Introduction
Overview of V&V techniques

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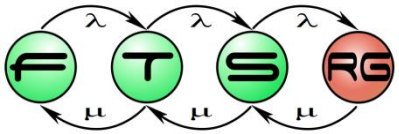


Main topics of the course

- Overview (1)
  - V&V techniques, Critical systems
- Static techniques (2)
  - Verifying specifications
  - Verifying source code
- Dynamic techniques: Testing (7)
  - Developer testing, Test design techniques
  - Testing process and levels, Test generation, Automation
- System-level verification (3)
  - Verifying architecture, Dependability analysis
  - Runtime verification

Who is this course for?

System Engineer	• Requirements, verifying specification
Architect, Designer	• Modeling and verifying designs
Developer, Coder	• Verifying source code, unit testing
Test Designer	• Test processes and techniques
Test Engineer	• Test automation, integration and system tests
Safety Engineer	• Certification, development standards

Stereotypes

"Testing is destructive."

"Testing is just pushing buttons and supplying values randomly."

"If your are not good for a developer, you can be a tester."

"Testing is boring."

"I tested in the debugger…"

V&V (and testing) in reality

V&V (and testing) is creative!

How is this working?

How can I prove it works?

How should it work?

How can it fail?

V&V (and testing) is constructive!

Testers are not breaking the SW (it was broken)

Testers help make the system better

Passion for quality

V&V (and testing) requires a different mindset

Intuition

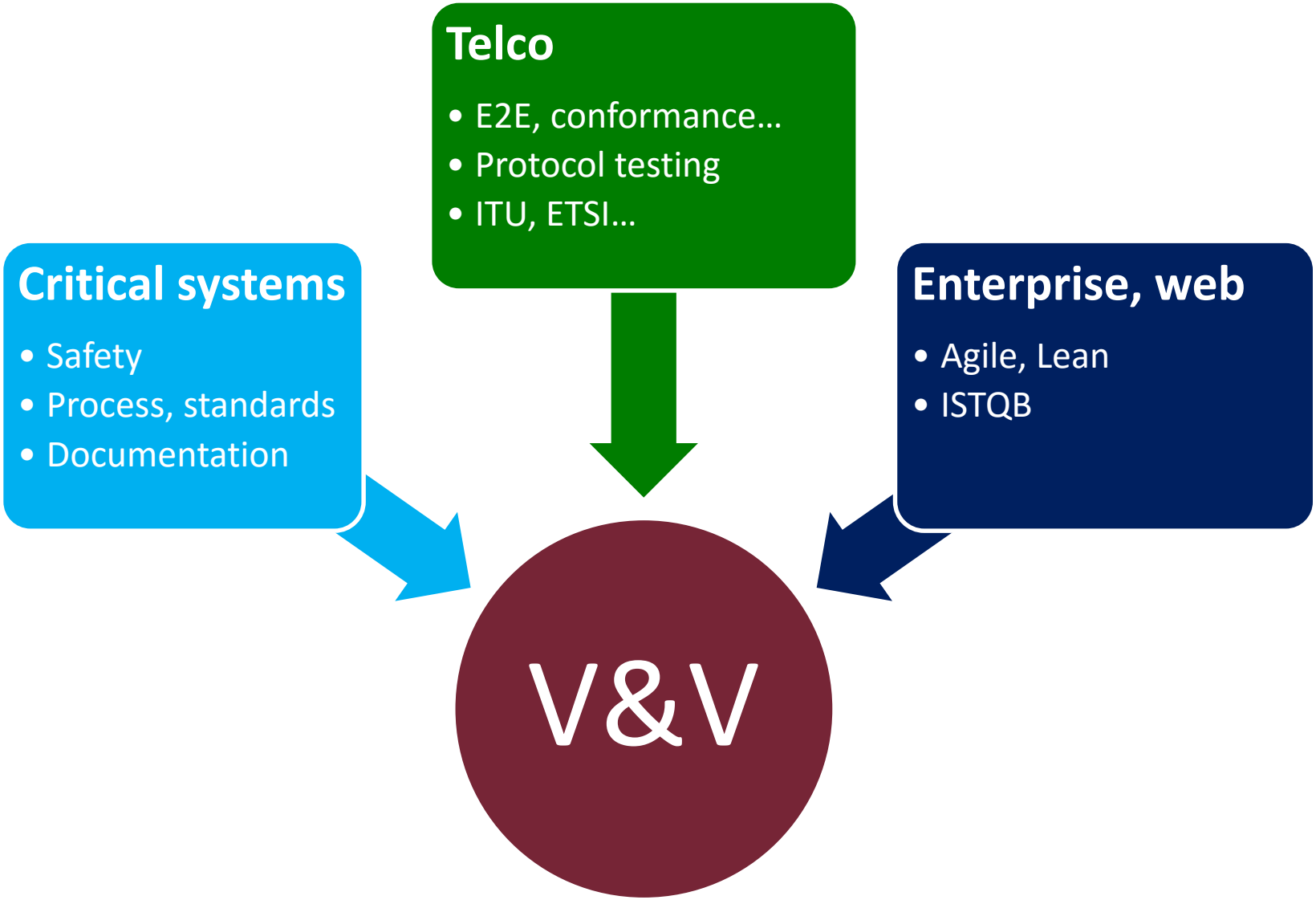
Attention to details

…

Systems level thinking

Specific knowledge

V&V is context dependent!



Useful resources (download now!)

- IEEE standards
  - 24765-2010 Systems and SW engineering – Vocabulary
  - 29148-2011 Requirements engineering
  - 29119 Software testing
    - Part 1 Concepts and definitions
    - Part 2 Test processes
    - Part 3 Test documentation
- International Software Testing Qualifications Board (ISTQB)
  - Foundation Level Syllabus (2011)
  - Glossary of Testing Terms
- Hungarian Testing Board (HTB)
  - Glossary / Kifejezésgyűjtemény (magyar fordítás)

MOTIVATION

Different kinds of faults

Development phase

- Specification faults
- Design faults
- Implementation faults

V&V during design

Operational phase

- Hardware faults
- Configuration faults
- Operator faults

Fault tolerance (e.g. redundancy)

Software is the cause of problems

„Defibtech issues a worldwide recall of two of its defibrillator products due to faulty self-test software that may clear a previously detected low battery condition.” (February 2007)

„Cricket Communications recalls about 285,000 of its cell phones due to a software glitch that causes audio problems when a caller connects to an emergency 911 call. (May 2008)”

Nissan recalls over 188,000 SUVs to fix brakes (Update) October 23, 2013

Nissan Motor Co. is recalling more than 188,000 Nissan and Infiniti SUVs worldwide to fix faulty brake control software that could increase the risk of a crash.

RECALLS Feb 12th 2014 at 9:15AM 67

Toyota recalling 1.9M Prius models globally for software update

How many bugs do we have to expect?

DB Mobility Networks Logistics

How many „Bugs“ do we have to expect?

