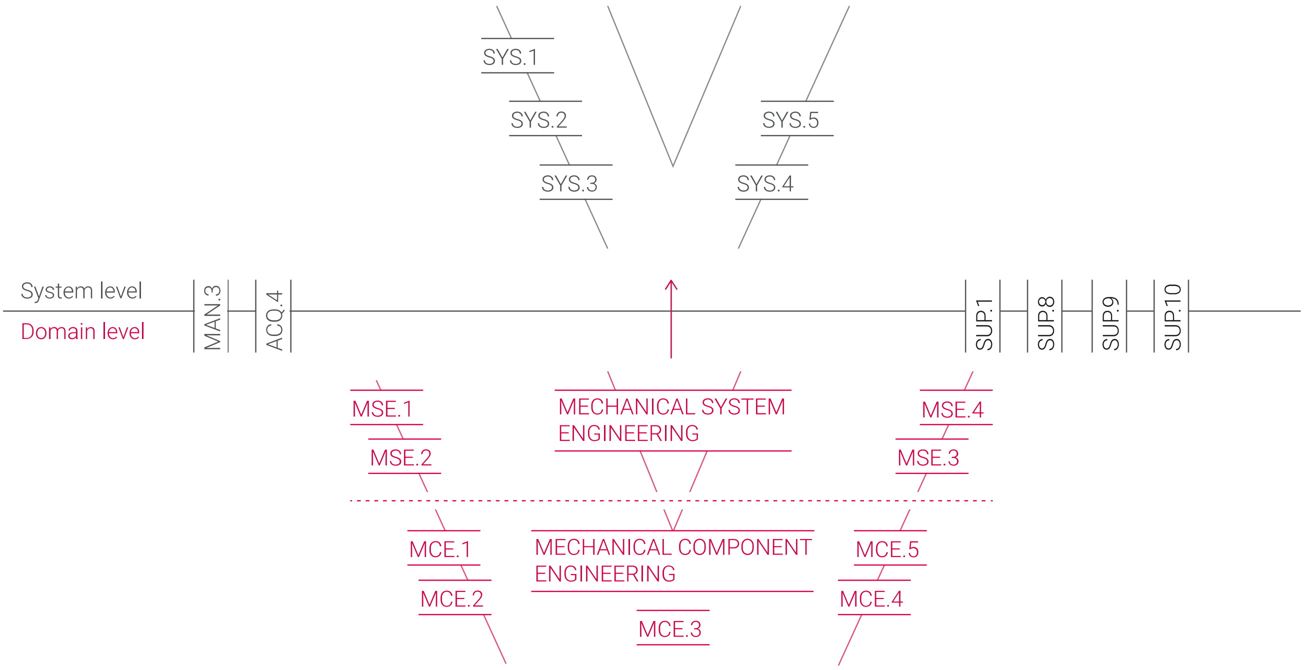
SPICE for Mechanical Engineering

Introduction to the process model



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Overview

About this white paper

This white paper is based on the information presented in the SPICE for Mechanical Engineering tutorial video on YouTube.

https://www.kuglermaag.com/mee-spice

Both the YouTube tutorial and this document cover the core concepts and they are not complete by any means. This publication has been prepared for general guidance only. Please do not act according to any information given in this document without receiving specific professional consultancy. The publisher, KUGLER MAAG CIE GmbH, shall not be liable for any damages resulting from any use of the information contained in this report.

If you want to learn more about SPICE for Mechanical Engineering and become a process improvement expert, check out our training:

https://www.kuglermaag.com/training-automotive-spice/introduction-to-me-spice-mechanical-engineering/

About the author

Andrei Donciuc is Managing Consultant and one of the experts in mechanical development at Kugler Maag Cie.

Not only he consults automotive companies on the application of SPICE for Mechanical Engineering, but he also gives trainings on SPICE for Mechanical Engineering and performs assessments. Additionally, he is the deputy lead of the intacs™ working group which developed the standard SPICE for Mechanical Engineering.

