Why standards for functional safety ? –

An introduction to the international standard IEC 61508

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Process of innovation

- 9000 customers
- Wide technical range
- Experimental resources
- Strong research environments
- High scientific quality

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- What is risk?
- What is “functional safety” and “safety function”?
- Is there “high” and “low” safety?
- What is the IEC 61508 standard?
- ISO 26262 for the automotive industry
- Failure rate
- An example of calculation of probability of failure
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- More to read

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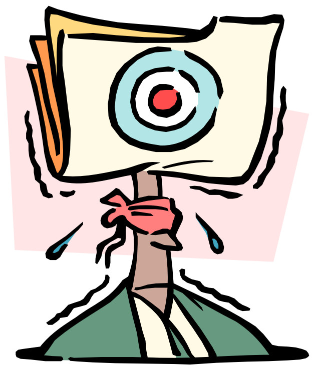
What is risk?



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Elements of risk

Risk	Severity	Probability of occurrence
		- frequency and duration - probability of occurrence of hazardous event - possibility to avoid or limit the harm

Risk is a function of severity and probability.

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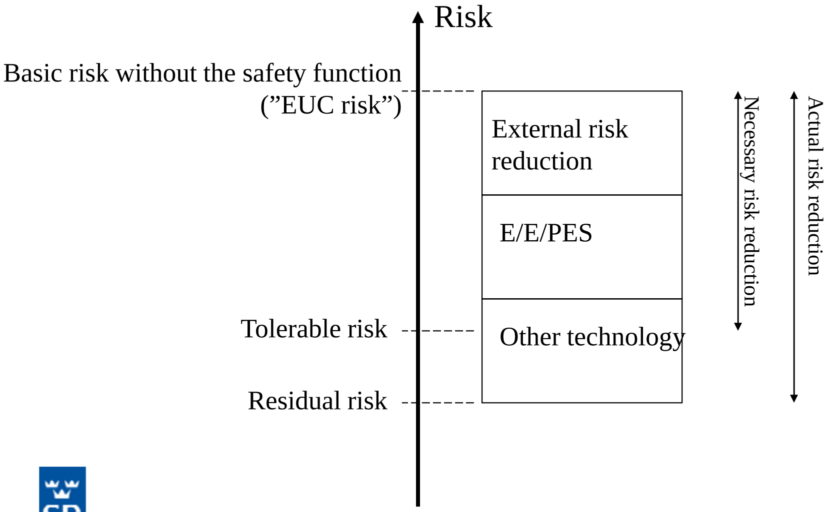
Risk reduction



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Risk reduction

- Risks will be reduced by
  - proper safety functions (correctly implemented)
  - expected system behaviour at fault
  - expected probability for faults
  - suitable development methods
  - suitable safety principles
  - ….

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Failures of the systems

Dangerous failures may arise from:
- incorrect specifications of the system, hardware or software;
- omissions in the safety requirements specification (e.g. failure to develop all relevant safety functions during different modes of operation);
- random failures of hardware;
- systematic failures of hardware and software;
- common cause failures;
- human error;
- environmental influences (e.g. electromagnetic, temperature, mechanical phenomena);
- supply system voltage disturbances (e.g. loss of supply, reduced voltages, re-connection of supply).


www.autoliv.se

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Example: Hydraulically operated guillotine

- ’hold-to-run’
- light curtain
- amputating his hand
- recently reconditioned
- replacing a hydraulic valve
- connections of ’up’ and ’down’ solenoids transposed
- HSE ’Out of Control’

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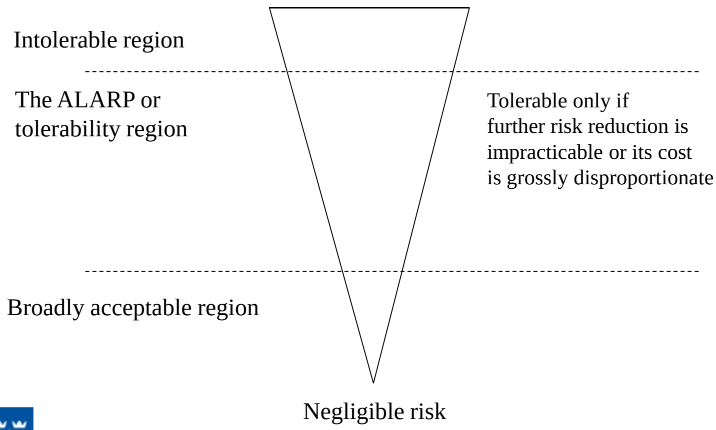
ALARP (As Low As Reasonably Practicable)



