Safety-critical systems: Basic definitions

Ákos Horváth

Based on István Majzik's slides
Dept. of Measurement and Information Systems

Introduction

- Safety-critical systems
  - Informal definition: Malfunction may cause injury of people
- Safety-critical computer-based systems
  - E/E/PE: Electrical, electronic, programmable electronic systems
  - Control, protection, or monitoring
  - EUC: Equipment under control

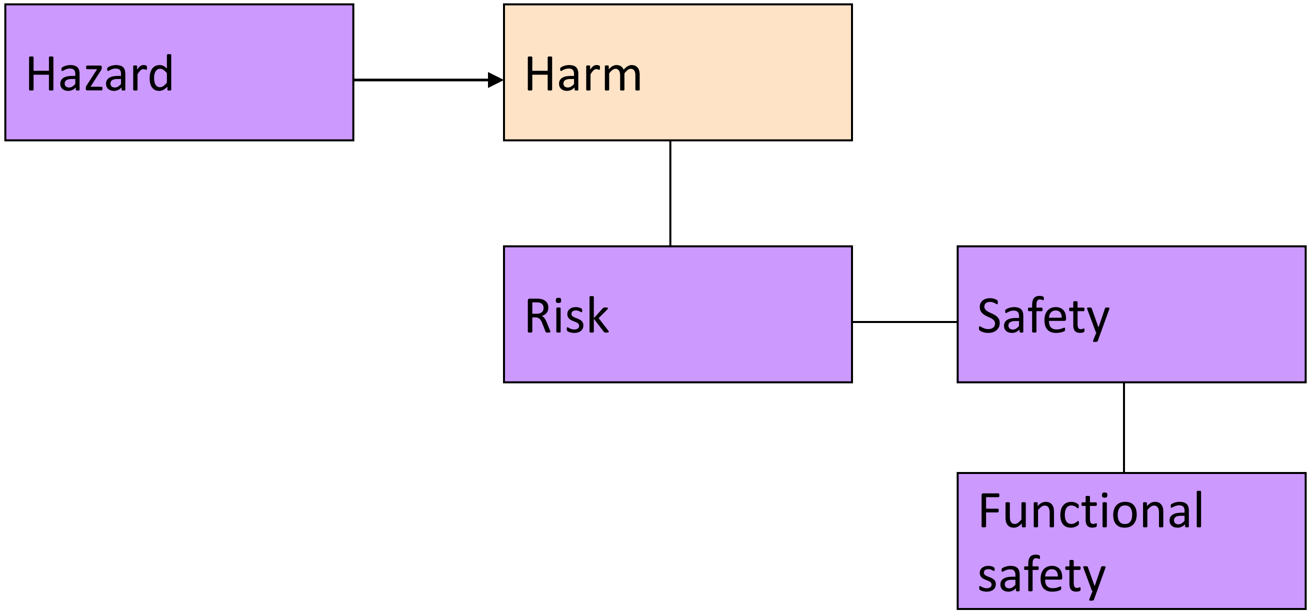
Railway signaling, x-by-wire, interlocking, emergency stopping, engine control, …

Specialities of safety critical systems

- Special solutions to achieve safe operation
  - Design: Requirements, architecture, tools, …
  - Verification, validation, and independent assessment
  - 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 and equipment
  - EN50129: Railway (control systems)
  - EN50128: Railway (software)
  - ISO26262: Automotive
  - Other sector-specific standards: Medical, process control, etc.

Definition of safety

- Central concepts: Hazard, risk and safety



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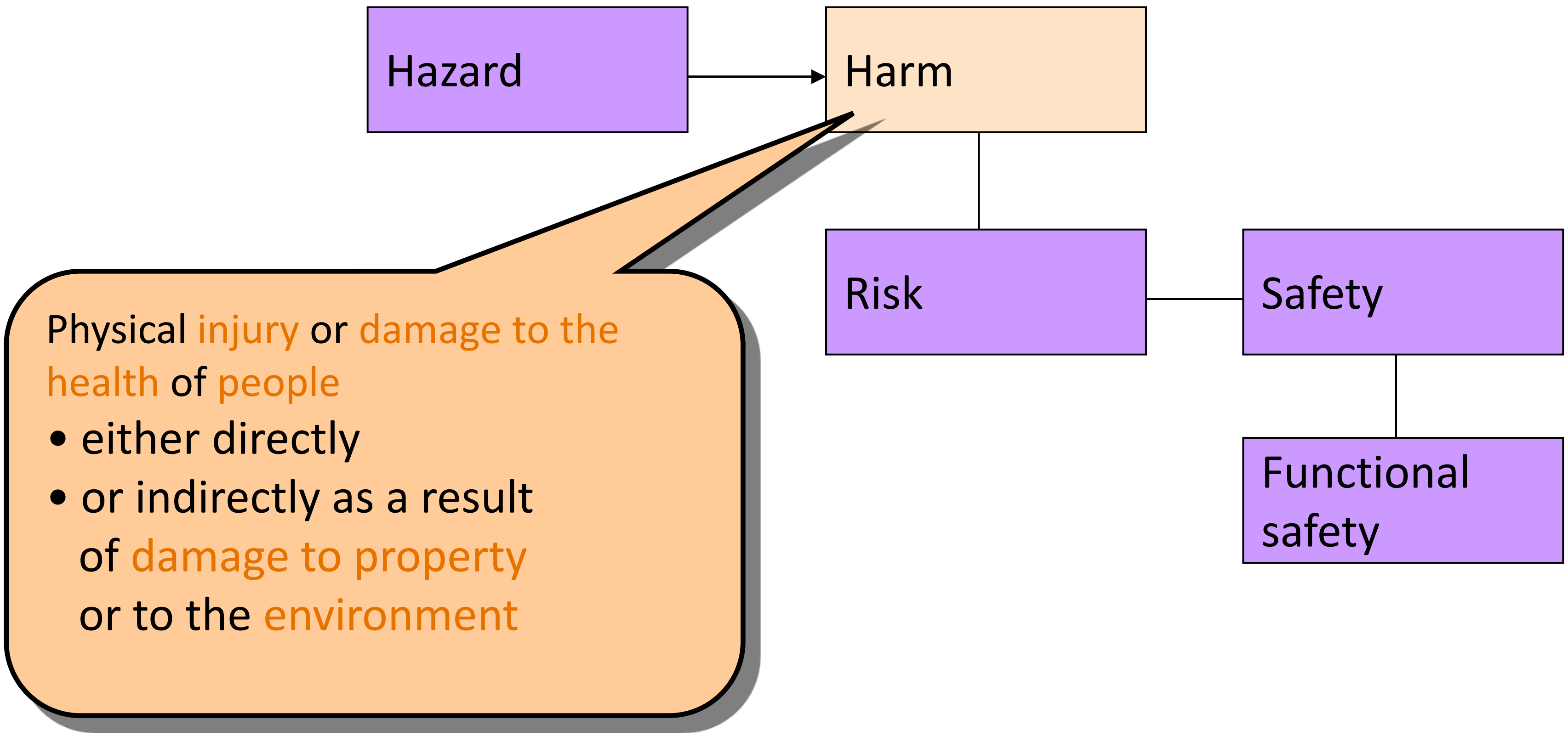

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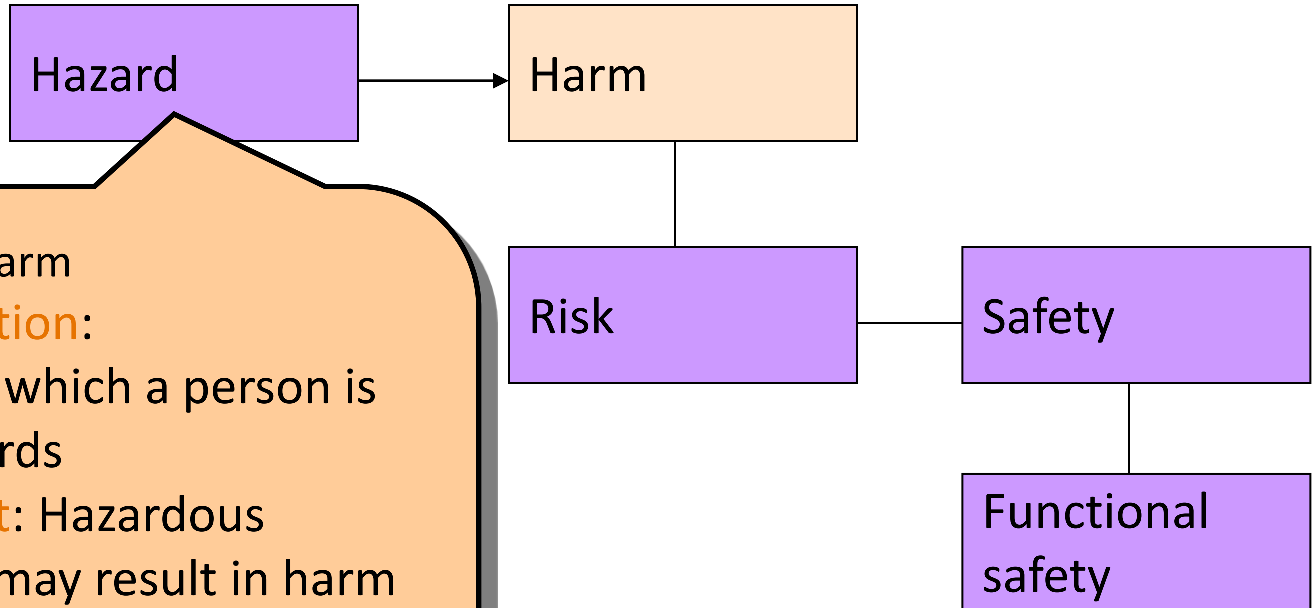

Potential cause of harm

- Hazardous situation: Circumstance in which a person is exposed to hazards
- Hazardous event: Hazardous situation which may result in harm
- Accident: Unintended event that results in harm
- Incident (near miss): Event that has the potential of harm

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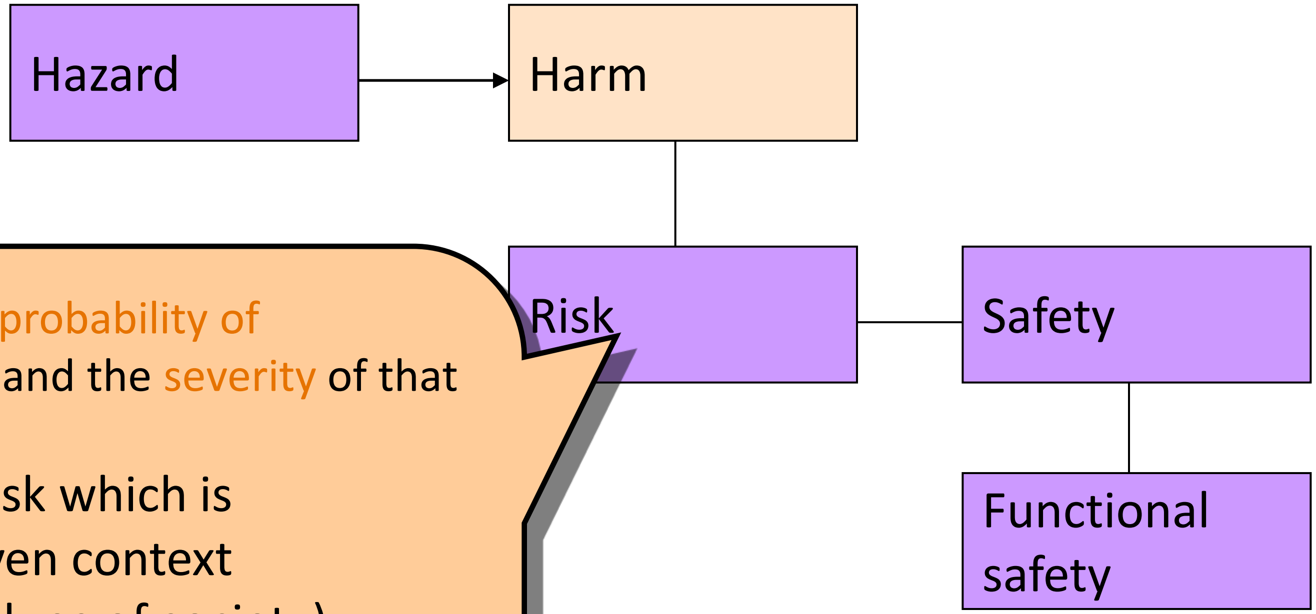