Introduction

In this white paper, those who develop their mechanical systems in coordination with the software parts will learn how SPICE for Mechanical Engineering works.

Since there are mutual influences between the mechanical, software and electric/electronic design aspects – to build a high-quality mechatronic product it is also required that all disciplines work well together:

- **Automotive SPICE®**
  was developed for system and software development.

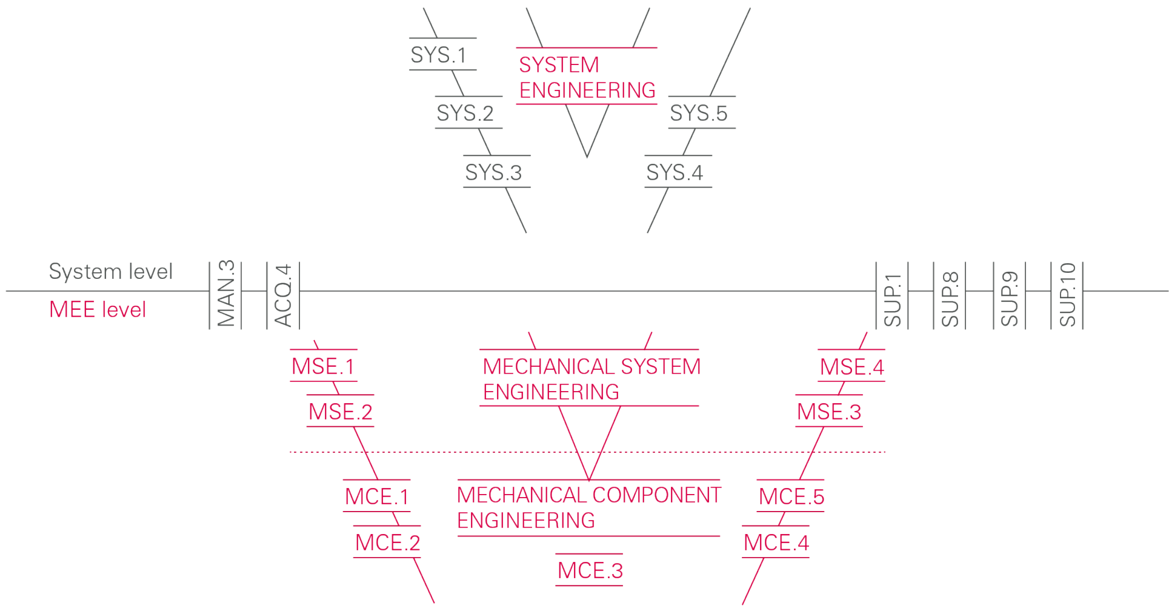
- **SPICE for Hardware Engineering**
  is intended to support EE hardware development.

- **SPICE for Mechanical Development**
  provides a reference model for mechanical development.

Modern product engineering utilizes software development tools in nearly all phases of the development lifecycle. This has caused an increase in the number of intermediate and final work products which teams create and use to design and analyze their product. Consequently, support and demand for processes such as configuration and change request management will need to be even stronger.

Furthermore, higher computing performance and new production methods have both significantly changed the mechanical systems. Shapes with a considerably higher complexity can be developed and produced. The production lines are developed in parallel with the product. This dependency leads to very high costs and effort to be spent when changes are introduced after the design freeze – in contrast to software. Therefore, front loading and high process quality in the engineering processes are indispensable for the mechanical aspects of a product's design.

In brief: SPICE for Mechanical Engineering defines best practices for automotive mechanical development to achieve the required product quality. This video gives you a very condensed overview of the SPICE for Mechanical Engineering standard.

