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Functional Safety Implications for Development Infrastructures

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Contents

- What is functional safety?
- What does the upcoming standard on functional safety in the automotive domain ISO/DIS 26262 require regarding software tools?
- What is the software tool qualification method according to ISO/DIS 26262?
- How is software tool qualification performed by manufacturers and by users?

Functional Safety

Definitions ISO/DIS 26262-1

Safety: Absence of unreasonable risk

Risk: Combination of the probability of occurrence of harm and the severity of that harm

Functional safety: Absence of unreasonable risk due to hazards caused by malfunctioning behavior of E/E systems

E/E system: System that consists of electrical and/or electronic elements, including programmable electronic elements

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Functional Safety Standards

Common principles

- Functional safety is an attribute of products/systems
- Standards describe the state-of-the-art technology for achieving functional safety of products: E.g. IEC 61508, ISO/DIS 26262
- Such standards are used as guidance for product developments, in product liability lawsuits, for marketing purposes, …
- Contain process- and product-related requirements and recommendations
- Process-related requirements include requirements related to development and test environments as well as related to software tools used
- Argument: Risk reduction through a controlled development process and its tools
- Standards require/recommend methods to be applied. Examples: Semi-formal notations for software design, static code analysis, statement coverage
- In practice most methods need to be implemented using software tools
- No specifically named software environments or tools from a specific manufacturer recommended

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ISO/DIS 26262 Tool Requirements

Miscellaneous requirements

- Adequate resources shall be provided, incl. tools, databases, templates
- Software tools for software development shall be selected and their use planned; including guidelines for their application
- Shall be consistent across the software lifecycle and compatible with system and hardware lifecycles
- In case of modifications to previously suited software tools: Impact analysis
- Requirements/recommendations for software implementation: Related to dynamic objects or variables, related to unconditional jumps, … -> Need to be supported by the environment/language and/or tools
- Examples but no requirement for integration and test environments: MiL, SiL, PiL, HiL, vehicle
- No specific requirement for certified or proven in use compiler
- No distinction between development and test tools
- **Software tools used must be suited for purpose.** Evidence by applying ISO/DIS 26262-8, clause 11, Qualification of software tools

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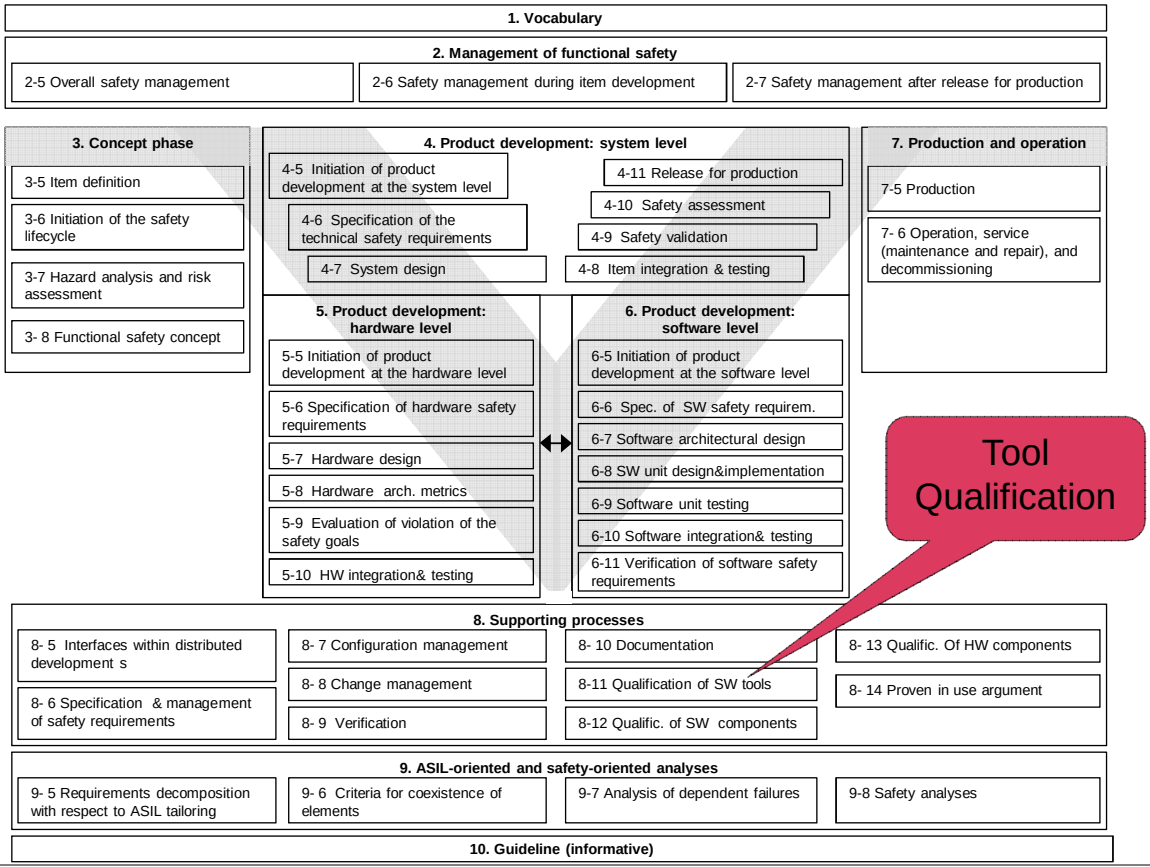
ISO/DIS 26262 Overview