Combination of the probability of occurrence of harm and the severity of that harm

- Tolerable risk: Risk which is accepted in a given context (based on the values of society)
- Residual risk: Risk remaining after protective measures have been taken

Definition of safety

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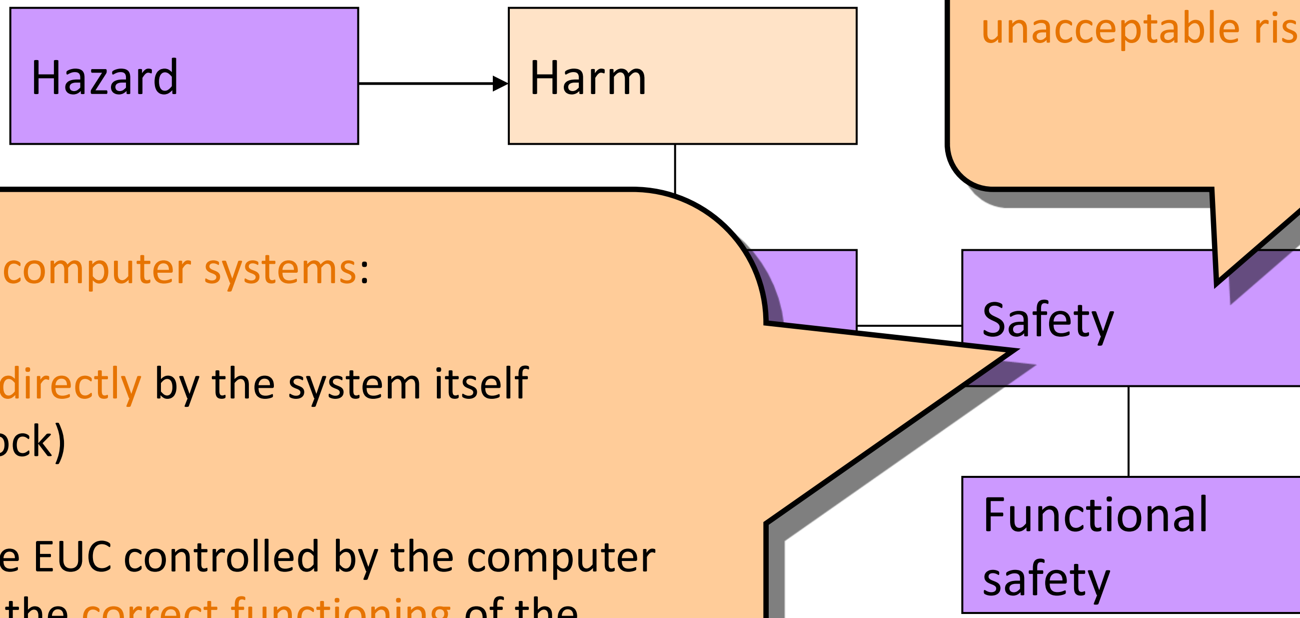


Freedom from unacceptable risk

Forms of safety in computer systems:

Primary safety:

- Dangers caused directly by the system itself (e.g., electric shock)

Functional safety:

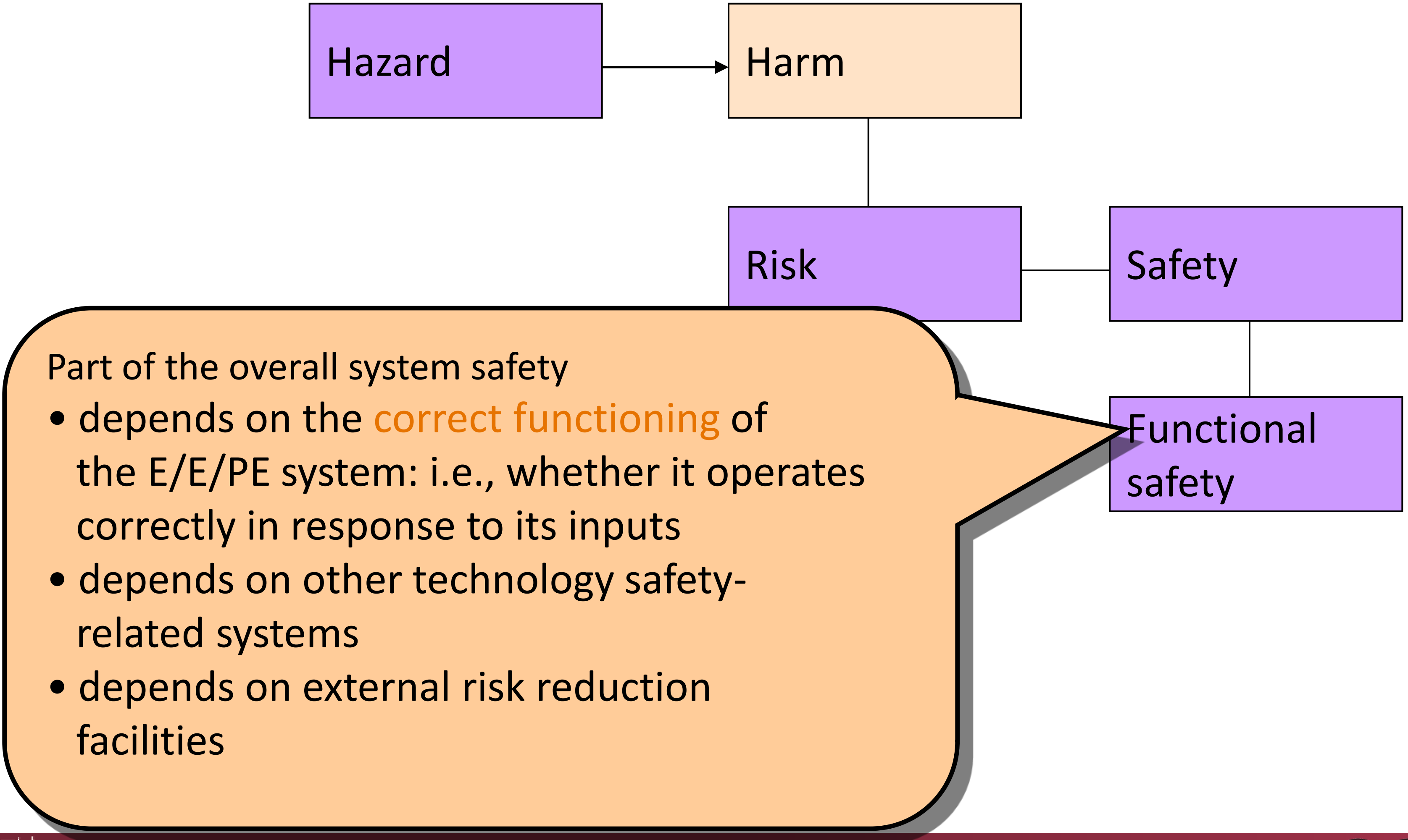
- This concerns the EUC controlled by the computer and is related to the correct functioning of the computer and software.

Indirect safety:

- This relates to the indirect consequences of a computer failure or the production of incorrect information.

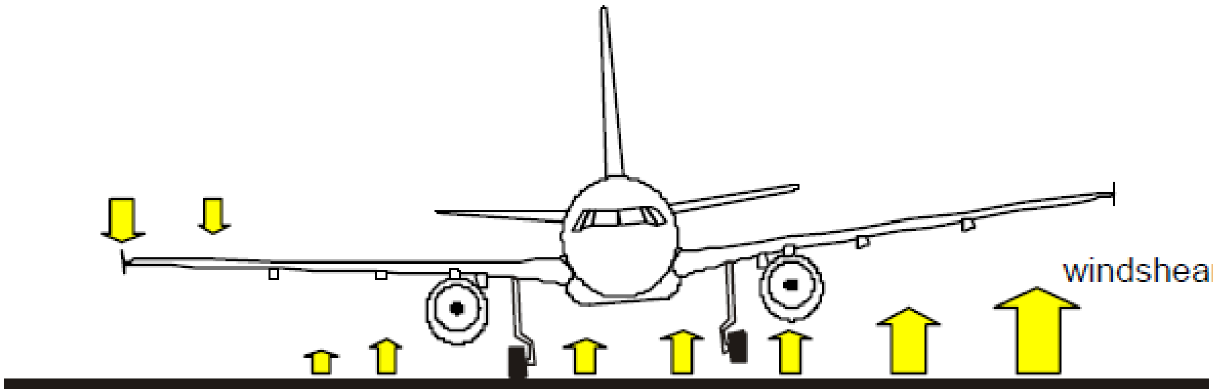
Definition of safety

- Central concepts: Hazard, risk and safety



Accident examples

- A320-211 Accident in Warsaw (14 September 1993)
  - Windshear
  - Left gear touched the ground 9 sec later than the right
  - Intelligent braking is controlled by shock absorber + wheel rotation -> delayed braking -> hitting the embankment
- Is the control system ”too intelligent”?
- Correct functioning but not safe behaviour!

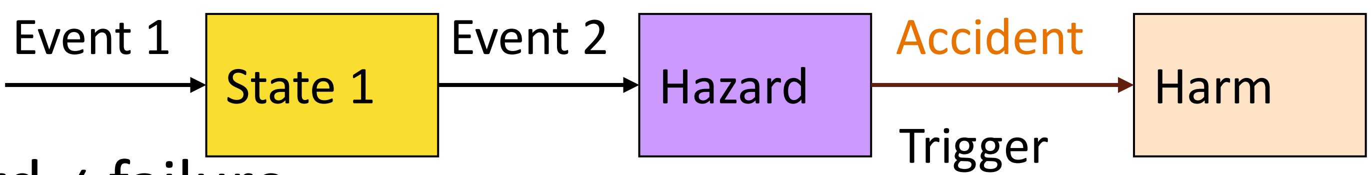


Accident examples

- Toyota car accident in San Diego, August 2009
- Hazard: Stuck accelerator (full power)
  - Floor mat problem
- Hazard control: What about…
  - Braking?
  - Shutting off the engine?
  - Putting the vehicle into neutral? (gearbox: D, P, N)