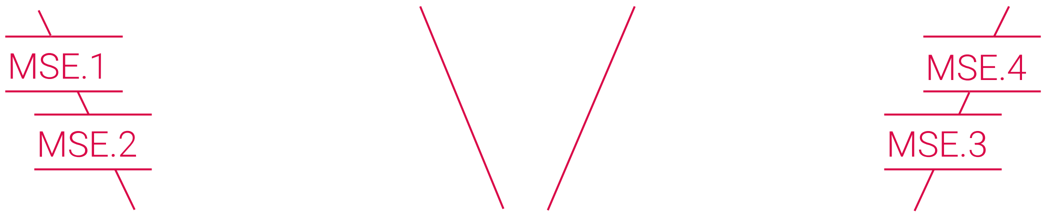


SPICE for Mechanical Engineering, inserted in the Automotive SPICE® process model

The SPICE for Mechanical Engineering standard can be used as a plug-in for Automotive SPICE®. In doing so, the processes of Automotive SPICE are used for both system and software development, additionally for management and support processes.

The formal structure of SPICE for Mechanical Engineering processes consists of two process groups:

1. Mechanical System Engineering



2. Mechanical Component Engineering

The Mechanical Systems Engineering process group contains four processes, while the Mechanical Components Engineering process group comprises five processes.

A mechanical component is the lowest level of your assembly drawing. This could be a screw or a part which is developed by the supplier. In the second case, the supplied part is a mechanical component for you. But from the supplier's perspective, it is a mechanical system. In other words, mechanical components are all parts that you do not need to refine further in the assembly drawings, so you can consider them as a black box.

A mechanical system, in turn, consists of two or more mechanical components.

SPICE for Mechanical Engineering was developed by intacs™. In this community of interest, delegates from the entire automotive industry organize themselves to expand and share their knowledge on process improvement topics and their assessment.

Automotive SPICE® is a trademark of the VDA QMC. intacs™ cooperates with the VDA QMC to ensure consistent quality of process assessments in the industry.

1. MSE.1/MCE.1 Requirement Analysis

Let's take a closer look at the processes that make up the standard. We do not need to look at all nine processes individually. Many processes are similar at the system and component level. The only difference is the degree of detail.

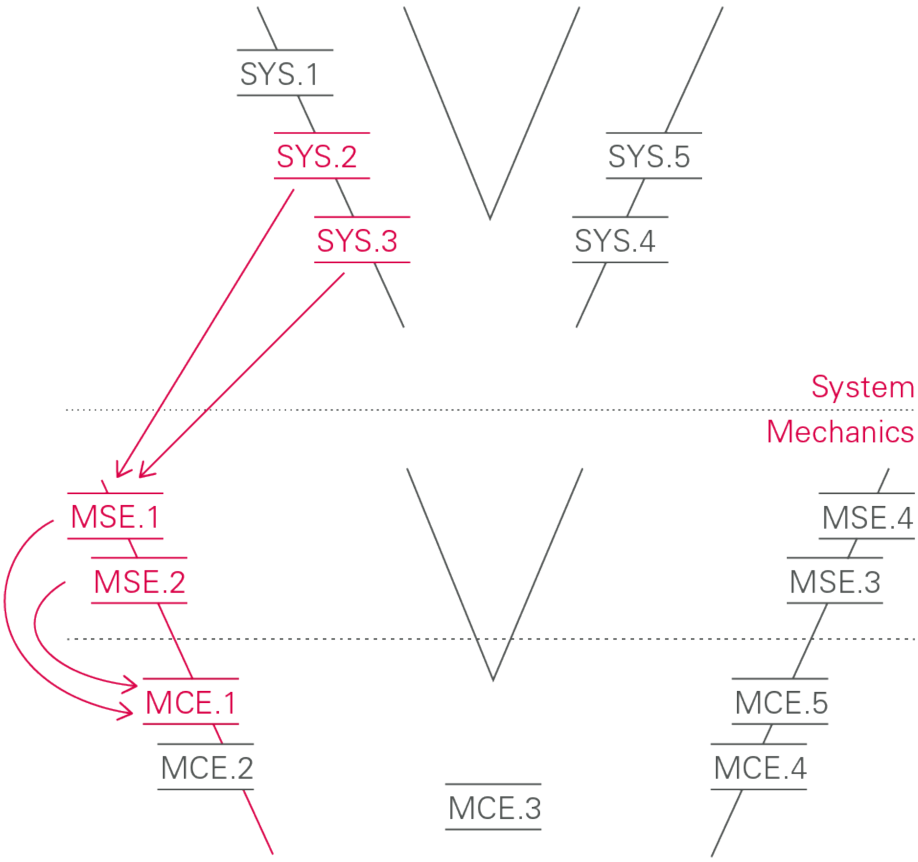
MSE.1 Mechanical System Requirements Analysis

MCE.1 Mechanical Component Requirements Analysis

The “Mechanical System or Component Requirements Analysis” processes documents a specification for a structured way of identification, analysis and the documentation of the Mechanical System or Component Requirements.