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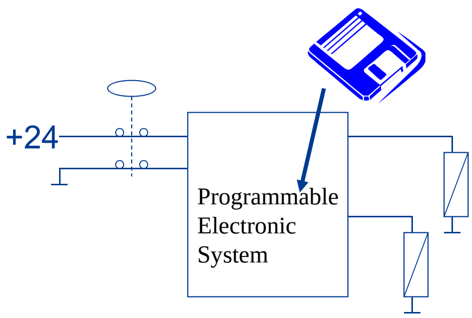

What is ”functional safety” and ”safety function”?

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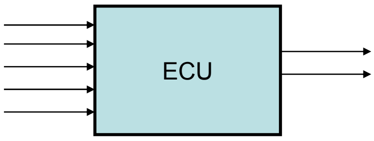
Functional safety

- Functional safety is part of the overall safety that depends on a system or equipment operating correctly in response to its inputs.
- Functionality ≠ Functional safety
- Focus on development of functions must not reduce efforts for functional safety.
- It will be expensive to try to “add functional safety” late in the development process.



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Safety function

- *”Function to be implemented by an E/E/PE safety-related system, other technology safety related system or external risk reduction facilities, which is intended to achieve or maintain a safe state for the EUC, in respect of a specific hazardous event”*
- Defined in standard IEC 61508

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Safety requirements specification

- Overall safety requirements specification :
  safety functions AND safety integrity levels

- Example:
  safety function: pressure monitoring (alarm at high pressure)
  safety integrity: 1 fault/10 years

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Is there ”high” and ”low” safety?

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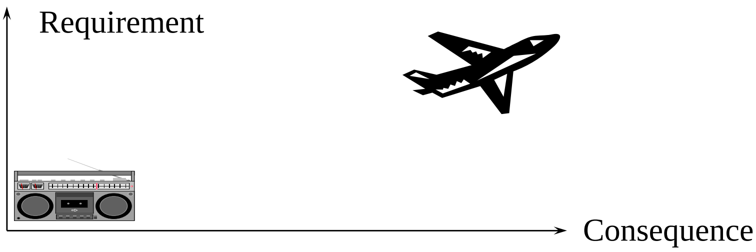
Different safety requirements



•Serious consequences – high requirements
•Moderate consequences – moderate requirements

… but the safety integrity level depends on other parameters also.

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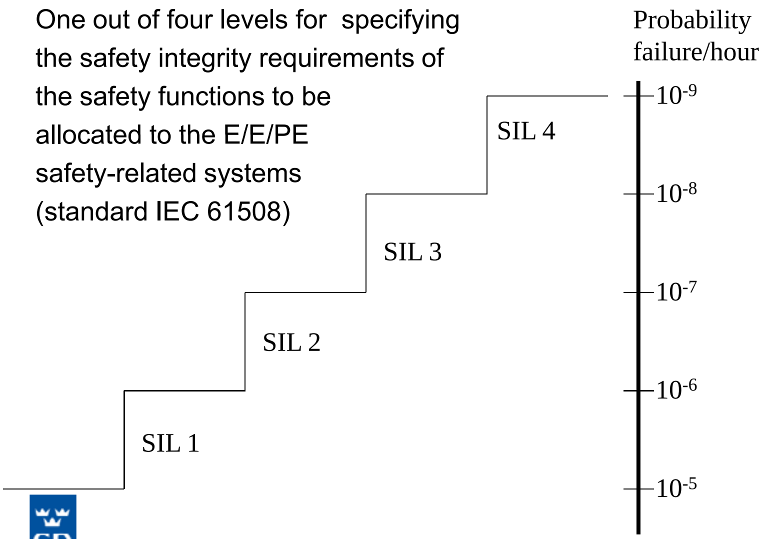
Safety Integrity Level (SIL)