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ISO/DIS 26262-8 Supporting Processes

Qualification of software tools

- **Software tools** used in the lifecycle of safety-related items or elements must be **suited** for its use.
- Suitability must be analyzed and evidence must be provided.
  - Perform an analysis of the use case in the workflow: Does the use of the tool have the potential to violate a safety requirement?
  - Judgement whether an error in the tool can still be detected so that nevertheless no safety requirement will be violated
- In case there is a hazard by the tool a **qualification of the tool** must be performed resp. evidence of qualification must be given.
- ISO/DIS 26262 defines different methods for the qualification depending on the hazard and the ASIL of the item or the element.
- TCL (Tool Confidence Level) is not a required attribute of a tool but an attribute of the use of a tool in the safety lifecycle.
- Tool qualification can largely be performed before item development, assuming a TCL.

ISO/DIS 26262-8, clause 11

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ISO/DIS 26262-8 Supporting Processes

Qualification of software tools

- Classification of software tools according to two attributes:
  - **TI** (**Tool Impact**): Probability of violating a safety requirement by an error of the tool
  - **TD** (**Tool error Detection**): Probability of preventing or detecting a malfunction or erroneous output of the tool
- Both attributes TI and TD are determined and translated into a required **Tool Confidence Level** (**TCL**).

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ISO/DIS 26262-8 Supporting Processes

Qualification of software tools

- **TI** (**Tool Impact**): Probability of violating a safety requirement by an error of the tool
  - *TI0 shall be chosen when there is an argument that there is no such possibility*
  - *TI1 shall be chosen in all other cases*
- **TD** (**Tool error Detection**): Probability of preventing or detecting a malfunction or erroneous output of the tool
  - *TD1 shall be chosen if there is a high degree of confidence that a malfunction or an erroneous output from the software tool will be prevented or detected*
  - *TD2 shall be chosen if there is a medium degree of confidence that a malfunction or an erroneous output from the software tool will be prevented or detected*
  - *TD3 shall be chosen if there is a low degree of confidence that a malfunction or an erroneous output from the software tool will be prevented or detected*
  - *TD4 shall be chosen in all other cases*

ISO/DIS 26262-8 Supporting Processes

Qualification of software tools

- **TCL1**: Tools that cannot violate a safety requirement (TI0) or whose malfunction can be prevented or detected with a high degree of confidence (TI1 und TD1) need the lowest level of confidence TCL1. No qualification measures necessary
- **TCL2** is for tools with TI1 and TD2.
- **TCL3** is for tools with TI1 and TD3.
- **TCL4** is the highest level of confidence needed. It is for such tools that have the potential to violate a safety requirement and a low degree of confidence to detect an erroneous output by other means.

