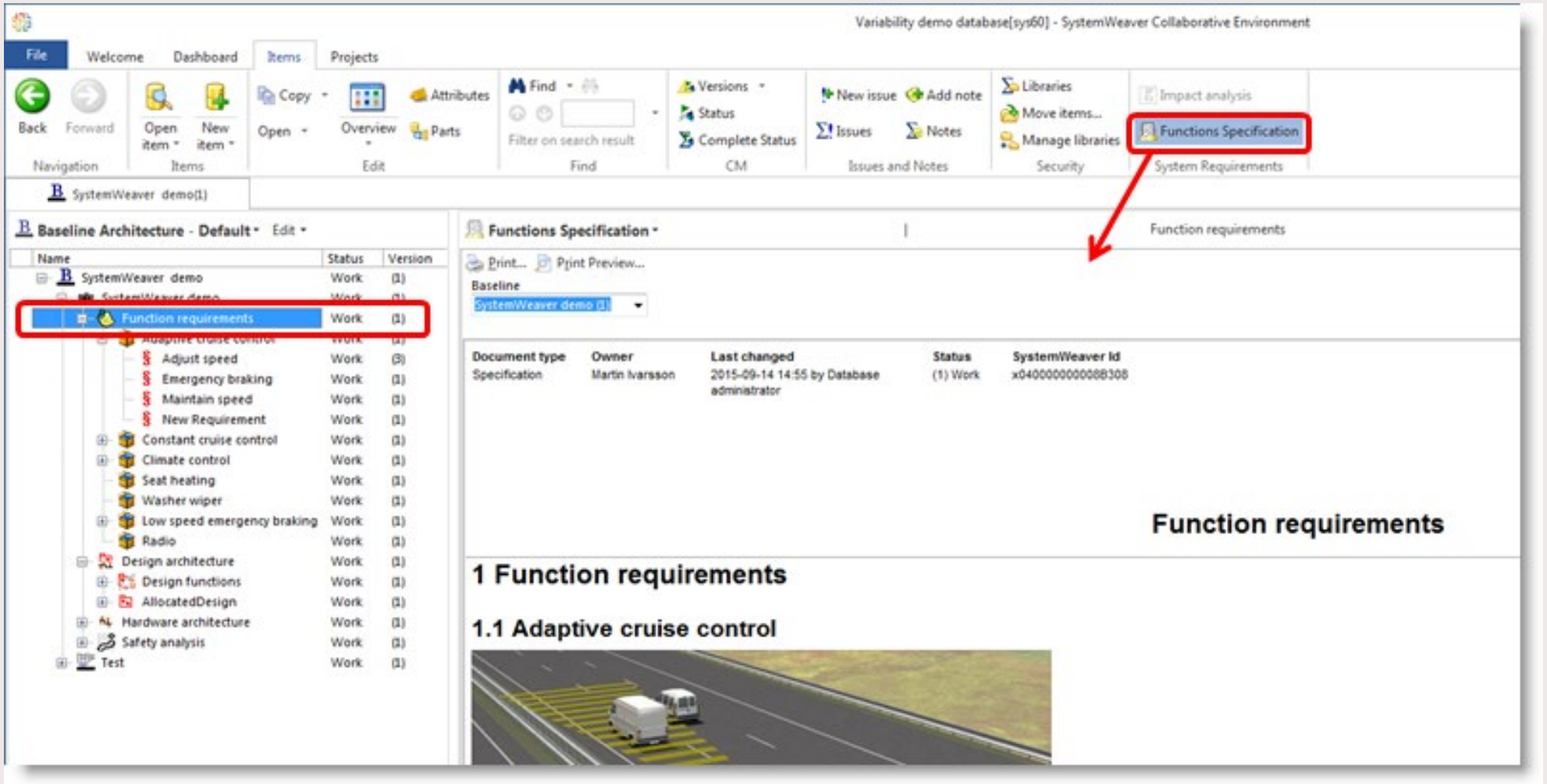
Viewing Function Specifications - Adaptive cruise control