One out of four levels for specifying the safety integrity requirements of the safety functions to be allocated to the E/E/PE safety-related systems (standard IEC 61508)



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Qualitative assessment of SIL

- Consequence
  - –C1 minor injury
  - –C2 serious permanent injury to one or more persons. Death to one person
  - –C3 death to several people
  - –C4 very many people killed
- Frequence & exposure
  - –F1 rare to more often
  - –F2 frequent to permanent
- Possibility of avoiding
  - –P1 Possible under certain conditions
  - –P2 Almost impossible
- Probability of the unwanted occurrence
  - –W1 very slight probability
  - –W2 slight probability
  - –W3 relatively high probability

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Risk graph

Basic risk: Serious injury to person depending on uncontrolled start of remote controlled machine.

Safety function: Emergency stop. Estimated parameters are C2, F1, P1, W3.

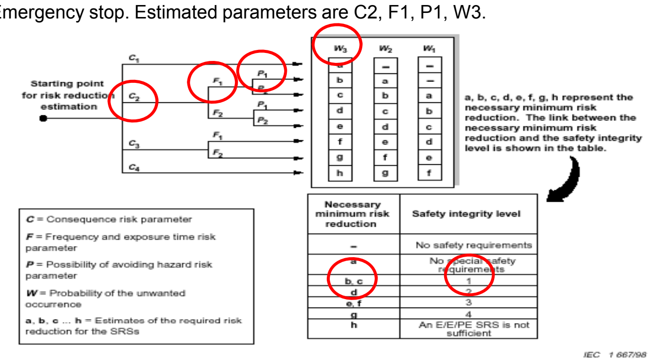
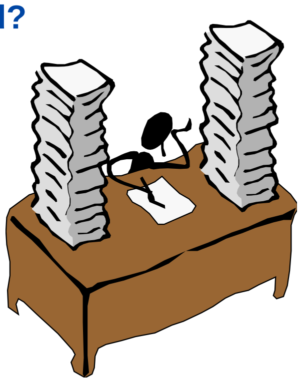


Figure D.2 – Risk graph: example (illustrates general principles only)

What is the IEC 61508 standard?



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IEC 61508

Functional safety of
electrical/electronic/programmable electronic (E/E/PE)
safety related systems

- Part 1: General requirements
- Part 2: Requirements for E/E/PE safety-related systems
- Part 3: Software requirements
- Part 4: Definitions and abbreviation
- Part 5: Examples of methods for the determination of safety integrity levels
- Part 6: Guidelines on the application of IEC 61508-2 and IEC 61508-3
- Part 7: Overview of techniques and measures

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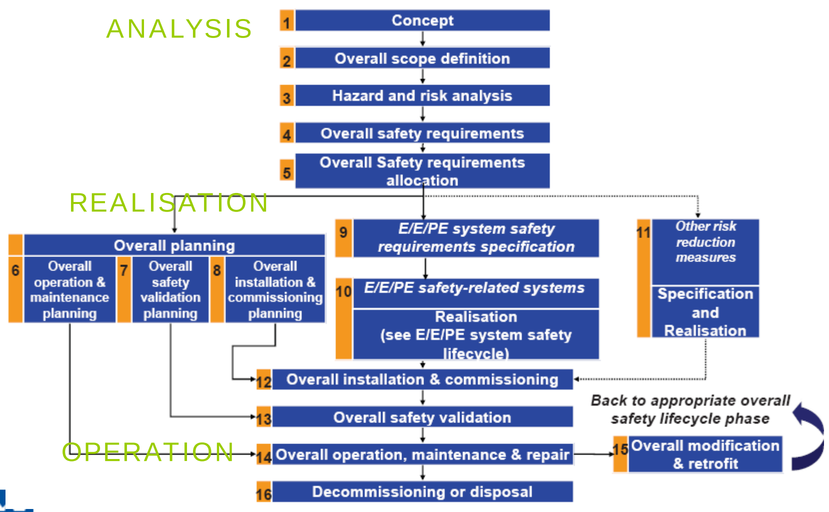
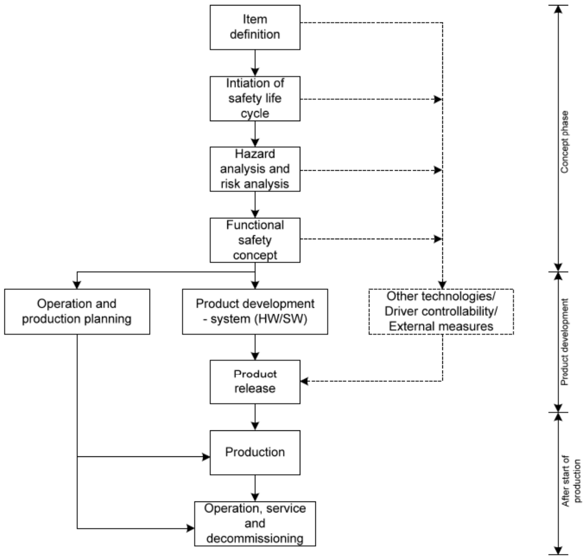
IEC 61508