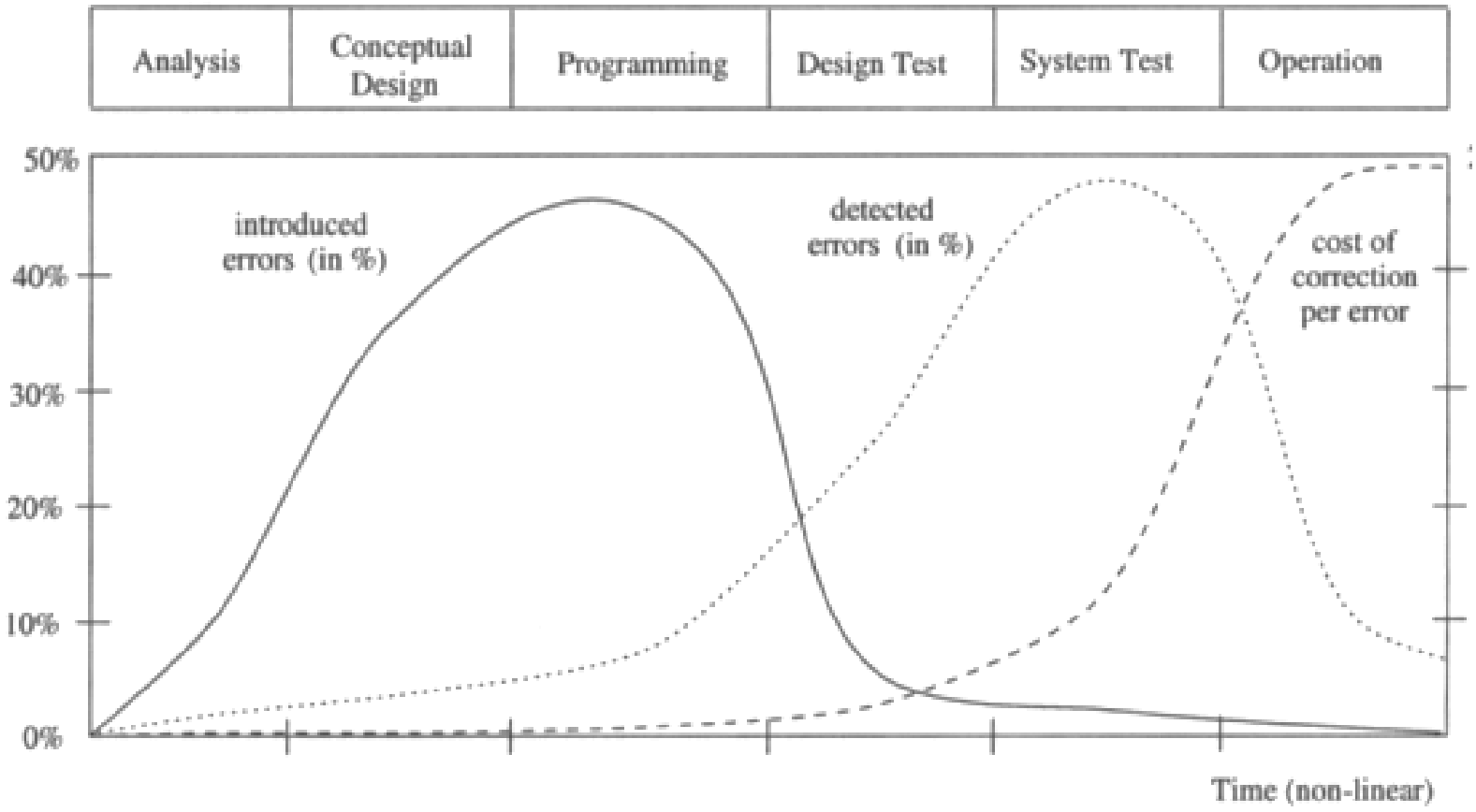
- Typical production type SW has 1 … 10 bugs per 1.000 lines of code (LOC).
- Very mature, long-term, well proven software: 0,5 bugs per 1.000 LOC
- Highest software quality ever reported :
  - *Less than 1 bug per 10.000 LOC*
  - At cost of more than 1.000 US$ per LoC *(1977)*
  - *US Space Shuttle with 3 m LOC* costing 3b US$ (out of 12b$ total R&D)

➔ Cost level not typical for the railway sector (< 100€/LoC)

- Typical ETCS OBU kernel software size is about 100.000 LOC or more
  - That means: 100 … 1.000 undisclosed defects per ETCS OBU
  - Disclosure time of defects can vary between a few days …. thousands of years

Source: K-R. Hase: „Open Proof in Railway Safety Software”, FORMS/FORMAT Conference, December 2-3, 2010, Braunschweig, Germany

Distribution and cost of bugs



Early V&V reduces cost!

V&V: Verification and Validation

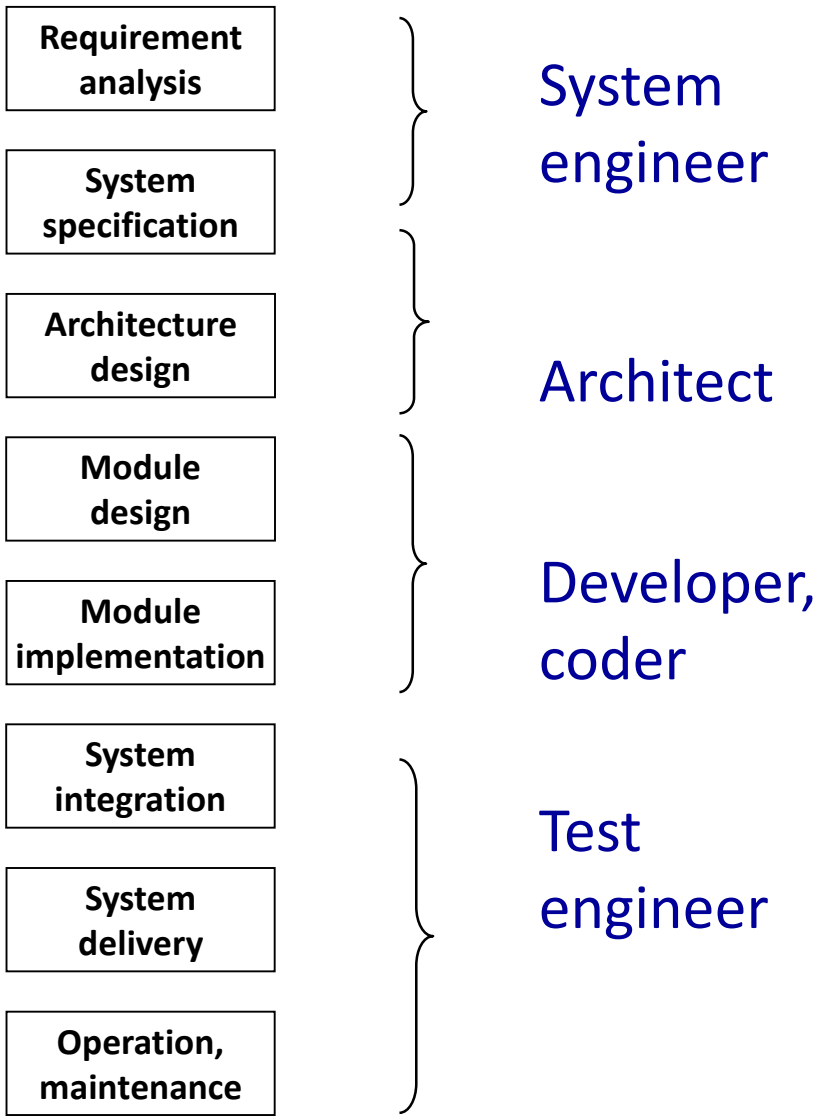
Verification	Validation
„Am I building the system right?”	„Am I building the right system?”
Check consistency of development phases	Check the result of the development
Conformance of designs/models and their specification	Conformance of the finished system and the user requirements
Objective; can be automated	Subjective; checking acceptance
Fault model: Design and implementation faults	Fault model: problems in the requirements
Not needed if implementation is automatically generated from specification	Not needed if the specification is correct (very simple)