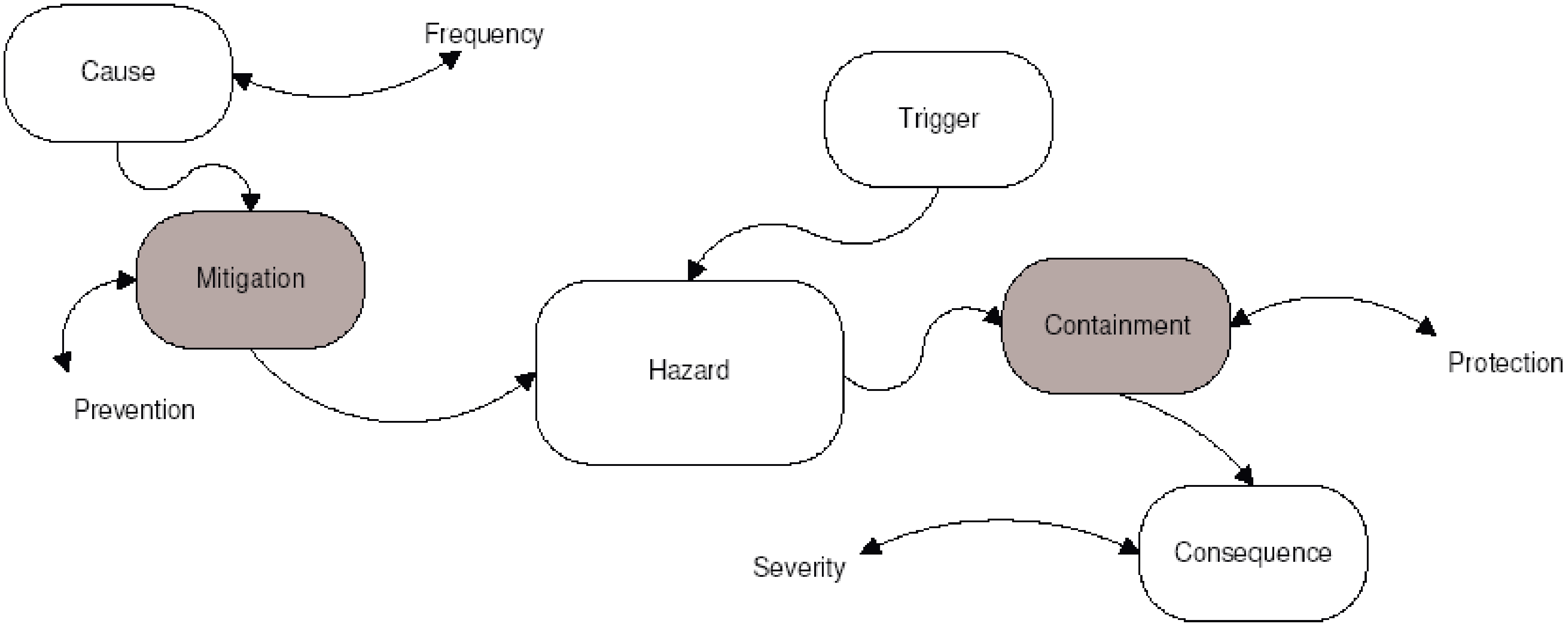
Experiences

- Harm is typically a result of a complex scenario
  - (Temporal) combination of failure(s) and/or normal event(s)
  - Hazards may not result in accidents



- Hazard ≠ failure
  - Undetected (and unhandled) error is a typical cause of hazards
  - Hazard may also be caused by (unexpected) combination of normal events
- Central problems in safety-critical systems:
  - Analysis of hazards
  - Assignment of functions to avoid hazards → accidents → harms

Hazard control



- Risk characteristics:
  - Frequency of occurrence
  - Severity of its consequence
- Mitigation: Eliminate or decrease the chance of a hazard
- Containment: Reduce the consequence of a hazard

Safety-related system

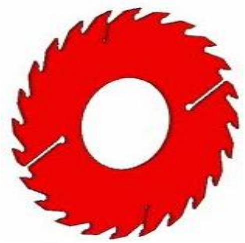
- Safety function:
  - Function which is intended to achieve or maintain a safe state for the EUC
- Safety-related system:
  - Implements the required safety functions necessary to achieve or maintain a safe state for the EUC,
  - and is intended to achieve the necessary safety integrity for the required safety functions
- Requirements for a safety-related system:
  - What is the safety function: Safety function requirements
  - What is the likelihood of the correct operation of the safety function: Safety integrity requirements

Safety integrity

- Safety integrity:
  - Probability of a safety-related system satisfactorily performing the required safety functions (i.e., without failure)
    - under all stated conditions
    - within a stated period of time
- Types of safety integrity:
  - Random (hardware): Related to random hardware failures
    - Occur at a random time due to degradation mechanisms
  - Systematic: Related to systematic failures
    - Failures related in a deterministic way to faults that can only be eliminated by modification of the design / manufacturing process / operation procedure / documentation / other relevant factors
- Safety integrity level (SIL):
  - Discrete level for specifying safety integrity requirements of the safety functions (i.e., probabilities of failures)

Example: Safety function

- Machine with a rotating blade
  - Blade is protected by a hinged solid cover
- Cleaning of the blade: Lifting of the cover is needed
- Hazard analysis: Avoiding injury of the operator when cleaning the blade
  - If the cover is lifted more than 5 mm then the motor should be stopped
  - The motor should be stopped in less than 1 sec
- Safety function: Interlocking
  - When the cover is lifted to 4 mm, the motor is stopped and braked in 0,8 s
- Safety integrity:
  - The probability of failure of the interlocking (safety function) shall be less than 10^{-4} (one failure in 10.000 operation)
  - Failure of interlocking is not necessarily result in an injury since the operator may be careful



Safety and dependability

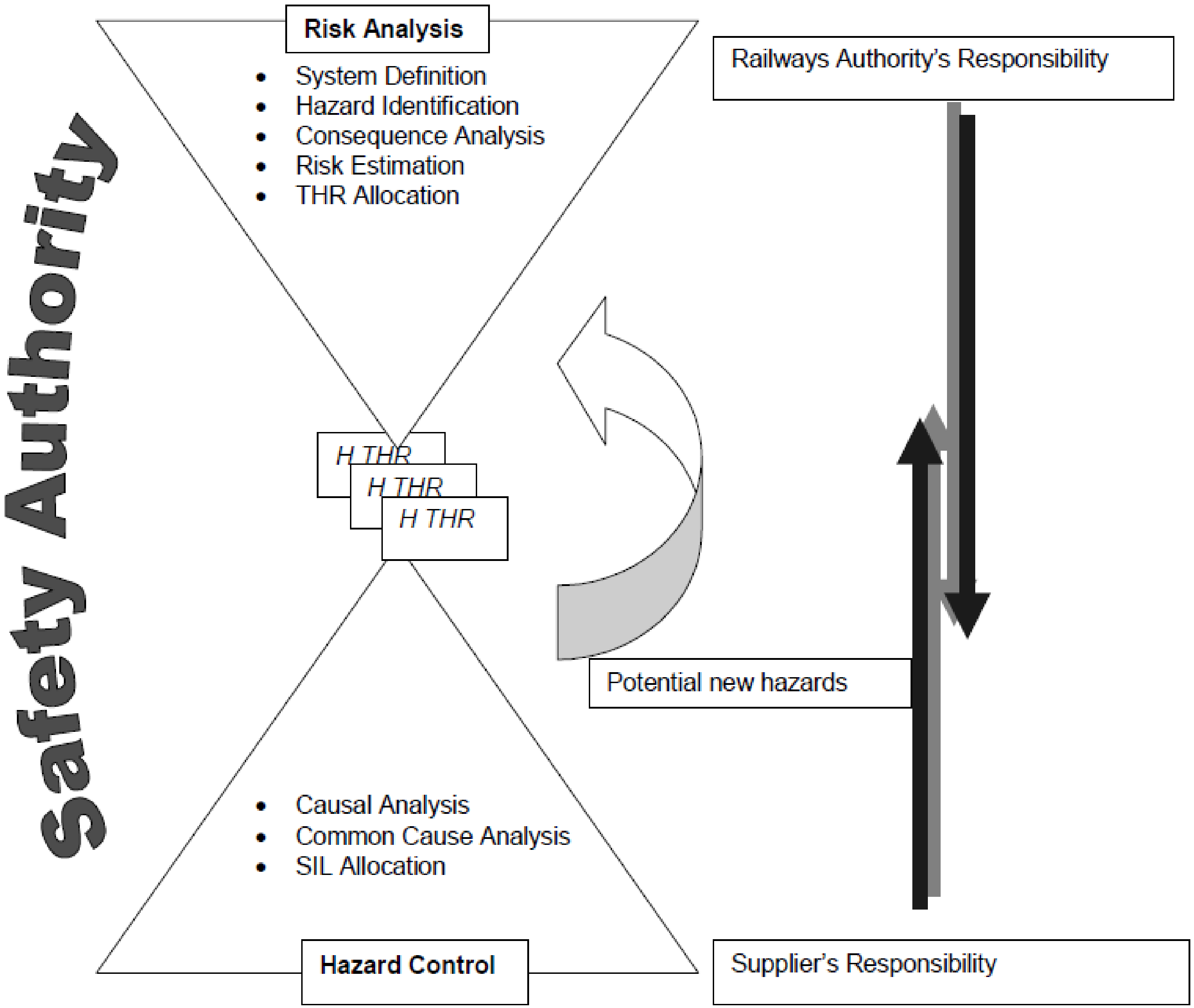
- Safety vs. reliability:
  - Fail-safe state: safe, but 0 reliability
    - Railway signaling, red state: Safety $\neq$ reliability
    - Airplane control: Safety = reliability
- Safety vs. availability:
  - Fail-stop state: safe, but 0 availability (and reliability)
  - High availability may result in (short) unsafe states

Safety requirements

- Requirements for a safety-related system:
  - Safety function requirements:
    - Derived from hazard identification
  - Safety integrity requirements:
    - Related to target failure measure of the safety function
    - Derived from risk estimation: Acceptable risk
- Safety standards: Risk based approach for determining target failure measure
  - Tolerable risk: Risk which is accepted in a given context based on the current values of society
  - It is the result of risk analysis
    - Performed typically by the customer
    - Considering the environment, scenarios, mode of operation, …

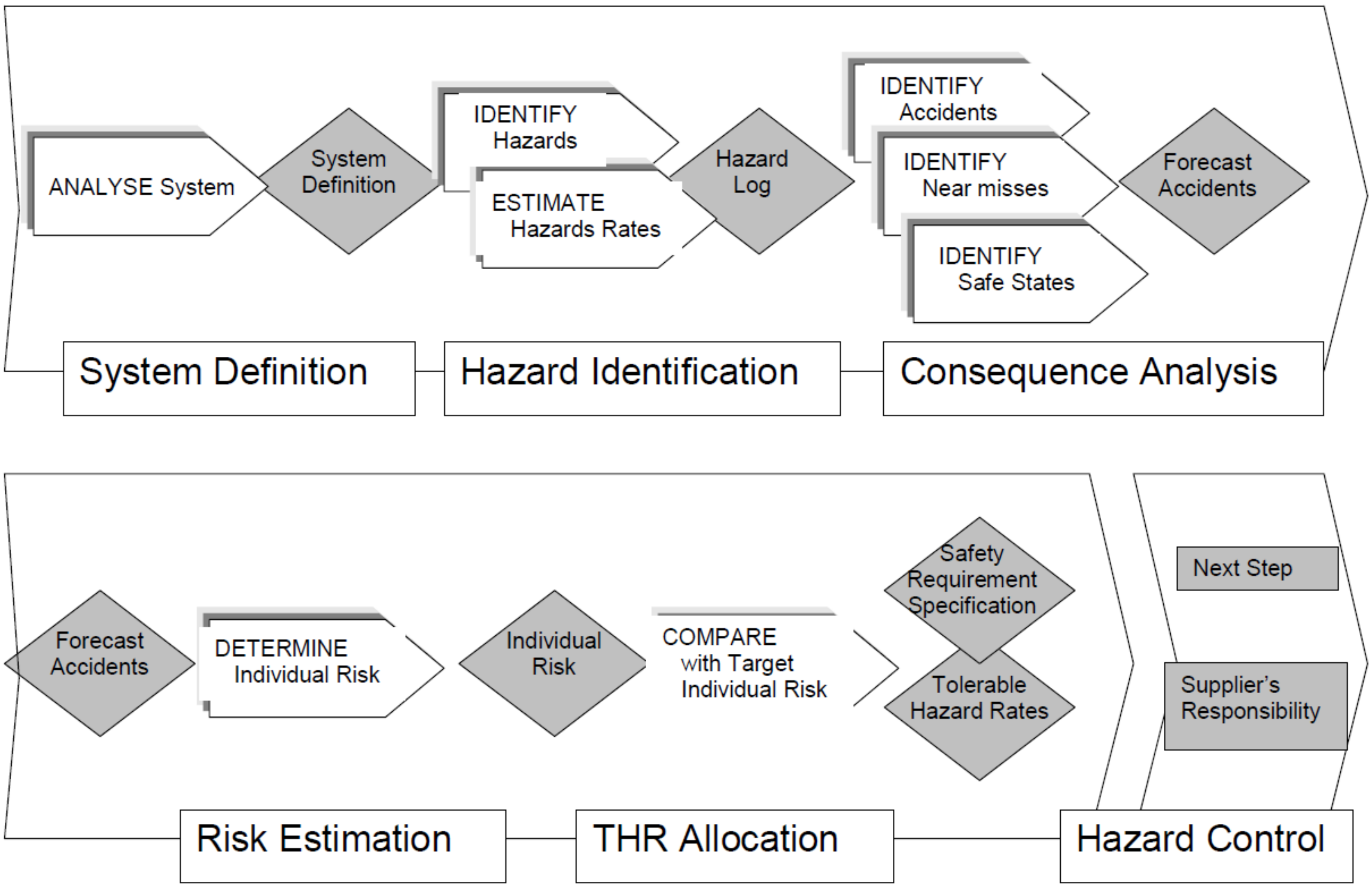
Risk based approach

- EN50129: Railway applications
- THR: Tolerable hazard rate (continuous operation)