Tool Confidence Levels

Examples of what could typically be expected

- Compilers and code generators: TCL2 or TCL3
  - Heavily depends on the quality of subsequent tests. Even TCL4 possible.
- Simulation and analysis tools: TCL1 or TCL2
- Test automation: TCL2
- Configuration management system for the product itself: TCL2
- Most other tools: TCL1

- In a well organized workflow we would expect no tool to be TCL4

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ISO/DIS 26262-8 Supporting Processes

Qualification of software tools

TCL4

Highest requirements

Methods		ASIL A	ASIL B	ASIL C	ASIL D
1a	Increased confidence from use	++	++	+	o
1b	Evaluation of the development process	++	++	++	+
1c	Validation of the software tool	+	+	++	++
1d	Development in compliance with a safety standard[a]	+	+	++	++

TCL3

Medium requirements

Methods		ASIL A	ASIL B	ASIL C	ASIL D
1a	Increased confidence from use	++	++	++	+
1b	Evaluation of the development process	++	++	++	++
1c	Validation of the software tool	+	+	+	++
1d	Development in compliance with a safety standard[a]	+	+	+	++

TCL2

Lowest requirements

Methods		ASIL A	ASIL B	ASIL C	ASIL D
1a	Increased confidence from use	++	++	++	++
1b	Evaluation of the development process	++	++	++	++
1c	Validation of the software tool	+	+	+	+
1d	Development in compliance with a safety standard[a]	+	+	+	+

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Software Tool Qualification Methods

1a Increased confidence from use (1/2)

- **Used** previously for the same purpose with comparable use-cases and with a comparable determined environment and with similar functional constraints
- **Specification** of the software tool unchanged
- **No violation of a safety requirement** allocated to a previously developed safety-related item or element occurred as a consequence of malfunctions or erroneous outputs of this software tool
  - To create such evidence, data about the occurrence of malfunctions or of erroneous output of the software tool, observed or detected during previous developments shall be accumulated in a systematic way and made available.

Software Tool Qualification Methods

1a Increased confidence from use (2/2)

- The requirements of the *proven in use* argument from clause 14 are not applicable.
  - I.e. e.g. no requirement for at least one year operating time and no limit for incident rate
- Analyze previous use:
  - Identify tool and version, details of period of use
  - Documentation of malfunctions
  - Measures taken to deal with known malfunctions, related to identified versions
- Confidence from use argument only valid for the considered **version**
  - May be valid only for a specific variant of use: Was the compiler used with or without code optimization option?

Software Tool Qualification Methods

1b Evaluation of the development process

- **Development process** shall comply with an appropriate **standard**
- Provide evidence by an assessment
  - E.g. Automotive SPICE, CMMI, ISO 15504

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Software Tool Qualification Methods

1c Validation of the software tool

- Validation measures shall demonstrate that the software tool fulfils its specified **requirements**
  - E.g. by using a test suite with a determined functional and structural coverage
- **Analyze** eventually occurring **erroneous outputs**, including analysis of possible consequences and measures for avoidance and detection
- The reaction of the software tool to **anomalous operating conditions** shall be examined
  - E.g. use of prohibited use of configuration settings
- Examine **robustness**
- Validation can largely be automated using a validation suite
  - Ensure correctness and robustness of such functionality that will actually be used for the development of safety-related elements

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Software Tool Qualification Methods

1d Development in compliance with a safety standard

- No safety standard is fully applicable to the development of software tools.
- Instead, a relevant **subset** of requirements of the safety standard can be **selected**.