OVERVIEW OF V&V TECHNIQUES

Learning outcomes

- **List typical V&V activities (K1)**
- **Classify the different verification techniques according to their place in the lifecycle (K2)**

Typical steps in development lifecycle

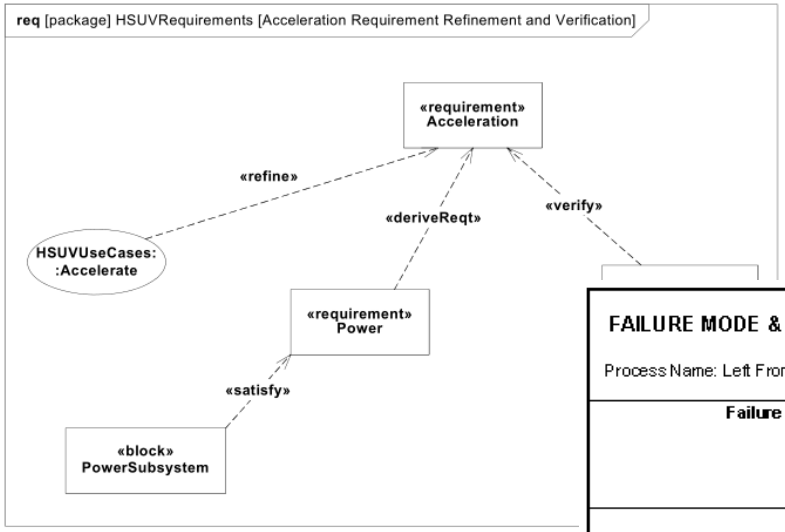


Schedule, sequencing depends on lifecycle model!

Requirement analysis

- **Requirement analysis**
- **System specification**
- **Architecture design**
- **Module design**
- **Module implementation**
- **System integration**
- **System delivery**
- **Operation, maintenance**

Task	V&V criteria	V&V technique
Defining functions, actors, use cases	- Risks - Criticality	- Checklists - Failure mode and effects analysis



FAILURE MODE & EFFECTS ANALYSIS (FMEA)

Date: 1/1/2000
Revision: 1.3

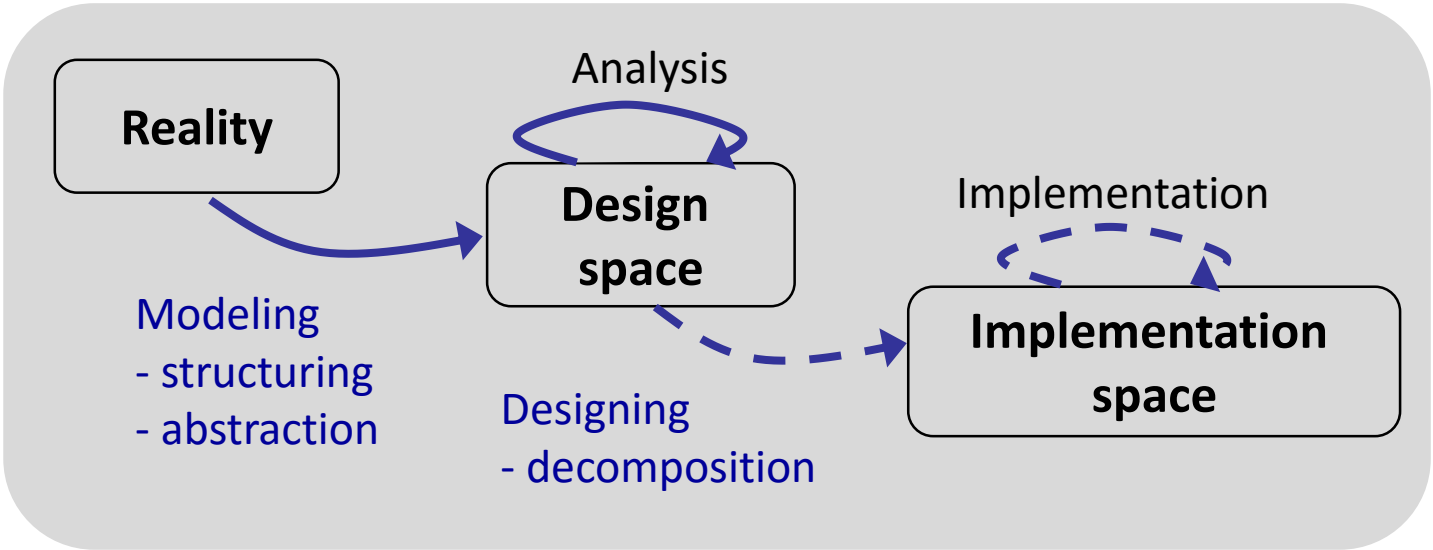
Process Name: Left Front Seat Belt Install Process Number: SBT 445

Failure Mode	A) Severity Rate 1-10 10 = Most Severe	B) Probability of Occurance Rate 1-10 10 = Highest Probability	C) Probability of Detection Rate 1 - 10 10 = Lowest Probability	Risk Preference Number (RPN) AxBxC
1) Select Wrong Color Seat Belt	5	4	3	**60**
2) Seat Belt Bolt Not Fully Tightened	9	2	8	**144**
3) Trim Cover Clip Misaligned	2	3	4	**24**