Risk analysis

- EN50129 (railway applications)



Mode of operation

- Way in which a safety-related system is to be used:
  - Low demand mode: Frequency of demands for operation is
    - no greater than one per year and
    - no greater than twice the proof-test frequency
  - High demand (or continuous) mode: Frequency of demands for operation is
    - greater than one per year or
    - greater than twice the proof-test frequency
- Target failure measure:
  - Low demand mode: Average probability of failure to perform the desired function on demand
  - High demand mode: Probability of a dangerous failure per hour
    - Acceptable risk -> Tolerable hazard rate (THR)

Safety integrity requirements

- Low demand mode:

SIL	Average probability of failure to perform the function on demand
1	$10^{-2} \leq PFD < 10^{-1}$
2	$10^{-3} \leq PFD < 10^{-2}$
3	$10^{-4} \leq PFD < 10^{-3}$
4	$10^{-5} \leq PFD < 10^{-4}$

- High demand mode:

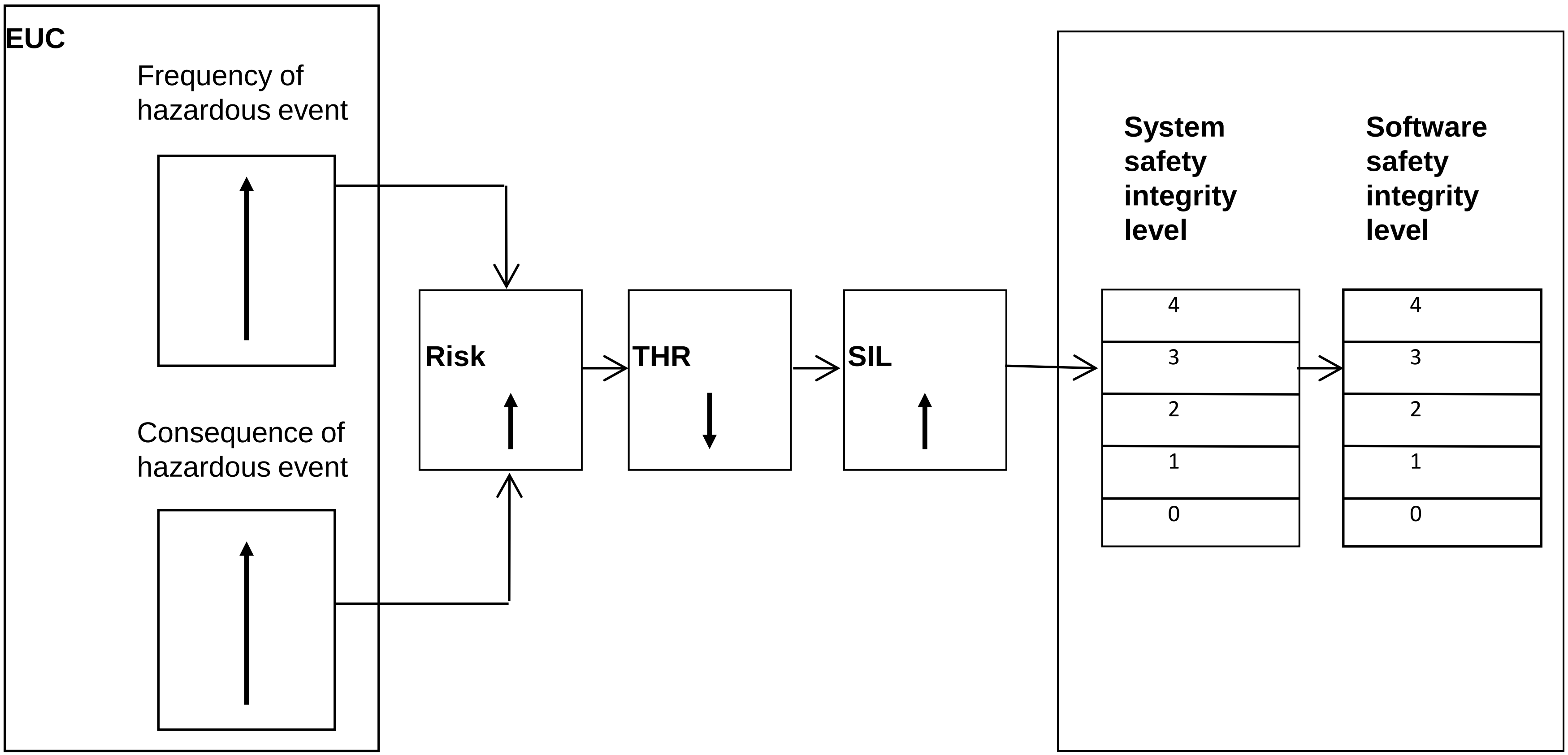
SIL	Probability of dangerous failure per hour per safety function
1	$10^{-6} \leq PFH < 10^{-5}$
2	$10^{-7} \leq PFH < 10^{-6}$
3	$10^{-8} \leq PFH < 10^{-7}$
4	$10^{-9} \leq PFH < 10^{-8}$

15 years lifetime:
1 failure in case of
750 equipment

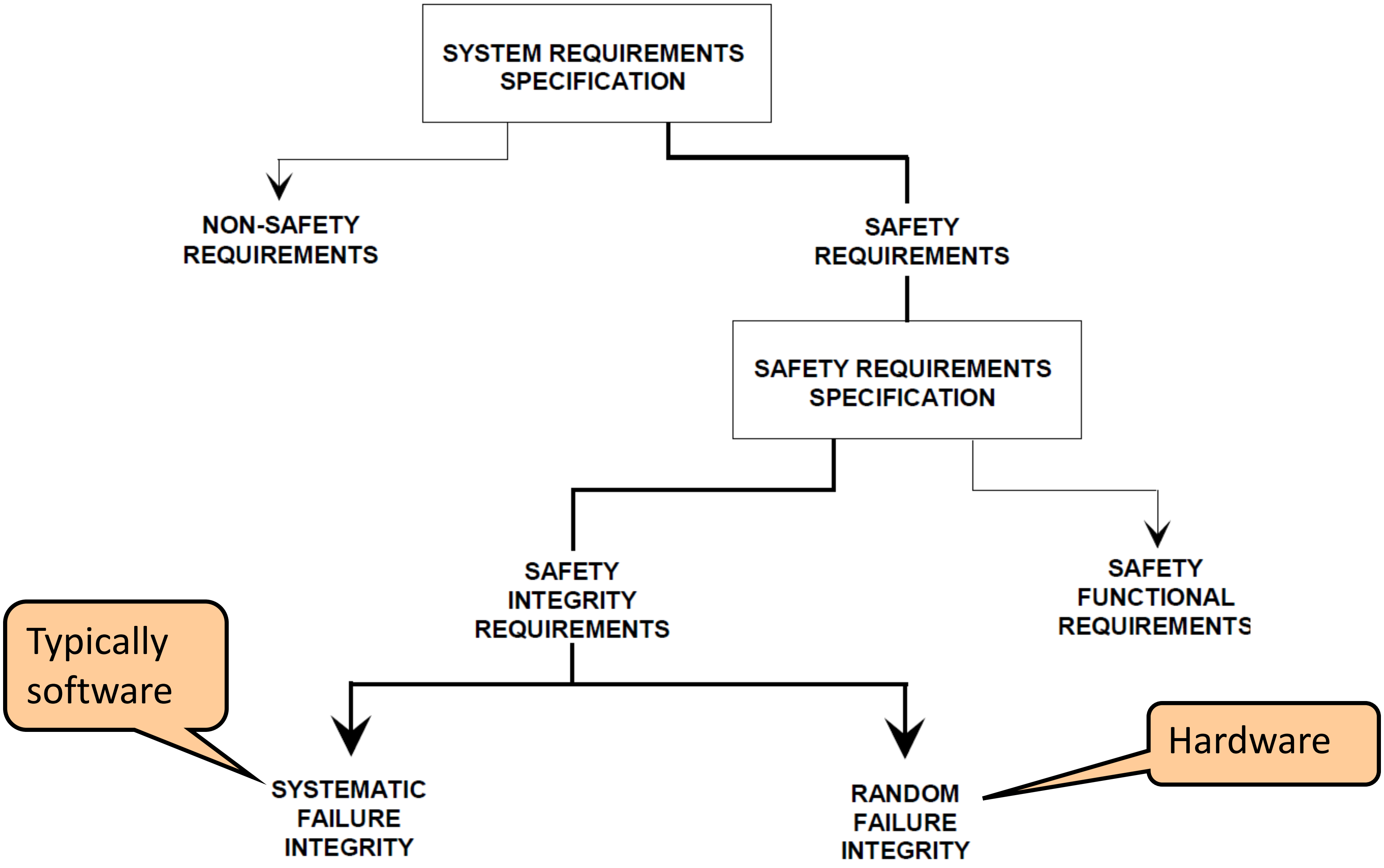
(PFH or THR)

Determining SIL: Overview

- Hazard identification and risk analysis -> Target failure measure



Structure of requirements



Challenges in achieving functional safety

- E/E/PE systems: Complexity
  - Impossible to determine every failure mode
  - Difficult to predict safety performance
- Preventing/controlling dangerous failures resulting from
  - Incorrect specification (system, HW, SW)
  - Omissions in safety requirement specification
  - Hardware failure mechanisms: Random or systematic
  - Software failure mechanisms: Systematic
  - Common cause failures
  - Human (operator) errors
  - Environmental influences (e.g., temperature, EM, mechanical)
  - Supply system disturbances (e.g., power supply)
  - …

Demonstrating SIL requirements

- Approaches:
  - Random failure integrity:
    - Quantitative approach: Based on statistics, experiments
  - Systematic failure integrity:
    - Qualitative approach: Rigor in the engineering
      - Development life cycle
      - Techniques and measures
      - Documentation
      - Independence of persons
- Safety case:
  - Documented demonstration that the product complies with the specified safety requirements
  - Systematic demonstration

Summary of the basic concepts

System safety

- emphasizes building in safety, not adding it to a completed design
- deals with systems as a whole rather than with subsystems or components
- takes a larger view of hazards than just failures
- emphasizes analysis rather than past experience and standards
- emphasizes qualitative rather than quantitative approaches

Dependability related requirements

(Safety is not enough)

Characterizing the system services

- Typical characteristics of services:
  - Reliability, availability, integrity, ...
  - These depend on the failures during the use of the services (the good quality of the production process is not enough)
- Composite characteristic: Dependability
  - Definition: Ability to provide service in which reliance can justifiably be placed
    - Justifiably: based on analysis, evaluation, measurements
    - Reliance: the service satisfies the needs
  - Basic question: How to avoid or handle the faults affecting the services?