In your project you can combine the MSE.1 and the MCE.1 processes into one process. Nevertheless, it is important to define requirements for both - the mechanical systems and the mechanical components.

Based on the upper system requirements and upper system architectural design, the specific mechanical system or component requirements shall be specified and documented. The requirements answer to the question WHAT the mechanical system or component shall implement – and not HOW to implement it.



Specification of mechanical system and/or component requirements

Examples of the mechanical system or component requirements are:

- weight
- speed
- torque and force

Structure, categorize and prioritize the mechanical system or component requirements to keep an overview and control over the requirements.

Analyze the technical requirements with particular care. This is to ensure the quality of the product requirements or to find and correct any errors as early as possible.

When analyzing the product requirements, involve the relevant development departments or engineering disciplines and consider both, product-specific aspects and general quality criteria. Early involvement of the relevant development departments or disciplines, e.g. V&V responsible, system and electronic developers, is crucial.

2. MSE.2 Mechanical System Architectural Design

A typical example of a Mechanical System Architectural Design is the assembly model and the assembly drawing including the description of the interfaces and the corresponding design constraints.

Examples of the mechanical interfaces are:

- design spaces
- shafts
- mounting geometries

Design constraints could be:

- design guidelines
- legal norms and regulations or
- the defined costs of the mechanical system

which restrict you to choose certain types of materials. In addition, you could have also a functional architecture and a mechanical system breakdown structure.

Allocate the requirements to the corresponding elements to ensure that all requirements are considered in the mechanical system architectural design. Identify special characteristics of your

Mechanical System Architectural Design. The special characteristics are the riskiest elements of your architectural design and are typically identified within the FMEA method.

Analyze static and dynamic behavior, for example via axis deflection and modal analysis. Verify the mechanical system architectural design against the requirements, defined in the MSE.1 process. This ensures at an early point in time the designed mechanical system will meet its requirements.

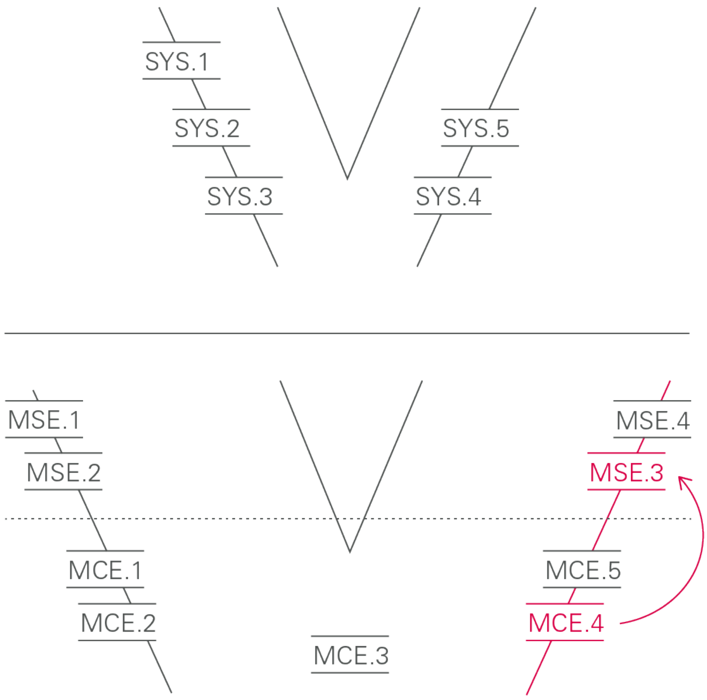
The typical verification methods are:

- simulations, e.g. FEM
- calculations
- risk assessments
- design reviews

A typical example of a mechanical component design is a drawing of single mechanical component, e.g of a screw.