System specification

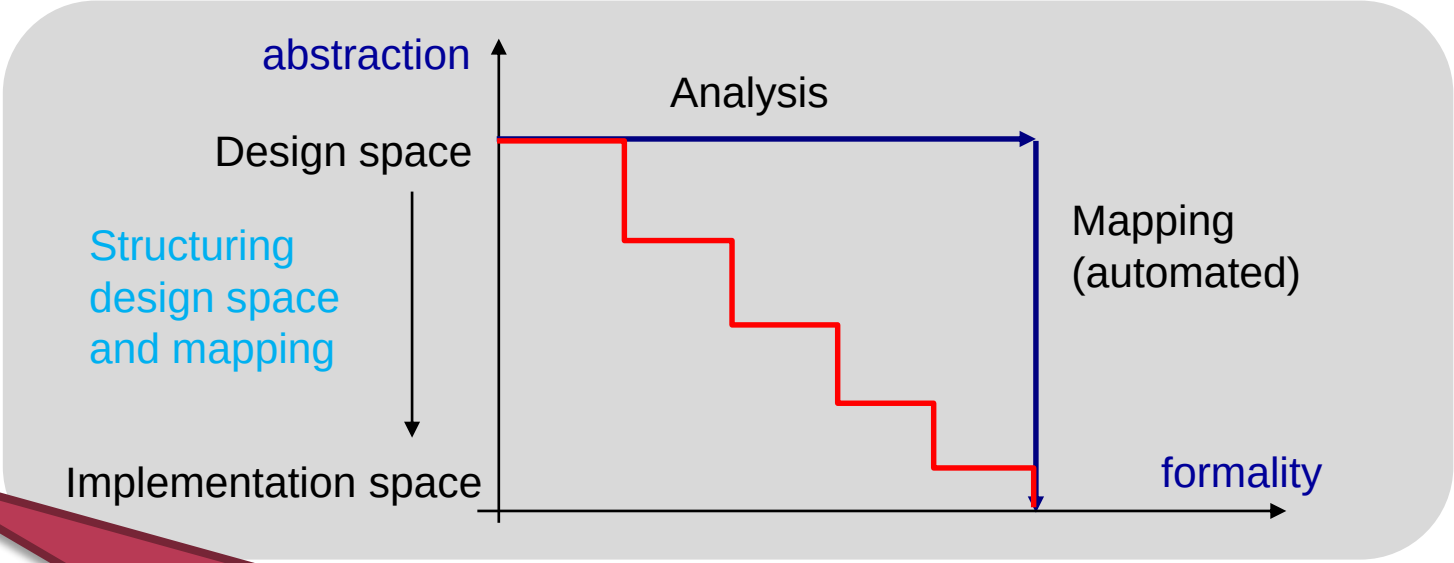
- Requirement analysis
- **System specification**
- Architecture design
- Module design
- Module implementation
- System integration
- System delivery
- Operation, maintenance

Task	V&V criteria	V&V technique
Defining functional and non-functional requirements	- Completeness - Unambiguity - Verifiability - Feasibility	- Reviews - Static analysis - Simulation



Architecture design

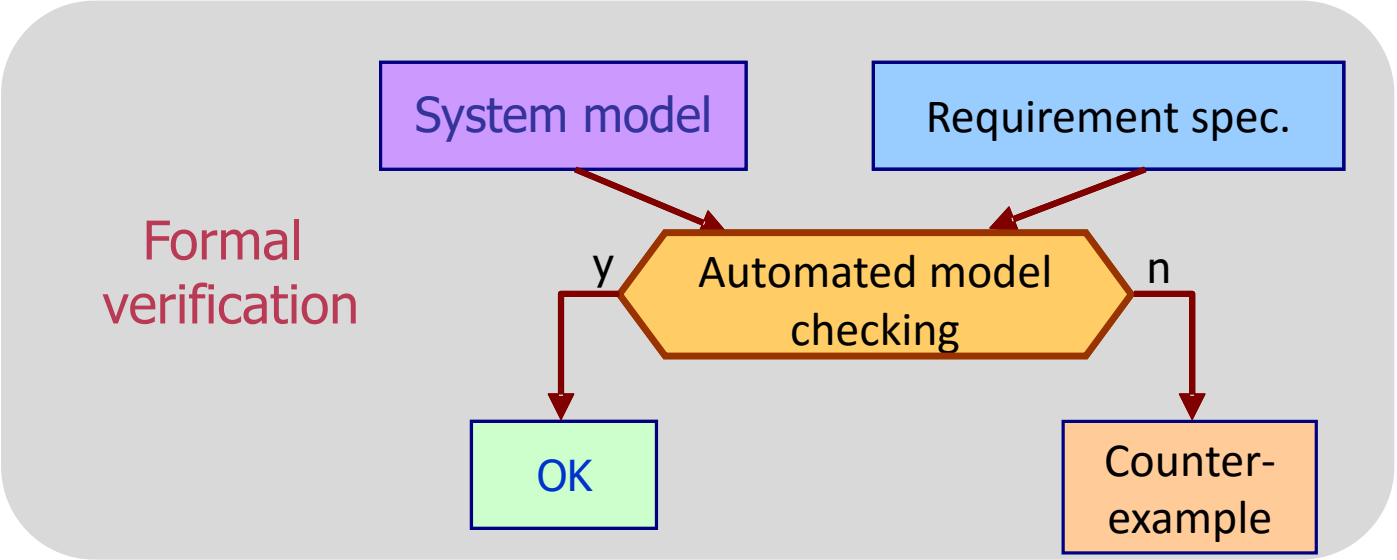
- Requirement analysis
- System specification
- **Architecture design**
- Module design
- Module implementation
- System integration
- System delivery
- Operation, maintenance



Task	V&V criteria	V&V technique
- Decomposing modules - HW-SW co-design - Designing communication	- Function coverage - Conformance of interfaces - Non-functional properties	- Static analysis - Simulation - Performance, dependability, security analysis

Module design (detailed design)

- Requirement analysis
- System specification
- Architecture design
- **Module design**
- Module implementation
- System integration
- System delivery
- Operation, maintenance



Task	V&V criteria	V&V technique
- Designing detailed behavior (data structures, algorithms)	- Correctness of critical internal algorithms and protocols	- Static analysis - Simulation - Formal verification - Rapid prototyping

Module implementation

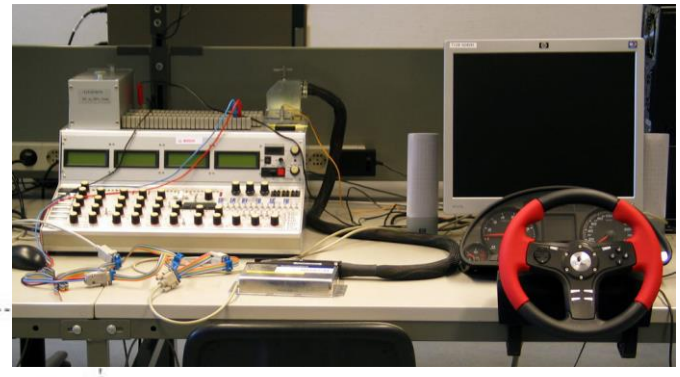
- Requirement analysis
- System specification
- Architecture design
- Module design
- **Module implementation**
- System integration
- System delivery
- Operation, maintenance

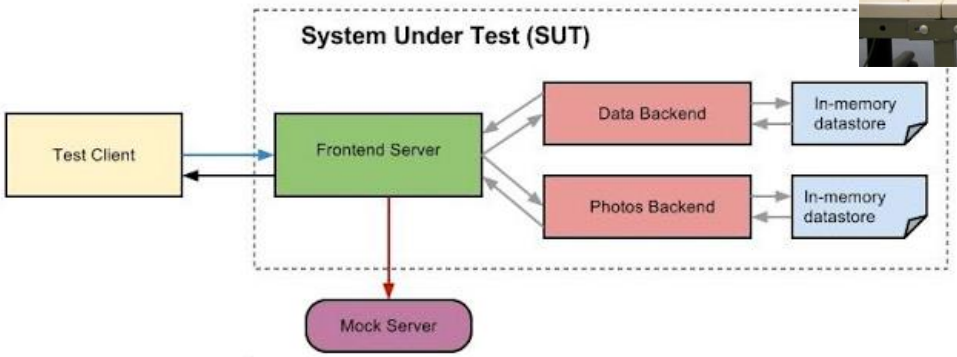
Task	V&V criteria	V&V technique
- Software implementation	Code is - Safe - Verifiable - Maintainable	- Coding conventions - Code reviews - Static code analysis
- Verifying module implementation	- Conformance to module designs	- Unit testing - Regression testing