Fault effects

Development process → **Product in operation**

- Design faults
- Implementation faults

- Hardware faults
- Configuration faults
- Operator faults

Fault effects

Development process → **Product in operation**

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Development process:

- Better quality management, better methodology
- But: Increasing complexity, difficulty in verification

Typical estimations for 1000 lines of code:

- Good development "by hand" : <10 faults
- Tool-supported development: ~1-2 faults
- Application of formal methods: <1 faults

Fault effects

Development process → **Product in operation**

- Design faults
- Implementation faults

- Hardware faults
- Configuration faults
- Operator faults

Limits of the technology:
- Better quality control, better materials
- But: increasing sensitivity to environment effects

Typical estimations:
- CPU: 10^{-5}…10^{-6} faults/hour
- RAM: 10^{-4}…10^{-5} faults/hour
- LCD: ~ 2…3 years lifetime

Fault effects

Development process → **Product in operation**

- Design faults
- Implementation faults

- Hardware faults
- Configuration faults
- Operator faults

Verification during the development

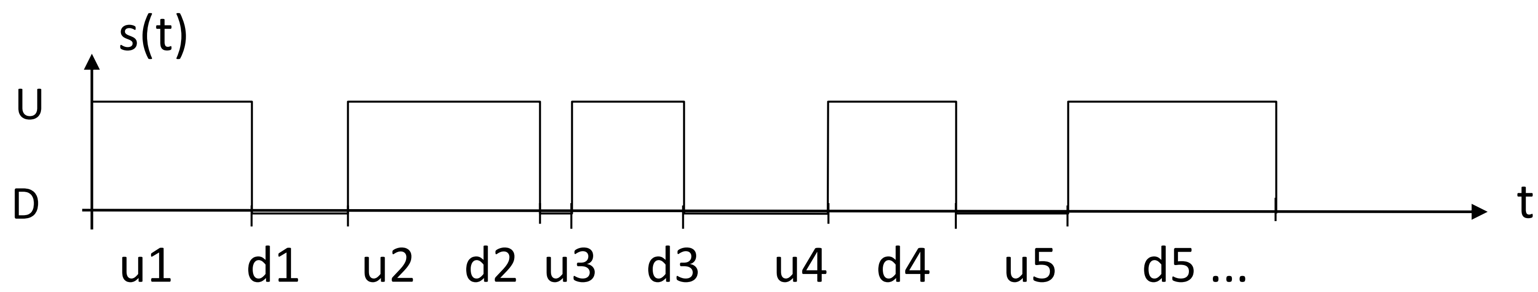
Fault tolerance during operation

Dependability and security

- Basic attributes of dependability:
  - Availability: Probability of correct service (considering repairs and maintenance)
  - Reliability: Probability of continuous correct service (until the first failure)
  - Safety: Freedom from unacceptable risk of harm
  - Integrity: Avoidance of erroneous changes or alterations
  - Maintainability: Possibility of repairs and improvements
- (Attributes of security:)
  - Availability
  - Integrity
  - Confidentiality: absence of unauthorized disclosure of information

Dependability metrics: Mean values

- Partitioning the state of the system: s(t)
  - Correct (U, up) and incorrect (D, down) state partitions



- Mean values:
  - Mean Time to First Failure: MTFF = E{u1}
  - Mean Up Time: MUT = MTTF = E{ui}
    (Mean Time To Failure)
  - Mean Down Time: MDT = MTTR = E{di}
    (Mean Time To Repair)
  - Mean Time Between Failures: MTBF = MUT + MDT

Dependability metrics: Probability functions

- **Availability**:

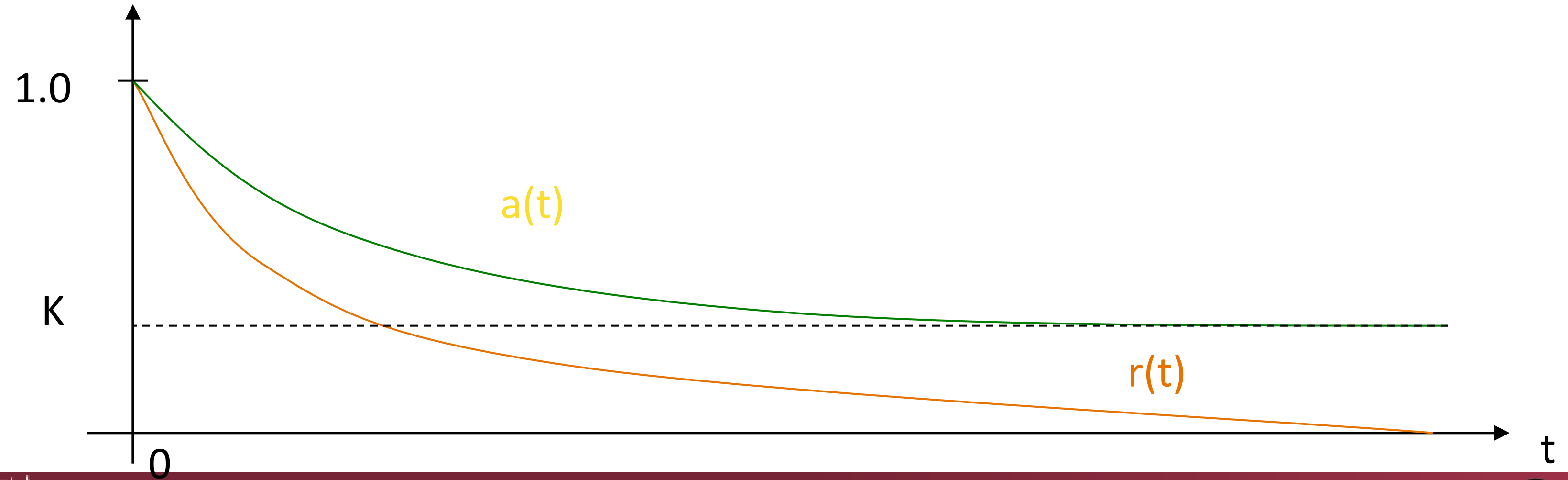
  $$a(t) = P\{s(t) \in U\}$$ (failures may occur)

- **Reliability**:

  $$r(t) = P\{s(t') \in U, \forall t' < t\}$$ (no failure until t)

- **Asymptotic availability**: $K = \lim_{t \to \infty} a(t)$ (regular repairs)

  In other way: $K = A = \mathrm{MTTF}/(\mathrm{MTTF} + \mathrm{MTTR})$



Availability related requirements

Availability	Failure period per year
99%	~ 3,5 days
99,9%	~ 9 hours
99,99% („4 nines”)	~ 1 hour
99,999% („5 nines”)	~ 5 minutes
99,9999% („6 nines”)	~ 32 sec
99,99999%	~ 3 sec

Availability of a system built up from components, where the availability of a component is 95%:

- Availability of a system built from 2 components: 90%
- Availability of a system built from 5 components : 77%
- Availability of a system built from 10 components : 60%

Attributes of components

- Fault rate: $\lambda(t)$
  - Probability density that the component will fail at time point t given that it has been correct until t

$$\lambda(t)\Delta t = P\{s(t+\Delta t)\in D \mid s(t)\in U\} \text{ while } \Delta t \to 0$$

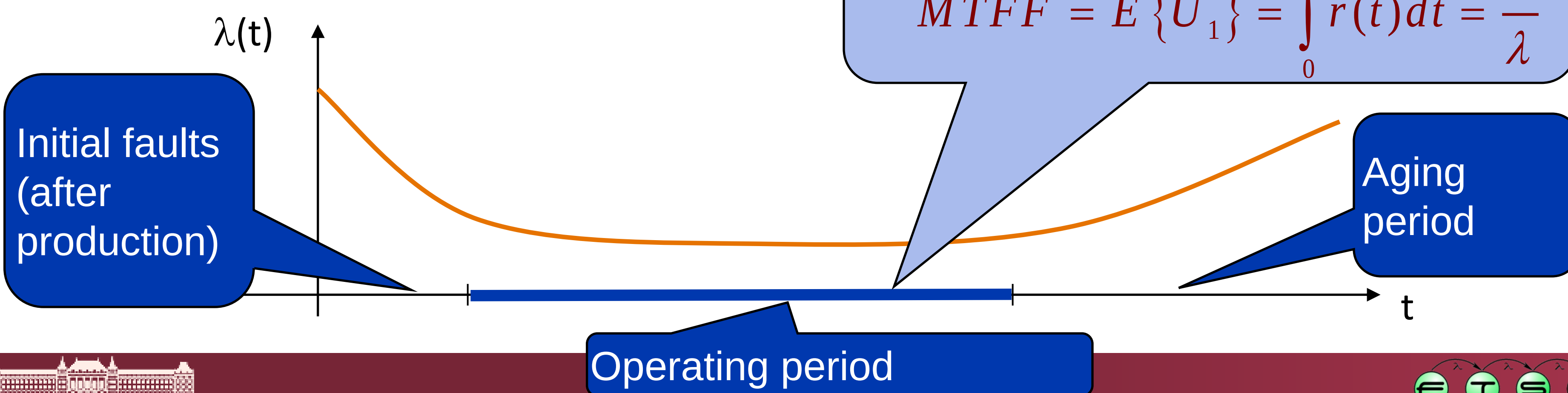
  - In other way (on the basis of the definition of reliability):

$$\lambda(t) = -\frac{1}{r(t)}\frac{dr(t)}{dt}, \quad \text{thus} \quad r(t) = e^{-\int_0^t \lambda(t)dt}$$

  - For electronic components:

$$\text{Here } r(t) = e^{-\lambda t}$$

$$MTFF = E\{U_1\} = \int_0^\infty r(t)dt = \frac{1}{\lambda}$$



Case study: development of a DMI

Driver

DMI

EVC

EVC:
European
Vital
Computer
(on board)

Maintenance centre

Characteristic:

- Safety-critical functions
  - Information visualization
  - Processing driver commands
  - Data transfer to EVC
- Safe wireless communication
  - System configuration
  - Diagnostics
  - Software update

Case study: DMI requirements

- Safety:
  - Safety Integrity Level: SIL 2
  - Tolerable Hazard Rate: 10^{-7} <= THR < 10^{-6} hazardous failures per hours
  - CENELEC standards: EN 50129 and EN 50128
- Reliability:
  - Mean Time To Failure: MTTF > 5000 hours
    (5000 hours: ~ 7 months)
- Availability:
  - A = MTTF / (MTTF+MTTR), A > 0.9952
    Faulty state: shall be less than 42 hours per year
    MTTR < 24 hours if MTTF=5000 hours

Threats to dependability

Fault: adjudged or hypothesized cause of an error → **Component or system**

Error: State leading to the failure → **Failure**: the delivered service deviates from correct service

Fault → Error → Failure examples:

Fault		Error		Failure
Bit flip in the memory due to a cosmic particle	→	Reading the faulty memory cell will result in incorrect value	→	The robot arm collides with the wall
The programmer increases a variable instead of decreasing	→	The faulty statement is executed and the value of the variable will be incorrect	→	The final result of the computation will be incorrect