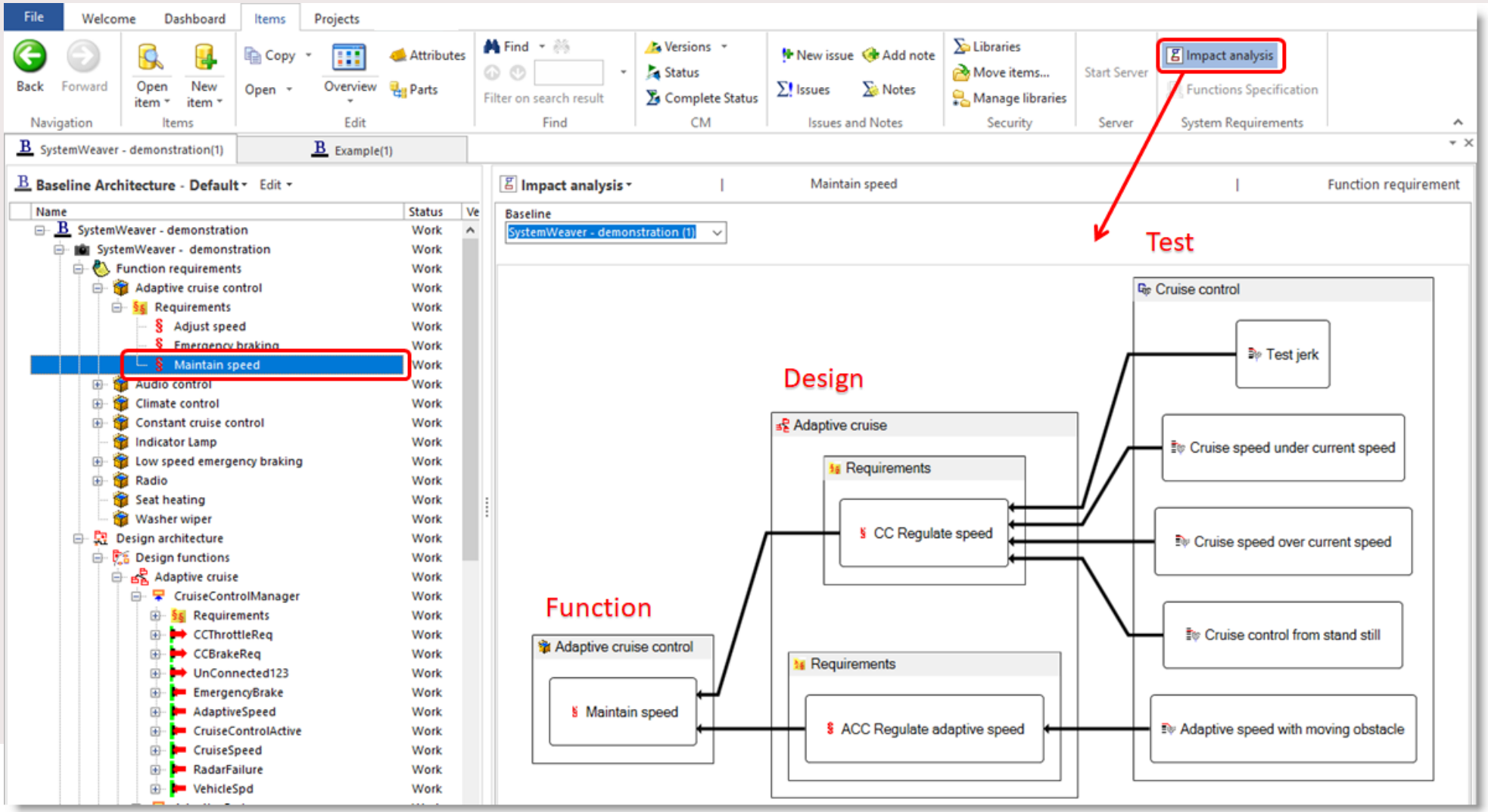
Overview of a requirement, you can view the requirement's default attributes, such as ID and Rationale in the example



Function Specification Report



Impact Analysis View - Assess Impact of a Requirement Change



When a function requirement is selected, it is possible to use the **Impact Analysis** view to see the effects of the requirement in the system. This can, for example, be an efficient way of assessing the impact a change of that requirement would have on design requirements and test specifications.

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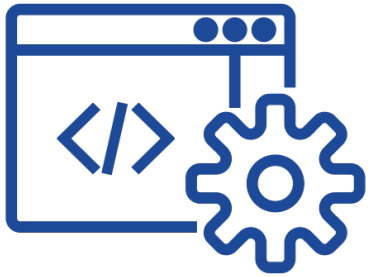
Questions?



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