System integration

- Requirement analysis
- System specification
- Architecture design
- Module design
- Module implementation
- **System integration**
- System delivery
- Operation, maintenance

Task	V&V criteria	V&V technique
- Integrating modules - Integrating SW with HW	- Conformance of integrated behavior - Verifying communication	- Integration testing (incremental)





System delivery and deployment

- Requirement analysis
- System specification
- Architecture design
- Module design
- Module implementation
- System integration
- **System delivery**
- Operation, maintenance

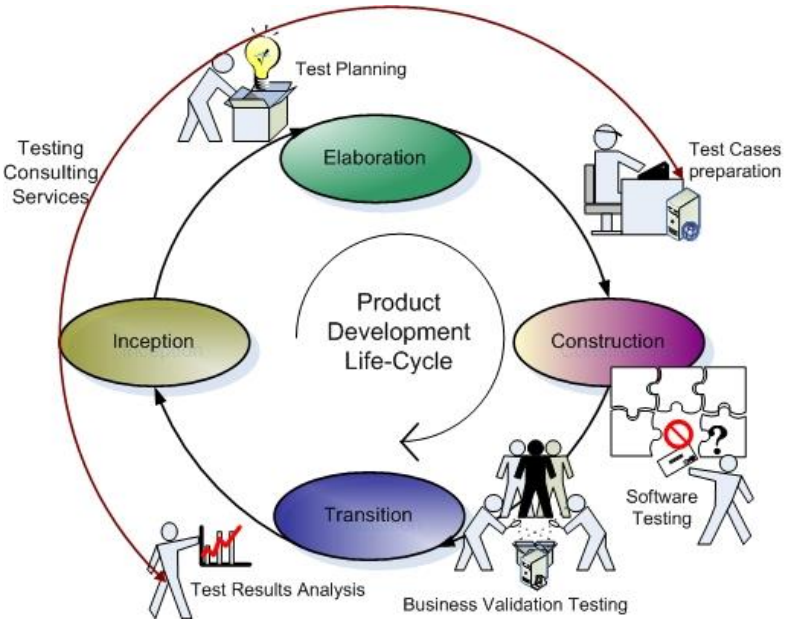
Task	V&V criteria	V&V technique
- Assembling complete system	- Conformance to system specification	- System testing - Measurements, monitoring
- Fulfilling user expectations	- Conformance to requirements and expectations	- Validation testing - Acceptance testing - Alfa/beta testing

Operation and maintenance

- Requirement analysis
- System specification
- Architecture design
- Module design
- Module implementation
- System integration
- System delivery
- **Operation, maintenance**

Tasks during operation and maintenance:
- Failure logging and analysis (for failure prediction)
- V&V of modifications

Mini-lifecycle for each modification



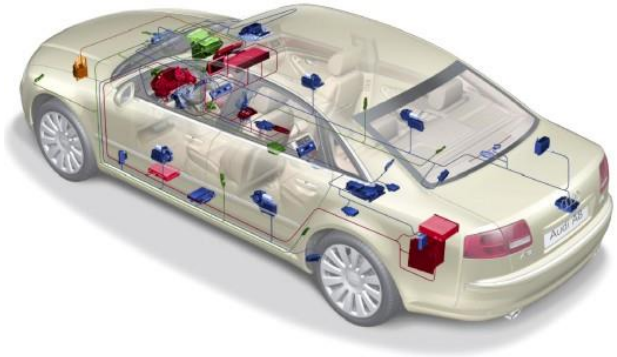
V&V TECHNIQUES IN CRITICAL SYSTEMS

Learning outcomes

- **Recall the safety concepts of critical systems (K1)**
- **List typical activities required by standards (K1)**

Safety-critical systems

Safety: “The expectation that a system does not, under defined conditions, lead to a state in which human life, health, property, or the environment is endangered.” [IEEE]



Certification

- Certification by safety authorities

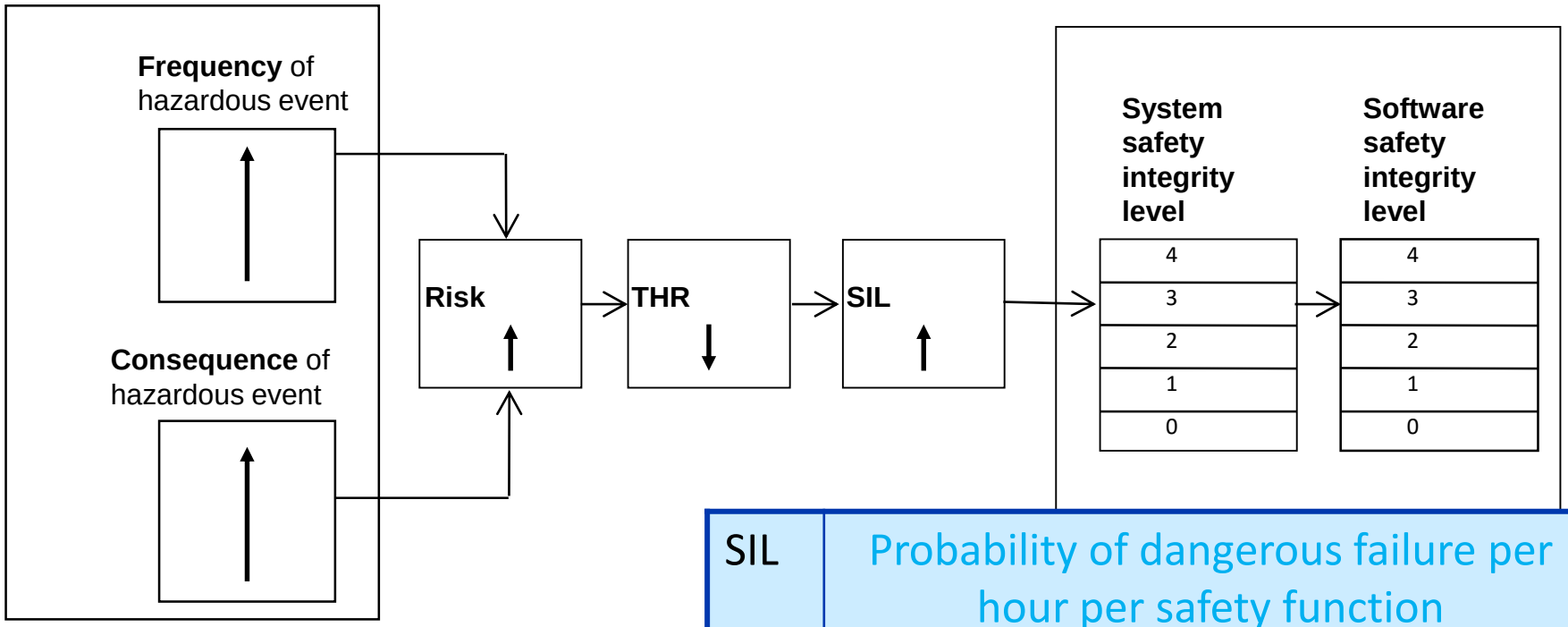
- Basis of certification: Standards
  - IEC 61508: Generic standard (for electrical, electronic or programmable electronic systems)
  - DO178B/C: Software in airborne systems
  - EN50128: Railway (software)
  - ISO26262: Automotive