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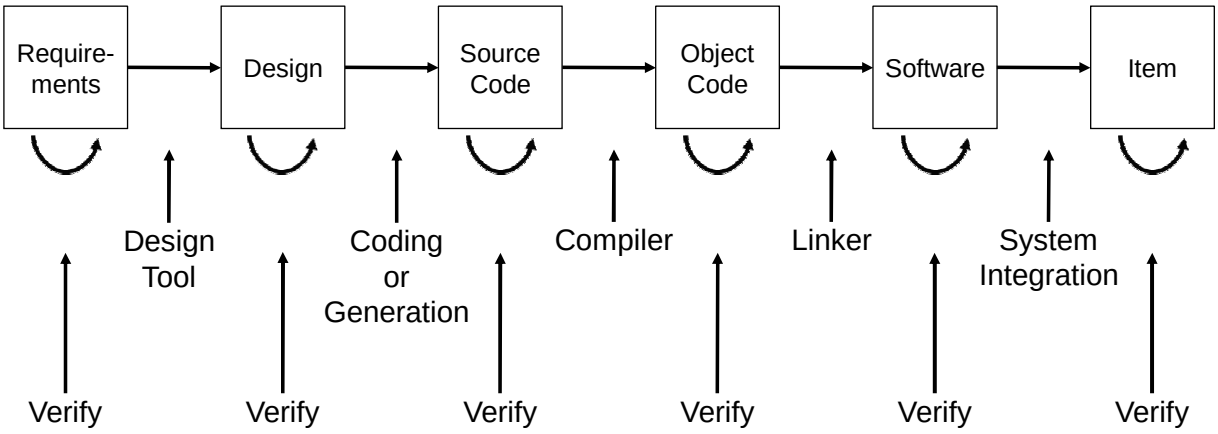
ISO/DIS 26262-8 Supporting Processes

Qualification of software tools

- **Example**: Workflow and TD classification



- What is the probability that a fault in the compiler is detected by subsequent tests?

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ISO/DIS 26262-8 Supporting Processes

Qualification of software tools

- **Procedure** for qualification
  - Precise identification of the candidate for qualification (version, parameters, …)
  - Analyze intended use of the tool in the lifecycle. Determine TI.
  - Estimate probability of the tool error detection. Determine TD.
  - Determine TCL
  - Determine maximum ASIL of the safety function or of the item
  - Determine method(s) for qualification (tables 2 through 4)
  - Apply method(s) for qualification („qualify“). Provide a report.
  - Confirm (review) the qualification
- **Output work products** of qualification
  - Qualification plan
  - Tool documentation
  - Tool classification analysis
  - Qualification report

ISO/DIS 26262-8 Supporting Processes

Qualification of software tools

- **Confirmation review** of the qualification recommended for ASIL B and required from ASIL C upwards (ISO/DIS 26262-2, 6.4.6.2, table 1)

	A	B	C	D	
Confirmation review of the qualification of software tools (see ISO°26262-8, Clause 11) - independent from the person performing the qualification of the software tool	-	I0	I1	I1	highest ASIL among safety goals of the item

- I0 = should be performed (recommendation)
- I1 = shall be performed (requirement)
- No requirement for independence of the reviewer
- Self qualification possible

Software Tool Qualification in Practice

By **manufacturers** (example)

1. Tool **development** including tool test and validation by the manufacturer (methods 1d and 1c)
2. Tool **maintenance**: Documentation of tool usage, bug reports, bug analysis, bug fixing and user information by the manufacturer (method 1a)
3. **Evaluation** of the development process and of the maintenance process for the tool by an independent inspection authority (KUGLER MAAG CIE, …) with qualification report and tool certificate (method 1b)
4. **Review** of the qualification report by different persons of the manufacturer and the inspection authority (Confirmation review according to part 2, 6.4.6.2)