The characteristics of faults

- Fault
  - Space
    - Internal
      - Physical (hardware)
      - Design (typ. software)
    - External
      - Physical (environment)
      - Data (input)
  - Time
    - Intermittent (transient)
    - Permanent

Software fault:

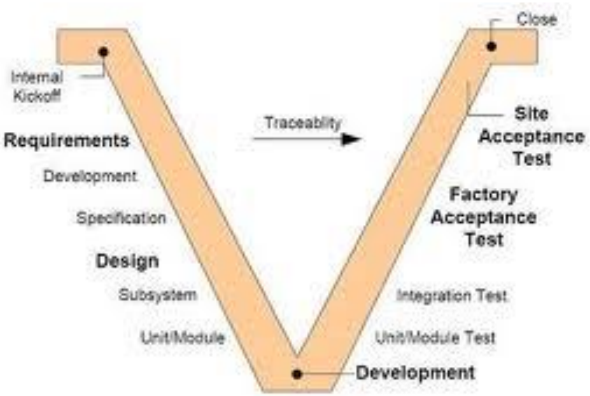
- Permanent design fault (systematic)
- Activation of the fault depends on the operational profile (inputs)

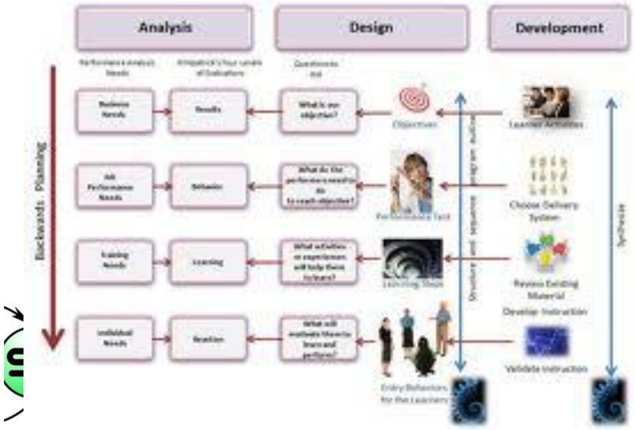
Means to improve dependability

- Fault prevention:
  - Physical faults: Good components, shielding, ...
  - Design faults: Good design methodology
- Fault removal:
  - Design phase: Verification and corrections
  - Prototype phase: Testing, diagnostics, repair
- Fault tolerance: avoiding service failures
  - Operational phase: Fault handling, reconfiguration
- Fault forecasting: estimating faults and their effects
  - Measurements and prediction

    E.g., Self-Monitoring, Analysis and Reporting Technology (SMART)

Overview of the development of safety-critical systems



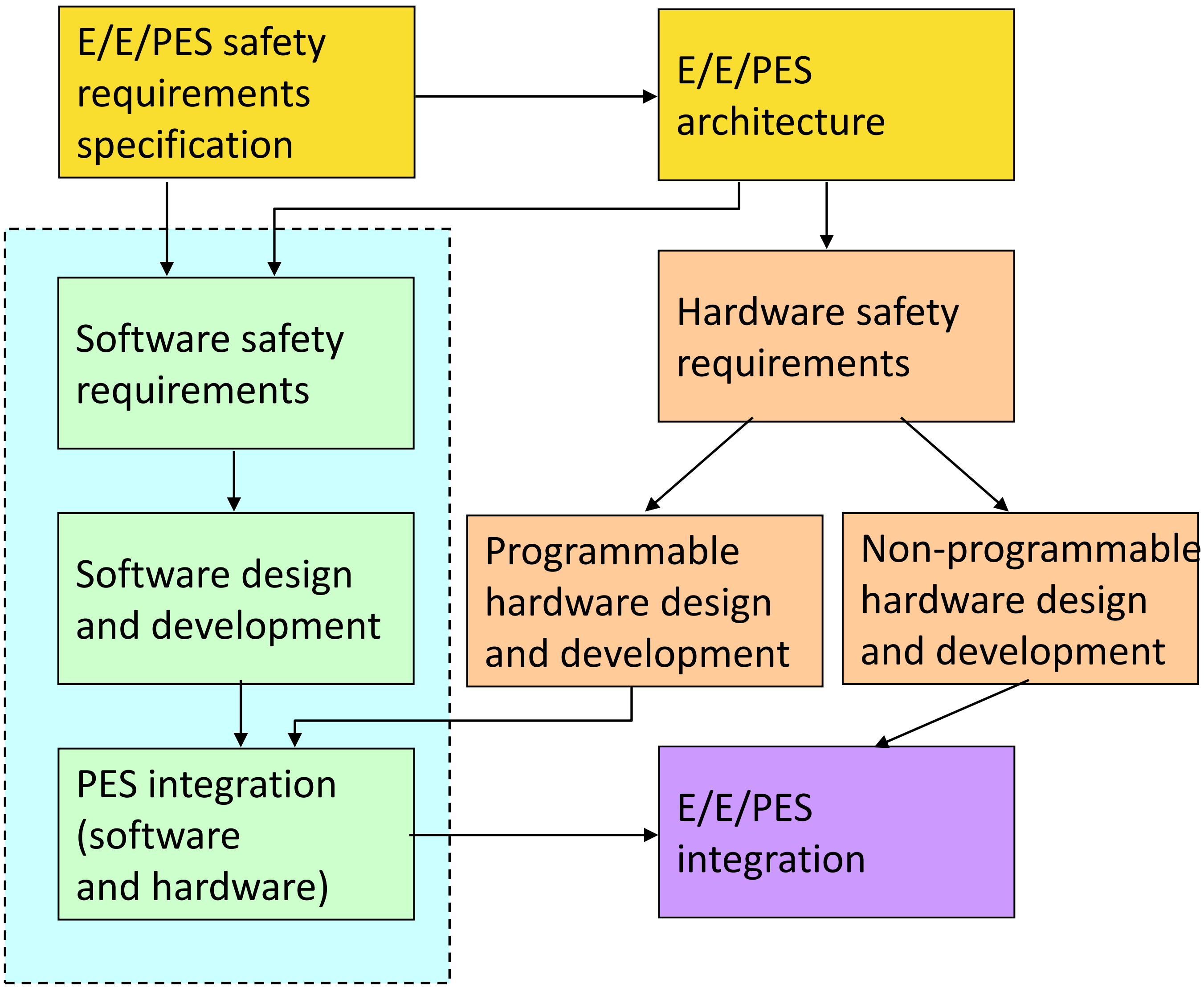


Overall safety lifecycle model: Goals

- Technical framework for the activities necessary for ensuring functional safety
- Covers all lifecycle activities
  - Initial concept
  - Hazard analysis and risk assessment
  - Specification, design, implementation
  - Operation and maintenance
  - Modification
  - Final decommissioning and/or disposal

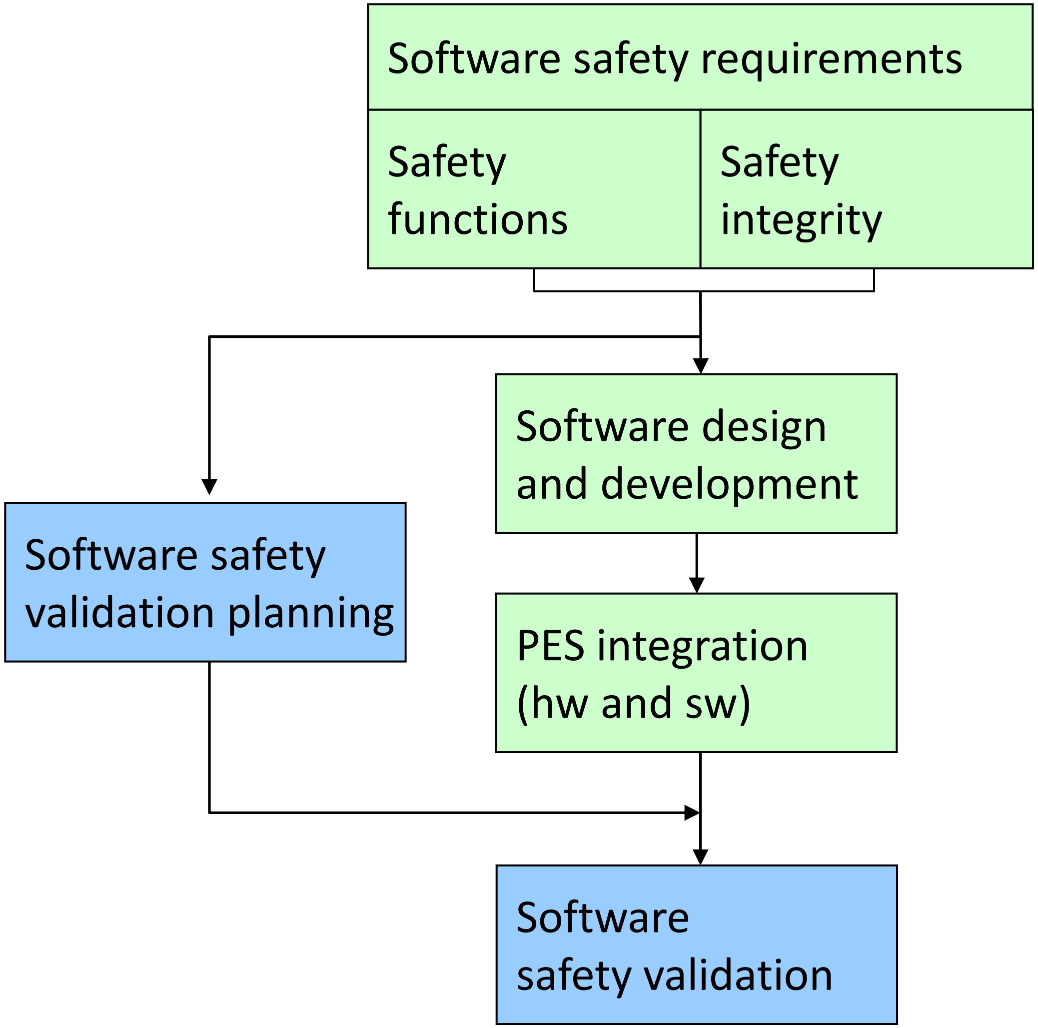
Hardware and software development

- PE system architecture (partitioning of functions) determines software requirements
- PES integration follows software development
- Final step: E/E/PES integration