- Generic standard, i.e. used as a base for generation of sector-specific standards
- Part 1-4 are ”basic safety publications”. These parts must be considered when developing sector-specific standards.
- IEC 61508 can be used when sector-specific standards do not exist
- Presently under maintenance
- Also as European standard (EN 61508) and national standards (e.g. DS/EN 61508 ’Funktionel sikkerhed for elektriske/elektroniske/programmerbare sikkerhedsrelaterede systemer’)

Overall safety lifecycle



Overall Safety Lifecycle



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Example: Engineer microwaves hand

- commercial 10.5 kW microwave oven
- '.. a sensation of warmth in his hands..'
- electric interlocks at oven doors
- single channel control system
- 4 times per day?
- 200 times per day
- contacts welded

- HSE 'Out of Control'

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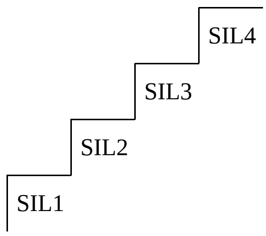
Measures and techniques to control failures

- Target : To control failures during operation
- A combination of techniques and measures
- HR = Highly Recommended
- R = Recommended
- NR = Not Recommended
- - = No statement



IEC 61508-2, Table A16

Technique/ measure	SIL 1	SIL 2	SIL 3	SIL 4
Programme sequence monitoring	HR Low coverage	HR Low coverage	HR Medium coverage	HR High coverage
On-line monitoring	R Low coverage	R Low coverage	R Medium coverage	R High coverage
…..				
Diverse hardware	-	-	R Medium coverage	R High coverage
…..				

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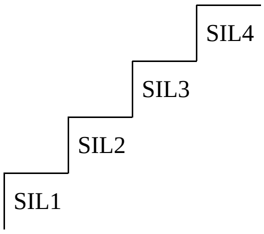
Measures and techniques to avoid failures

- Target : To avoid failures during the different phases of the safety life cycle.
- A combination of techniques and measures
- HR = Highly Recommended
- R = Recommended
- NR = Not Recommended
- - = No statement



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IEC 61508-2, Table B1 (during specification)

Technique/ measure	SIL 1	SIL 2	SIL 3	SIL 4
Project mangement	HR Low	HR Low	HR Medium	HR High
…..				
Semi-formal methods	R Low	R Low	HR Medium	HR High
…..				
Formal methods	-	-	R Medium	R High

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IEC 61508-2, Table B5 (during validation)

Technique/ measure	SIL 1	SIL 2	SIL 3	SIL 4
Functional testing	HR mandatory	HR mandatory	HR mandatory	HR mandatory
…..				
Static analysis	-	R Low	R Medium	R High
…..				
Field experience	R Low	R Low	R Medium	NR

ISO 26262 for the automotive industry

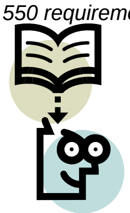
Draft International Standard ISO 26262

ISO 26262 Functional Safety – Road Vehicles

- Part 1: Vocabulary
- Part 2: Management of functional safety
- Part 3: Concept phase
- Part 4: Product development: system level
- Part 5: Product development: hardware level
- Part 6: Product development: software level
- Part 7: Production and operation
- Part 8: Supporting processes
- Part 9: ASIL-oriented and safety-oriented