Safety concepts

- Safety function
  - Intended to achieve or maintain a safe state
- Safety integrity
  - Probability of a safety-related system satisfactorily performing the required safety functions under all stated conditions and within a stated period of time
- Safety Integrity Level (SIL)
  - Based on risk analysis
  - Tolerable Hazard Rate (THR)

Basics of determining SIL

Risk analysis -> THR -> SIL



SIL	Probability of dangerous failure per hour per safety function
1	$10^{-6} \leq THR < 10^{-5}$
2	$10^{-7} \leq THR < 10^{-6}$
3	$10^{-8} \leq THR < 10^{-7}$
4	$10^{-9} \leq THR < 10^{-8}$

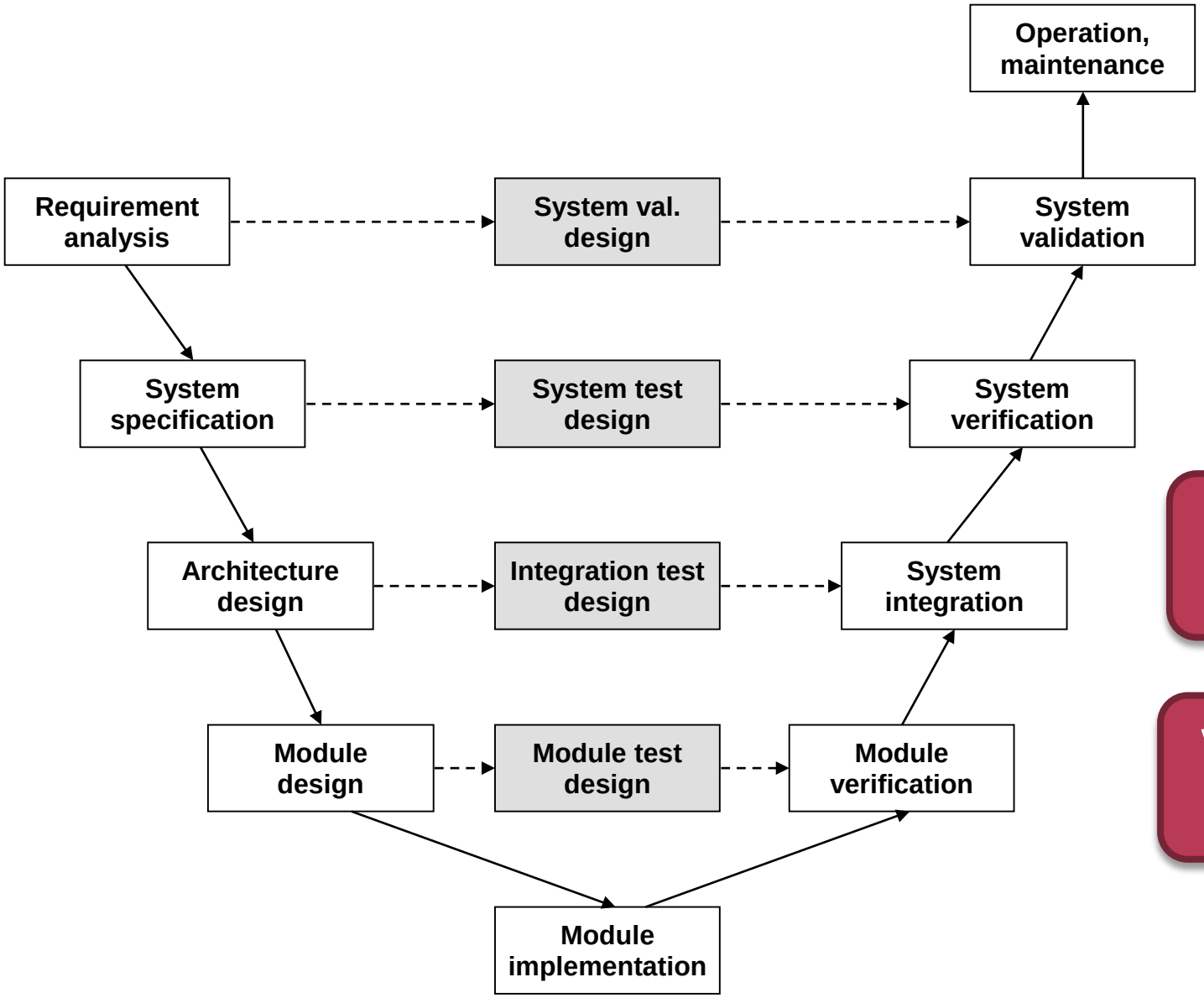
15 years lifetime:
1 failure in case
of 750 equipment

Demonstrating SIL requirements

Different approaches for types of failures

- Random failures (e.g. HW)
  - Qualitative analysis (statistics, experiments…)
- Systematic failures (e.g. SW)
  - Rigor in the engineering
  - Recommendations for each SIL
  - Process, techniques, documentation, responsibilities

Example: Process (V model)