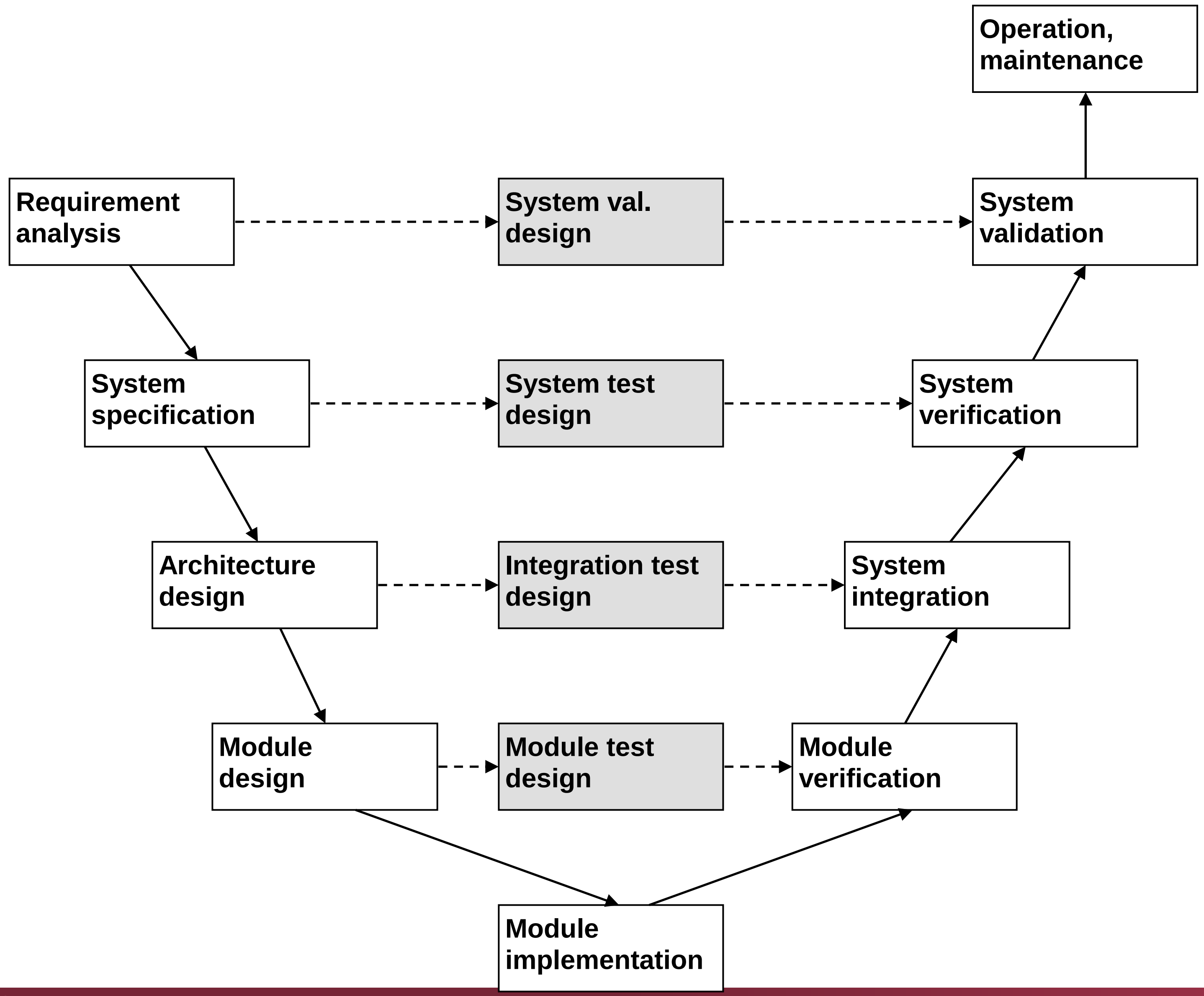


Software safety lifecycle

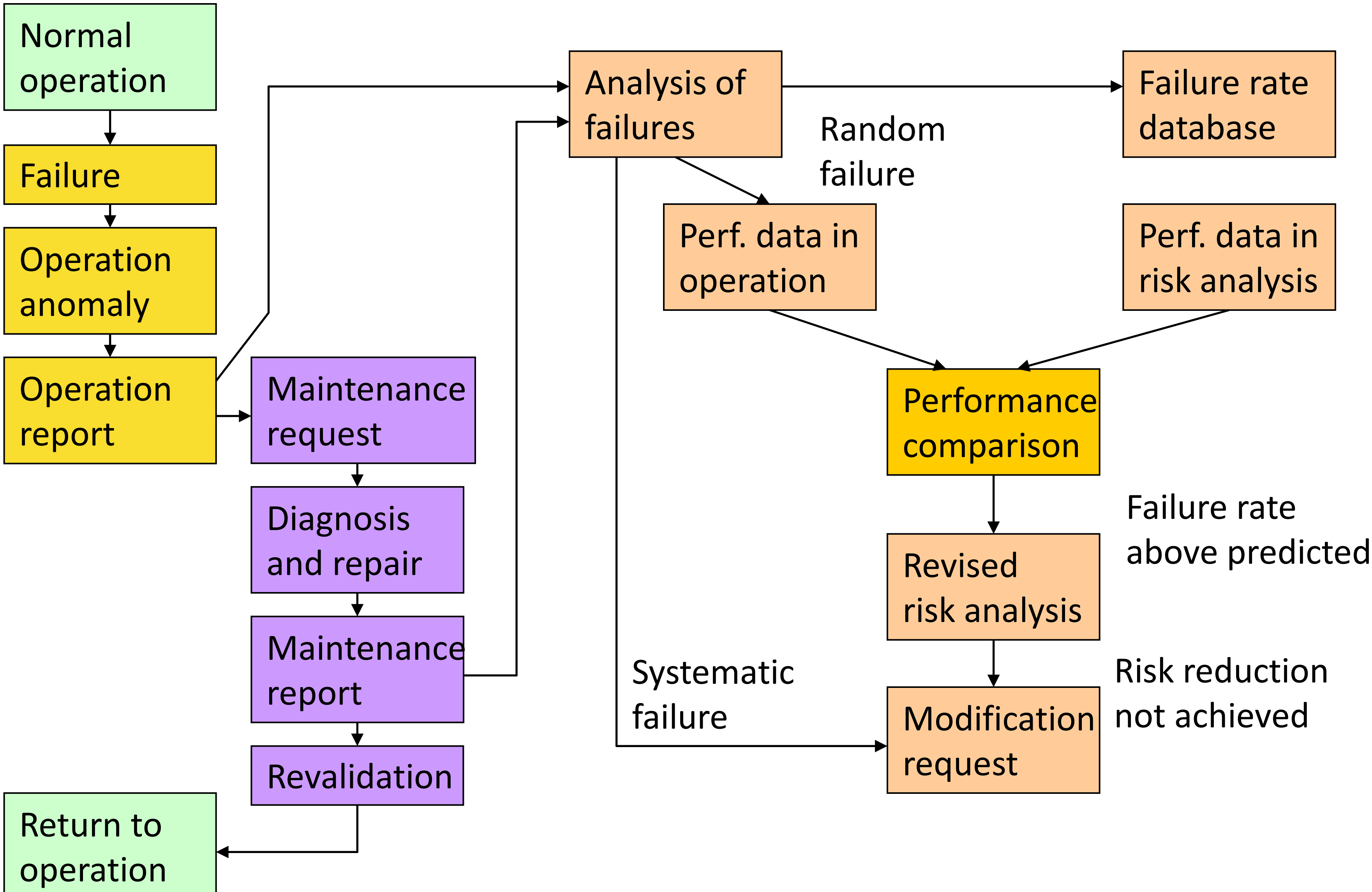
- Safety req. spec. has two parts:
  - Software safety functions
  - Software safety integrity levels
- Validation planning is required
- Integration with PE hardware is required
- Final step: Software safety validation



Example software lifecycle (V-model)



Maintenance activities



Techniques and measures: Basic approach

- Goal: Preventing the introduction of systematic faults and controlling the residual faults
- SIL determines the set of techniques to be applied as
  - 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
- Combinations of techniques are allowed
  - E.g., alternate or equivalent techniques are marked
- Hierarchy of methods is formed (references to tables)

Example: Guide to selection of techniques

- Software safety requirements specification:
  - Techniques 2a and 2b are alternatives

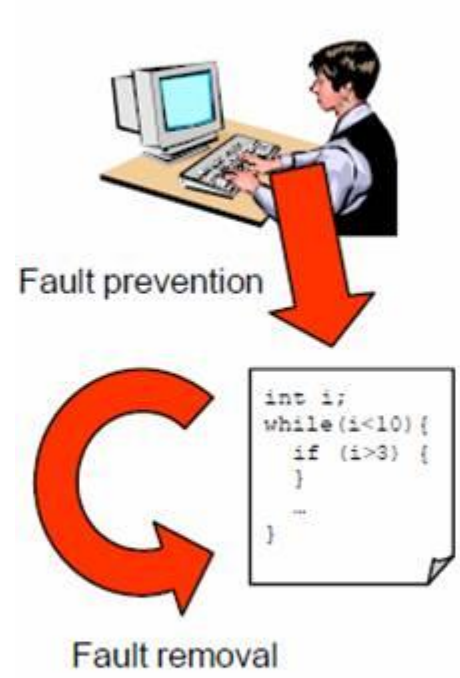
	Technique/Measure*	Ref.	SIL1	SIL2	SIL3	SIL4
1	Computer-aided specification tools	B.2.4	R	R	HR	HR
2a	Semi-formal methods	Table B.7	R	R	HR	HR
2b	Formal methods including for example, CCS, CSP, HOL, LOTOS, OBJ, temporal logic, VDM and Z	C.2.4	---	R	R	HR

  - Referred table: Semi-formal methods (B.7)

	Technique/Measure*	Ref	SIL1	SIL2	SIL3	SIL4
1	Logic/function block diagrams	see note below	R	R	HR	HR
2	Sequence diagrams	see note below	R	R	HR	HR
3	Data flow diagrams	C.2.2	R	R	R	R
4	Finite state machines/state transition diagrams	B.2.3.2	R	R	HR	HR
5	Time Petri nets	B.2.3.3	R	R	HR	HR
6	Decision/truth tables	C.6.1	R	R	HR	HR

Application of tools in the lifecycle

- Fault prevention:
  - Program translation from high-level programming languages
  - MBD, CASE tools: High level modeling and code/configuration generators
- Fault removal:
  - Analysis, testing and diagnosis
  - Correction (code modification)



Management tools
- Contributing both to fault prevention and removal
- Includes project management, configuration management, issue tracking

Safety concerns of tools

- Types of tools
  - Tools potentially introducing faults
    - Modeling and programming tools
    - Program translation tools
  - Tools potentially failing to detect faults
    - Analysis and testing tools
    - Project management tools
- Requirements
  - Use certified or widely adopted tools
    - "Increased confidence from use" (no evidence of improper results yet)
  - Use the well-tested parts without altering the usage
  - Check the output of tools (analysis/diversity)
  - Control access and versions

Safety of programming languages

- Factors for selection of languages
  - Functional characteristics (probability of faults)
    - Logical soundness (unambiguous definition)
    - Complexity of definition (understandability)
    - Expressive power
    - Verifiability (consistency with specification)
    - Vulnerability (security aspects)
  - Availability and quality of tools
  - Expertise available in the design team
- Coding standards (subsets of languages) are defined
  - “Dangerous” constructs are excluded (e.g., function pointers)
  - Static checking can be used to verify the subset
- Specific (certified) compilers are available
  - Compiler verification kit for third-party compilers

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Safety of programming languages

- Factors
  - Fun
    - L
    - C
    - E
    - V
    - V
  - Avai
  - Expe
- Coding
  - "Dangerous ... are excluded (e.g., function pointers)
  - Static checking can be used to verify the subset
- Specific (certified) compilers are available
  - Compiler verification kit for third-party compilers

Constructs that make verification difficult (61508):

- Unconditional jumps excluding subroutine calls
- Recursion
- Pointers, heaps or any type of dynamic variables
- Interrupt handling at source code level
- Multiple entries and exits of loops and subprograms
- Implicit variable initialization or declaration
- Variant records and equivalence
- Procedural parameters

Language comparison

	Structured assembler	C	CORAL 66	ISO Pascal	Modula-2	Ada
Wild jumps	*	?	?	?	?	*
Overwrites	?	X	X	?	?	?
Semantics	?	X	?	?	*	?
Model of math	?	X	?	*	*	?
Operational arithmetic	?	X	X	?	?	?
Data typing	?	X	?	?	?	*
Exception handling	X	?	X	X	?	*
Safe subset?	?	X	X	X	?	X
Exhaustion of memory	*	?	?	?	?	X
Separate compilation	X	X	?	?	*	*
Well understood?	*	?	?	*	*	?