350 pages

550 requirements



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Motivation for a sector-specific standard

- Control and safety functions usually inseparable (not separate safety functions)
- Mass-market products, not low-volume
- How to handle subcontracting?
- Life cycle: Validation before start-of-production (not validation before installation)
- Risk analysis for road vehicles
- ”Techniques and measures” more suitable for road vehicles
- Human factors, driver part of the control loop

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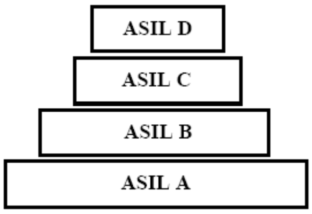
Automotive Safety Integrity Level



Draft standard ISO 26262

- All safety-related functions are expected to be assigned to an ASIL.
- ASIL D provides the highest risk reduction.

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ASIL and Risk Classification (draft ISO 26262)

		C1	C2	C3
S1	E1	QM	QM	QM
	E2	QM	QM	QM
	E3	QM	QM	A
	E4	QM	A	B
S2	E1	QM	QM	QM
	E2	QM	QM	A
	E3	QM	A	B
	E4	A	B	C
S3	E1	QM	QM	A
	E2	QM	A	B
	E3	A	B	C
	E4	B	C	D

- QM: Quality management => 26262 not applicable

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Examples of Hazard Analysis Using ISO 26262

- Airbag
  - Loss of airbag functionality in a crash situation is typically QM or ASIL A
  - Unintended airbag activation under normal driving is typically ASIL B or C
- Brake-by-wire
  - Unintended braking with maintained stability is typically ASIL B or C
  - Unintended braking on single wheel is typically ASIL D
  - Total symmetric loss of brake function (assume p-brake and engine-brake) is typically ASIL D
- Steer-by-wire
  - Loss of steer-by-wire functionality (S3, C3 and E4) gives ASIL D
- Head-lights
  - Loss of high-beam (assume low-beam functional) (S2, E3, C1) gives ASIL A

N.B. The hazard analysis may be different for other vehicles, drivers or traffic situations.
The above are only examples. There is no “always true ASIL”.

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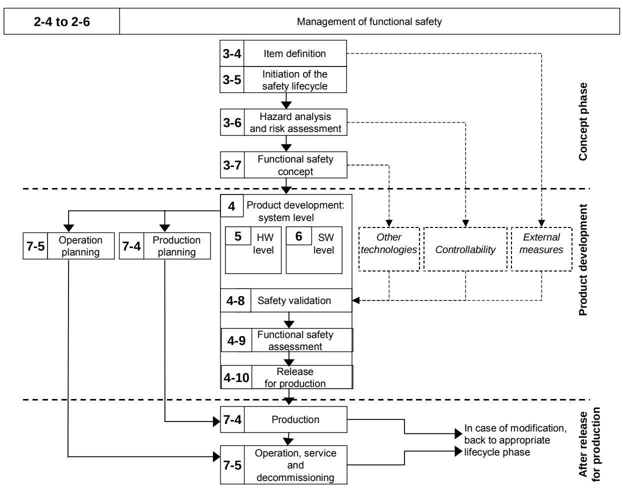
Safety lifecycle according to draft ISO 26262



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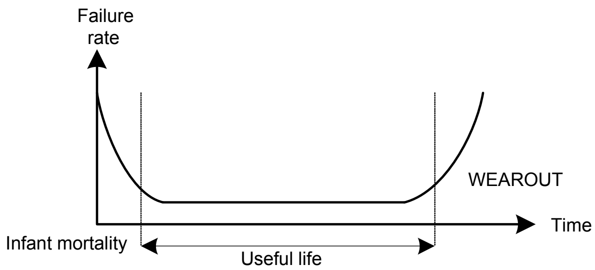
Failure rate

Failure rate as a function of time



- Electronic components can be often described by the above curve.
- The failure rate is assumed constant during the usefil life.
- Exponential distribution is assumed.

$$f(t) = \lambda e^{-\lambda t}$$ ”Exponential probability density function”