3. MSE.3/MCE.4 Integration and related tests

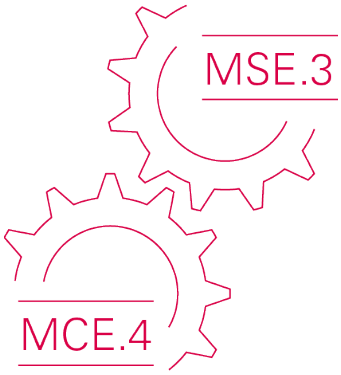
The MSE.3 Mechanical System Integration and Integration Test and MCE.4 Test against Mechanical Component Design processes specify a structured way how you can find failures where the built mechanical samples are not according to the defined design.



Integration of MSE.4 and MCE.4

You need an integration and test strategy incl. a regression test strategy. The integration strategy shall document the assembly steps of a prototype and their sequence. This is similar with an assembly instruction for a model kit.

Process parameters and the required environment shall be recorded while the integration is performed. Verify with a Mechanical System Integration Test whether the defined interfaces match: Do all the gears fit together or can you switch them? A typical Test against Mechanical Component Design is performed in the sample shop where all the defined dimensions are measured.



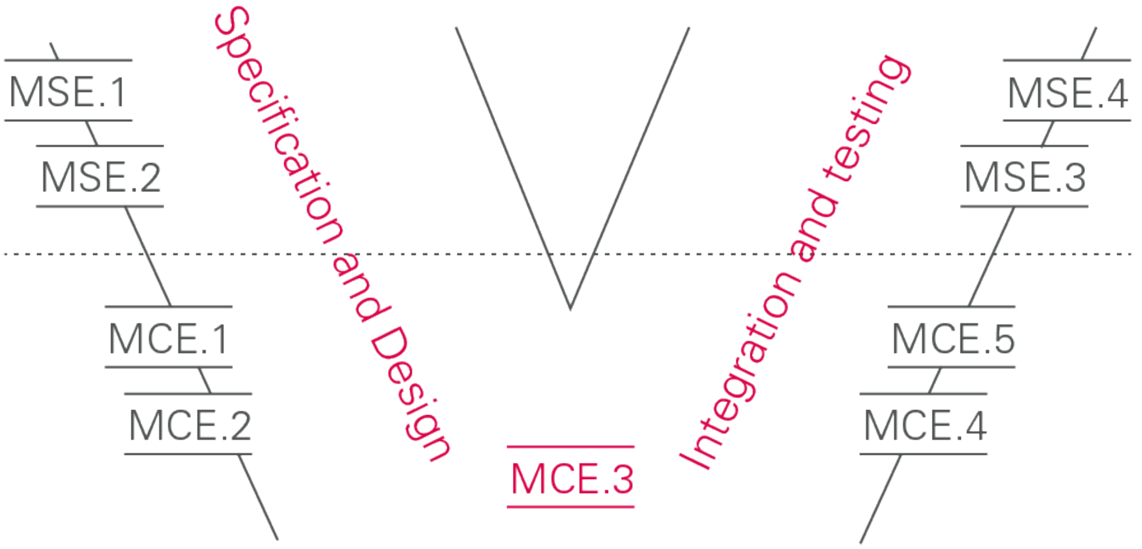
Define a test specification prior the testing of the mechanical system or of the mechanical component. This is necessary to perform the testing in a structured way.

A test specification contains as example a test design, test procedure with the test steps, test criteria for passed or failed. Test your mechanical system and mechanical components according to the test strategy and the test specifications.

The processes MSE.4 Mechanical System Qualification Test and MCE.5 Test against Mechanical Component Requirements have the same characteristics as the tests in the processes MSE.3 and MCE.4. The only difference is that during the tests within the processes MSE.4 and MCE.5, the requirements and not the design are verified.