X – not provided (may lead to unsafe behaviour)
? – some protection, but risk remains
* - sound protection is provided

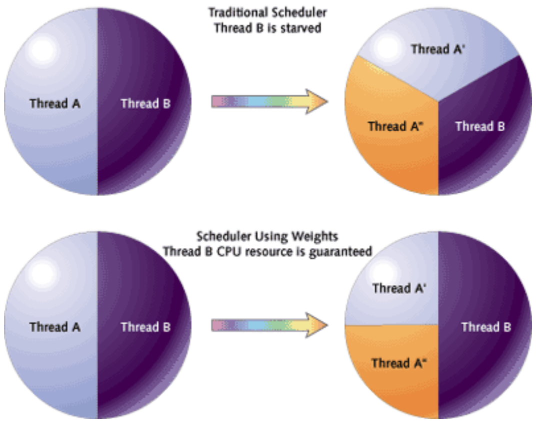
[Cullyer+1991]

Wild jumps: Jump to arbitrary address in memory
Overwrites: Overwriting arbitrary address in memory
Model of math: Well-defined data types
Separate compilation: Type checking across modules

Coding standards for C and C++

- MISRA C (Motor Industry Software Reliability Association)
  - Safe subset of C (2004): 141 rules (121 required, 20 advisory)
  - Examples:
    - Rule 33 (Required): The right hand side of a "&&" or "||" operator shall not contain side effects.
    - Rule 49 (Advisory): Tests of a value against zero should be made explicit, unless the operand is effectively Boolean.
    - Rule 59 (R): The statement forming the body of an "if", "else if", "else", "while", "do ... while", or "for" statement shall always be enclosed in braces.
    - Rule 104 (R): Non-constant pointers to functions shall not be used.
  - Tools to check "MISRA conformance" (LDRA, PolySpace, …)
    - Test cases to demonstrate adherence to MISRA rules
- MISRA C++ (2008): 228 rules
- US DoD, JSF C++: 221 rules (incl. metric guidelines)
  - "Joint Strike Fighter Air Vehicle C++ Coding Standard"

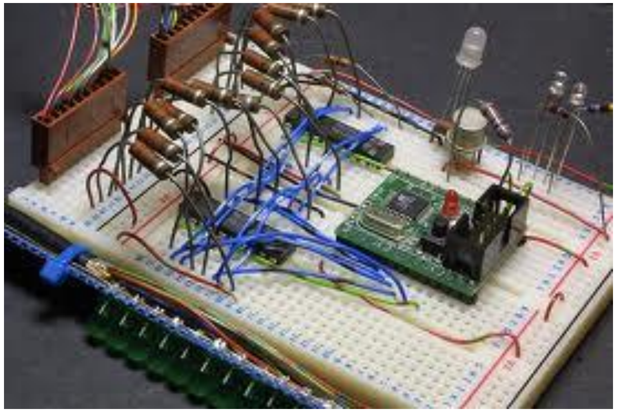
Safety-critical OS: Required properties



- Partitioning in space
  - Memory protection
  - Guaranteed resource availability
- Partitioning in time
  - Deterministic scheduling
  - Guaranteed resource availability in time
- Mandatory access control for critical objects
  - Not (only) discretionary
- Bounded execution time
  - Also for system functions
- Support for fault tolerance and high availability
  - Fault detection and recovery / failover
  - Redundancy control

Example: Safety and RTOS

- Compromise needed
  - Complex RTOS:
    - Difficult to test
  - "Bare machine":
    - Less scheduling risks
    - High maintenance risks



- Example: Tornado® for Safety Critical Systems
  - Integrated software solution uses Wind River's securely partitioned VxWorks® AE653 RTOS
  - ARINC 653: Time and space partitioning (guaranteed isolation)
  - RTCA/DO-178B: Level A certification
  - POSIX, Ada, C support

Principles for documentation

- Type of documentation
  - Comprehensive (overall lifecycle)
    - E.g., Software Verification Plan
  - Specific (for a given lifecycle phase)
    - E.g., Software Source Code Verification Report
- Document Cross Reference Table
  - Determines documentation for a lifecycle phase
  - Determines relations among documents

- Traceability of documents is required
  - Relationships between documents are specified (input, output)
  - Terminology, references, abbreviations are consistent
- Merging documents is allowed
  - If responsible persons (authors) shall not be independent

Document cross reference table (EN50128)

- ■ creation of a document
- ◆ used document in a given phase (read vertically)

clause	8	9	10	11	12	13	14	15	16	
title	SRS	SA	SDD	SVer	S/H I	SVal	Ass	Q	Ma	
PHASES *(*)=in parallel with other phases*										**DOCUMENTS**
SW REQUIREMENTS	■	◆	◆	◆	◆	◆	◆			Sw Requirements Specification
	■			◆	◆	◆	◆			Sw Requirements Test Specification
				■						Sw Requirements Verification Report
SW DESIGN		■	◆	◆	◆	◆	◆			Sw Architecture Specification
			■	◆	◆	◆	◆			Sw Design Specification
				■						Sw Arch. and Design Verification
SW MODULE DESIGN			■	◆	◆	◆	◆			Sw Module Design Specification
			■	◆	◆	◆	◆			Sw Module Test Specification
				■						Sw Module Verification Report
CODE			■	◆	◆	◆	◆			Sw Source Code
				■		◆	◆			Sw Source Code Verification Report
MODULE TESTING			■	◆						Sw Module Test Report
SW INTEGRATION				■						Sw Integration Test Report
										Data Test Report
SW/HW INTEGRATION					■					Sw/Hw Integration Test Report
VALIDATION (*)						■				Sw Validation Report

Example (EN50128)

Software Planning Phase
Software Development Plan
Software Quality Assurance Plan
Software Configuration Management Plan
Software Verification Plan
Software Integration Test Plan
Software/hardware Integration Test Plan
Software Validation Plan
Software Maintenance Plan

System Development Phase
System Requirements Specification
System Safety Requirements Specification
System Architecture Description
System Safety Plan

Software Requirements Spec. Phase
Software Requirements Specification
Software Requirements Test Specification
Software Requirements Verification Report

Software Architecture & Design Phase
Software Architecture Specification
Software Design Specification
Software Architecture and Design Verification Report

Software Module Design Phase
Software Module Design Specification
Software Module Test Specification
Software Module Verification Report

Coding Phase
Software Source Code & Supporting Documentation
Software Source Code Verification Report

Software Module Testing Phase
Software Module Test Report

Software Integration Phase
Software Integration Test Report

Software/hardware Integration Phase
Software/hardware Integration Test Report

Software Validation Phase
Software Validation Report

Software Assessment Phase
Software Assessment Report

Software Maintenance Phase
Software Maintenance Records
Software Change Records

- Document structure in EN50128
- 30 documents in a systematic structure
  - Specification
  - Design
  - Verification

Human factors

- In contrast to computers
  - Humans often fail in:
    - reacting in time
    - following a predefined set of instructions
  - Humans are good in:
    - handling unanticipated problems
- Human errors
  - Not all kind of human errors are equally likely
  - Hazard analysis (FMECA) is possible in a given context
  - Results shall be integrated into system safety analysis
- Reducing the errors of developers
  - Safe languages, tools, environments
  - Training, experience and redundancy (independence)
- Reducing operator errors:
  - Designing ergonomic HMI (patterns are available)
  - Designing to aid the operator rather than take over

Organization

- Safety management
  - Quality assurance
  - Safety Organization
- Competence shall be demonstrated
  - Training, experience and qualifications
- Independence of roles:
  - DES: Designer (analyst, architect, coder, unit tester)
  - VER: Verifier
  - VAL: Validator
  - ASS: Assessor
  - MAN: Project manager
  - QUA: Quality assurance personnel

Independence of personnel

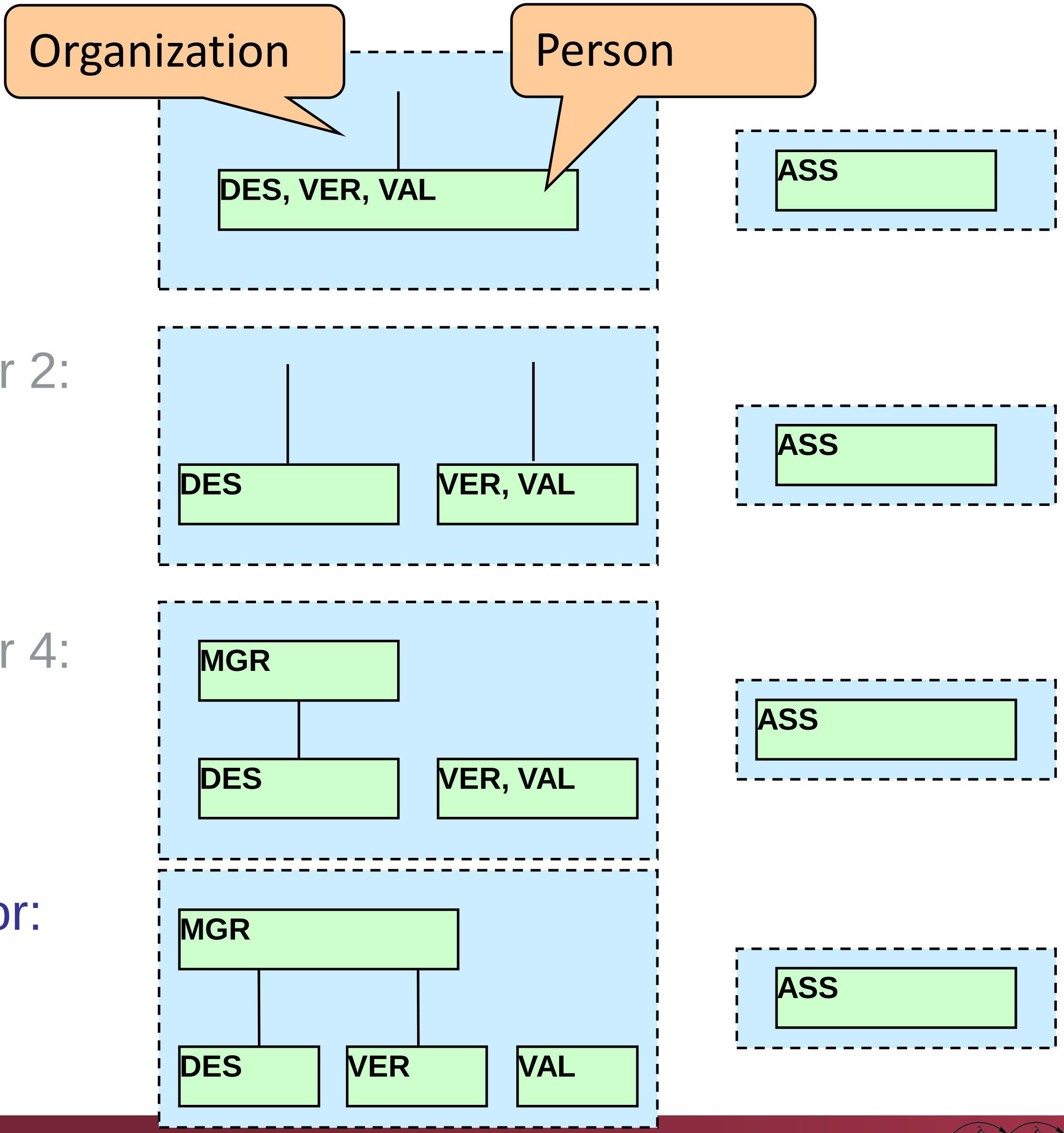
EN 50128:

SIL 0:

SIL 1 or 2:

SIL 3 or 4:

or:



Summary

- Safety-critical systems
  - Hazard, risk
  - THR and Safety Integrity Level
- Dependability
  - Attributes of dependability
  - Fault -> Error -> Failure chain
  - Means to improve dependability
- Development process
  - Lifecycle activities
  - Methods and techniques
  - Documentation
  - Organization