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Safe/dangerous and detected/undetected faults

The failure rate may be described through the consequences of a fault

S – Safe

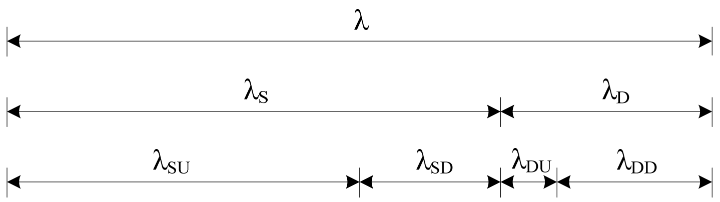
D – Dangerous

SU – Safe Undetected

SD – Safe Detected

DU – Dangerous Undetected

DD – Dangerous Detected



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Diagnostic Coverage

- ” fractional decrease in the probability of dangerous hardware failures resulting from the operation of the automatic diagnostic tests”

$$DC = \frac{\sum \lambda_{DD}}{\sum (\lambda_{DU} + \lambda_{DD})}$$

- $0 \leq DC \leq 100\%$

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Safe Failure Fraction

- ” fraction of the overall random hardware failure rate of a device that results in either a safe failure or a detected dangerous failure”

$$SFF = \frac{\sum \lambda_S + \sum \lambda_{DD}}{\sum \lambda_S + \sum \lambda_{DD} + \sum \lambda_{DU}}$$

- 0 ≤ SFF ≤ 100%

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An example of calculation of probability of failure

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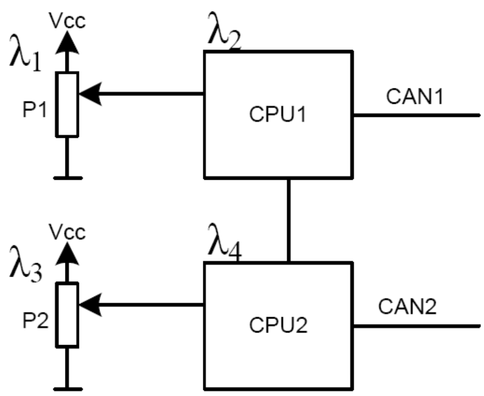
Example: Brake pedal sensing



- Failure rates:
- λ_1, λ_2, λ_3, λ_4
- (Failures/hour)

- What will be the
- total probability of
- dangerous failure
- per hour?

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Example: Brake pedal sensing

- FMEA Failure Mode and Effects Analysis

Monotoring function	Description
A- Comparison between redundant CPUs	The function continuously compares the potentiometer feed-back position values, performs control-flow tests of the CPUs and compares the communication channels. Any deviation between the redundant channels is handled by a special algorithm which forces the most incorrect channel into a passive safe-state.

Part 1 – Without considering monitoring functions							Part 2 – Taking the monitoring functions into account	
Comp.	Mode	Rate [FITs]	Distr. [%]	Effect	S [%]	D [%]	Monitoring function.	Coverage [%]
P1	SC	[700]	0.5	Either stucked at max or min position, or reduced range of the potentiometer	10	90	A	90
	OC		25	Floating feedback voltage	50	50	A	90
	D		65	Indicating the wrong position – continuously	30	70	A	90
	F		9.5	Indicating the wrong position - instantaneously	10	90	A	90
CPU1	F	[1300]	100	Indicating the wrong position	50	50	A	90

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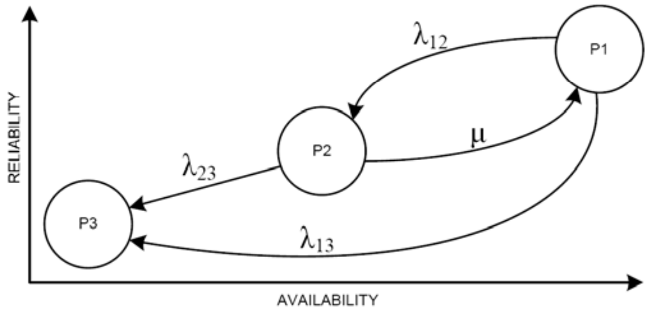
Example: Brake pedal sensing