Well-defined phases

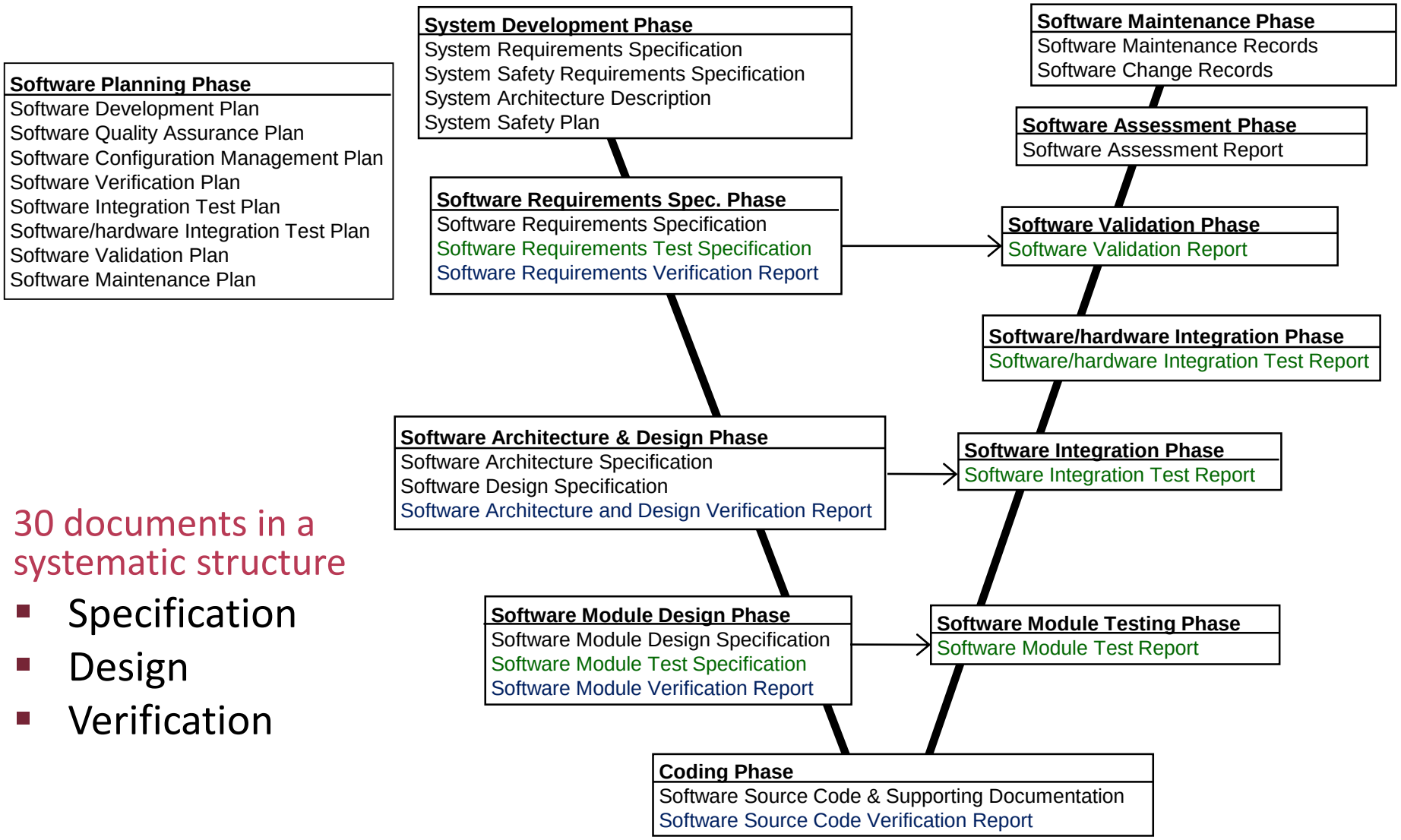
Verification of each step

Example: Techniques (EN 50128)

TECHNIQUE/MEASURE		Ref	SWS ILO	SWS IL1	SWS IL2	SWS IL3	SWS IL4
14.	Functional/ Black-box Testing	D.3	HR	HR	HR	M	M
15.	Performance Testing	D.6	-	HR	HR	HR	HR
16.	Interface Testing	B.37	HR	HR	HR	HR	HR

- M: Mandatory
- HR: Highly recommended (rationale behind not using it should be detailed and agreed with the assessor)
- R: Recommended
- ---: No recommendation for or against being used
- NR: Not recommended

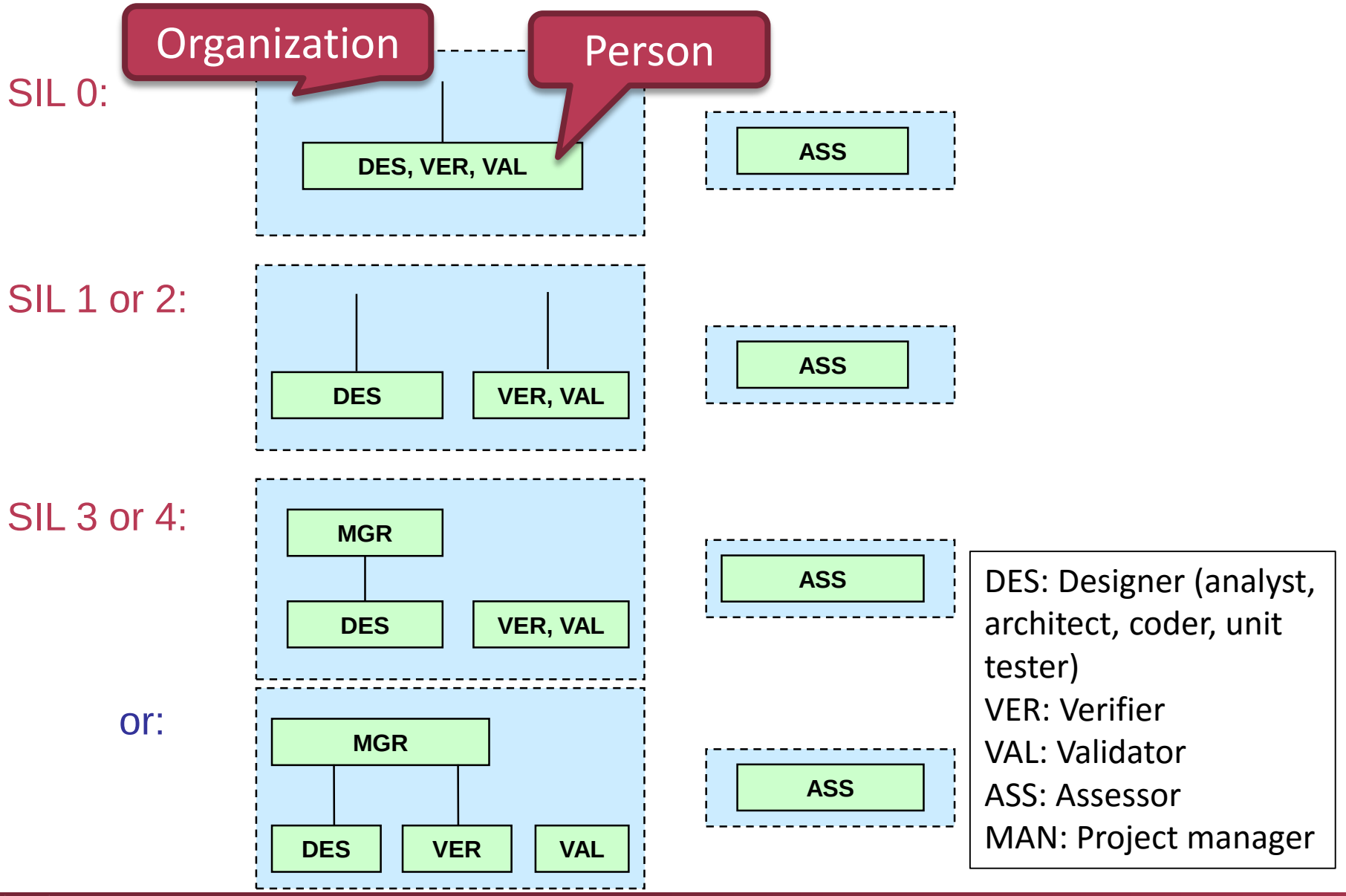
Example: Document structure (EN50128)