- Qualification is valid for a specific version of the tool
- A TCL, an ASIL, use cases and environments of usage are assumed
- Validity of the manufacturer's qualification needs to be evaluated for the particular use by the using organization/project

Software Tool Qualification in Practice

By **tool users** (example)

1. Assumed method 1d "development (of the tool) in compliance with a safety standard" is not possible
2. Evaluation of the tool's development process is also nearly impossible (method 1b)
3. Candidates for qualification are only such tools/development environments for which continuous **tool maintenance** is effective
4. Systematically collect information about the **tool usage** (in-house and external)
   - Includes information about violations of safety requirements as a consequence of malfunctions of the tool
5. Self qualification or commissioning of qualification using method "**increased confidence from use**" for ASIL A, B
6. Self qualification or commissioning of qualification using methods "**increased confidence from use**" and "**validation of the tool**" for TCL3/ASIL D, resp. TCL4/ASIL C, D
7. **Review** of the qualification report by different persons of the tool user's organization and/or the inspection authority (Confirmation review according to part 2, 6.4.6.2)

Software Tool Qualification in Practice

Example

- One such sheet for each software tool in the workflow

Software tool qualification report			
Tool name	*name*	Author	*name*
Tool short description	*This tool does …*	Date	*of the analysis*
Tool information (11.4.2.2)	*features, functions, properties, installation process, user manual, envonment, beahaviour under anomalous operating conditions, known malfunctions (or references)*		
Planning of qualification (11.4.2.1)	*unique identification, version, configuration, use-cases, environment, maximum ASIL*		
Tool use-cases (11.4.3.1)			
Purpose	*Intended pupose of the tool (in the workflow)*		
Output	*e.g. model, source code, object code, embedded software, executable test*		
Environmental and functional constraints			
Tool impact analysis (11.4.3.2.a)			
Hazards	*What kind of wrong output is hazardous? Which consequences could that*		
Tool Impact	*What is the tool impact?*		TI0/TI1
Tool error detection analysis (11.4.3.2.b)			
Hazard	Measure indicating error detection	Effectiveness	TD
reference above	*What measure could detect a tool error? E.g. review, test*	*low/medium/high*	*TD1/TD2/TD3/TD4*
Tool error Detection		*low/medium/high*	*TD1/TD2/TD3/TD4*
Tool confidence level (11.4.3.4)			*TCL1/TCL2/TCL3/TCL4*
Qualification required?			*yes/no*
Software tool qualification documentation			
Qualification methods		used?	Reference to evidence
1a Increased confidence from use		*yes/no*	*reference*
1b Evaluation of the development process		*yes/no*	*reference*
1c Validation of the software tool		*yes/no*	*reference*
1d Development in compliance with a safety		*yes/no*	*reference*
Summary of software tool qualification			ASIL A/B/C/D

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Software Tool Qualification in Practice

Remarks

- There is still very **little experience** with the qualification method according to ISO/DIS 26262
- Tool qualification is possible for an inspection authority without testing the tool itself
  - In case of TCL3/ASIL D or TCL4/ASIL C validation e.g. by the manufacturer
- There is not yet a consolidated opinion about the TCL classification of standard tools
  - A code generator was classified TCL1 because inserted errors would be found by the subsequent workflow. For TCL1 no specific methods for qualification are necessary.
  - Not defined what low, medium and high degree of confidence in tool error detection (TD) means

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Summary

- In the automotive application domain the possibility to violate a safety requirement needs to be assessed for all software tools used in the workflow
- Typically, tool qualification needs to be performed for only the main software tools used in the workflow
- Criteria for tool qualification are relatively vague in ISO/DIS 26262
- Tool qualification itself is not difficult
- Tools can be qualified by inspection authorities, manufacturers and users

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Thank you for your attention!

Should you have any questions please do not hesitate to contact us …

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Our Book about Functional Safety

(in German)

Can be ordered here:
http://www.kuglermaag.de/webshop.html

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