4. MCE.3 Mechanical Component Sample Production

We come to the next process, MCE.3 Mechanical Component Sample Production. This process was defined to ensure a structured way of sample production.



MCE.3 Mechanical Component Sample Production

Please note: This process is only valid for you if you create/produce a mechanical component. If you assembly a mechanical system with already produced mechanical components, use the MSE.3 Mechanical System Integration and Integration Test process instead.

The first outcome of this MCE.3 process is a mechanical component production strategy. It includes:

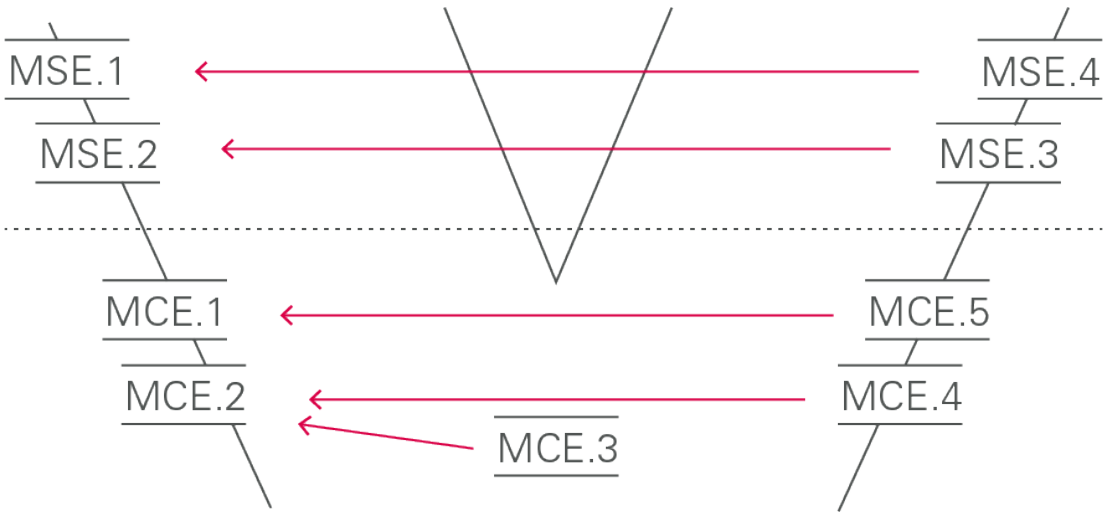
- sample production methods, for example casting or 3D printing
- production flow
- verification strategy
- production documentation
- measures reports etc.

Agree the mechanical component production strategy with all affected parties, e.g. with sample shop, development department, serial production, project management. Produce the component samples according to this strategy and record the production data.

5. Conclusion

Now we are through with the processes for mechanic development. Remember the V-shape with a left and right side with which these processes are arranged.

Each process on the right correlates with at least one of the elements on the left. To demonstrate that your results on the right match the requirements or architecture on the left, Automotive SPICE uses traceability.



Traceability

This establishes a link between elements of different development outcomes, e.g. between a requirement and the associated tests. On the right side, consistency checks are required. These build on traceability. SPICE for Mechanical Engineering defines traceability and consistency like Automotive SPICE.

In addition: Communicate on the left side of the V-model the agreed outcomes to all parties involved, e.g. communication of the agreed requirements. On the right side of the V-model, the summary and the communication of the verification results are required.

The process MCE.3 Mechanical Component Sample Production contains both requirements as this process is partly on the left side of the v-model and partly on the right side of the v-model.

Want to become an expert on Automotive SPICE®?

You'll have noticed, that we couldn't go into too much detail in this white paper. If you're serious about learning Automotive SPICE®, especially SPICE for Mechanical Engineering, we highly encourage you to participate to our Automotive SPICE® course "SPICE for Mechanical Engineering":

https://www.kuglermaag.com/training-automotive-spice/introduction-to-me-spice-mechanical-engineering/

Also feel free to subscribe to our Kugler Maag YouTube and LinkedIn channel to not miss any future videos and updates!

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