30 documents in a systematic structure

- Specification
- Design
- Verification

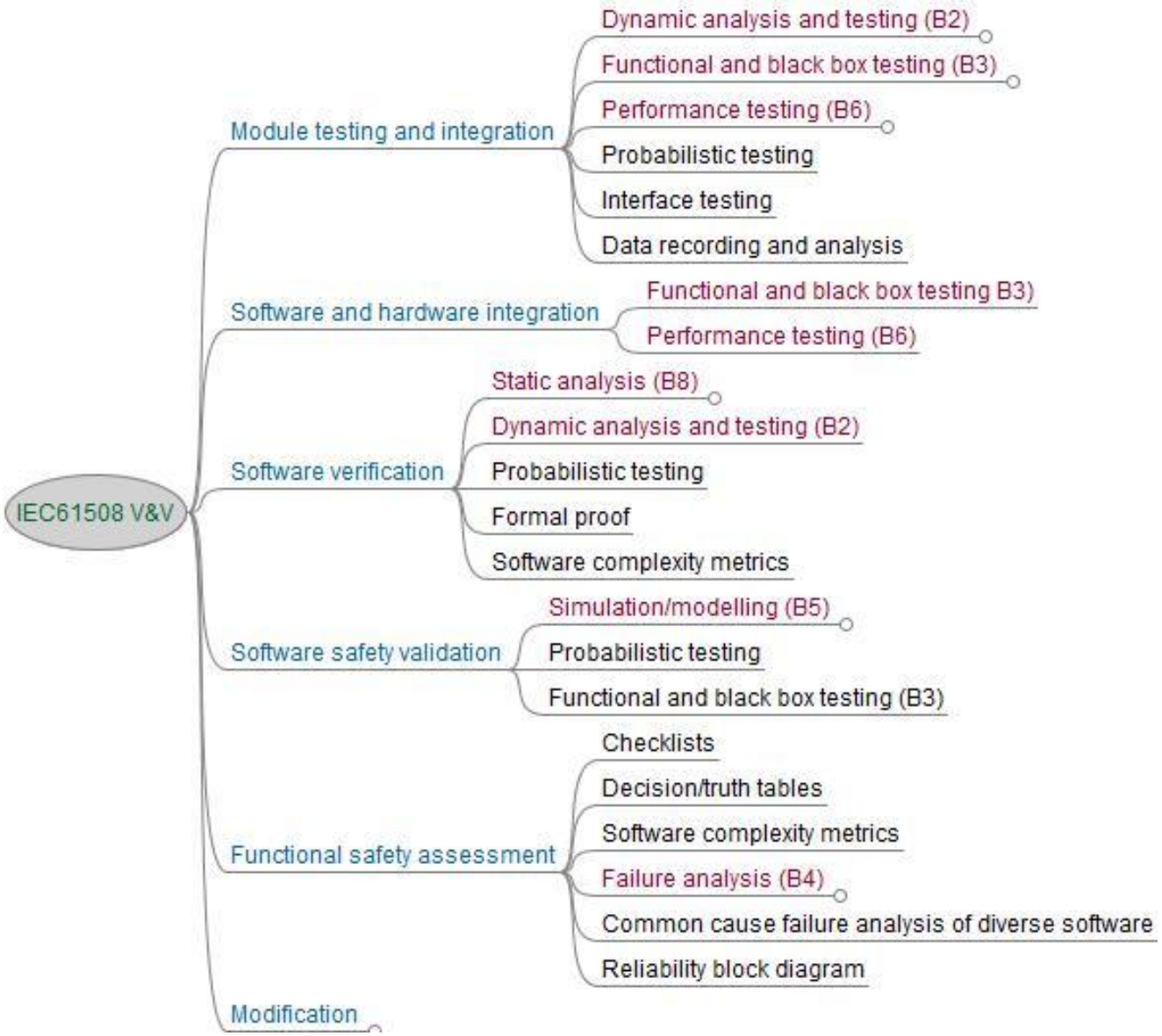
Example: Responsibilities (EN 50128)



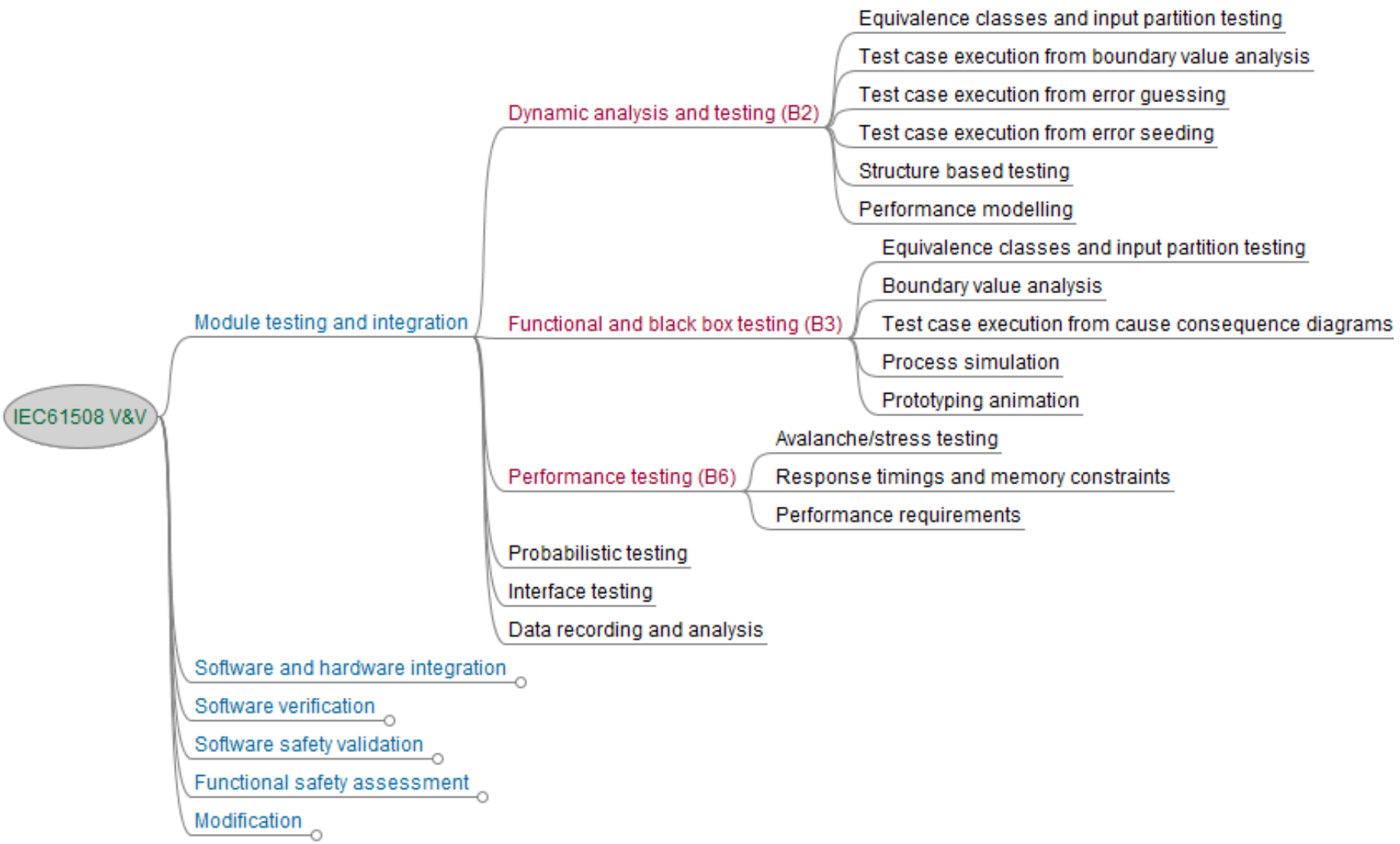
BACKGROUND MATERIAL

(For reference only, recommended to come back at the end of the course to see how many techniques are familiar)

IEC 61508 V&V methods



IEC 61508 V&V methods – Testing



IEC 61508 V&V methods – Static analysis