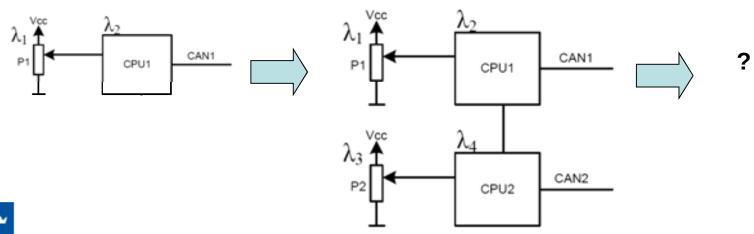
The Markov model



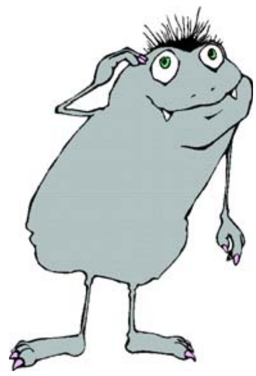
- State P1: Normal operation
- State P2: Degarded operation
  (Safe-state. Only one channel operating)
- State P3: Dangerous operation

Example: Brake pedal sensing

- FMEA, Markov modelling and calculations give
- the probability of failure per hour = 3,87 * 10^{-7}
- Will this be acceptable?
- Do we have to reduce the risk further?



Experiences regarding dependable systems



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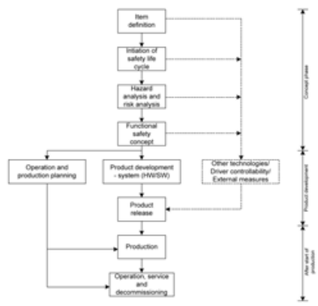
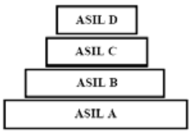
How to achieve functional safety?

- Overall safety lifecycle
- Risk management
- Safety functions
- Safety Integrity Level
- Avoid faults
- Control faults





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Some important conclusions

- ”Zero risk” can never be achieved
- It is important to understand the risks associated with the system
- Risks impossible to tolerate must be reduced (ALARP)
- Safety thinking must be applied from the beginning
- Correct function does no necessarily imply a safe system

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Some views on IEC 61508

- The probability-based thinking may be hard to learn
- Not perfect for automotive applications
- Large differences compared with earlier sector-specific standards
- The decision to apply IEC61508 must be taken early in a development project
- An extensive standard, hard for many small or medium-sized organisations to learn
- Large amounts of documentation generated

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Development acc. to the Safety Life Cycle

- Objective: Obtain functional safety through systematic development work

- Not to produce documentation by
- reverse engineering.

- Supporting the safety work,
- not an extra burden for the developer

- Who is responsible for
- the functional safety?

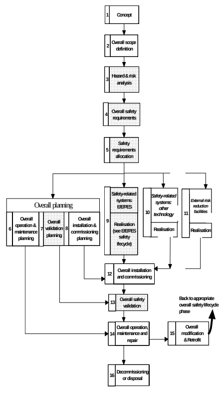

Fig. 1 Overall safety lifecycle

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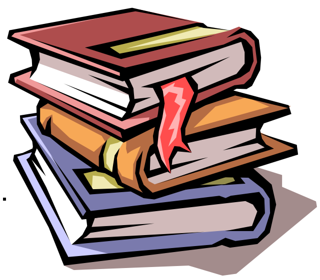
Documentation

- Size?
- Structure?
- Fit the establish quality management of the company.

- The progress of the work
- for dependability is indicated
- by the progress of the documentation.



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More to read …

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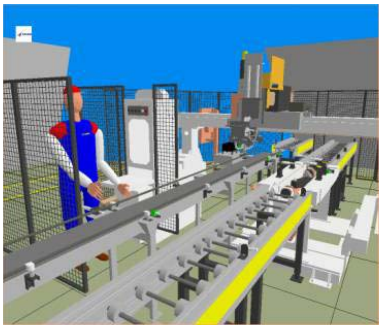
Sector-specific standards

- IEC 62061 Machinery
- IEC 61511 Process industry
- IEC 61513 Nuclear industry
- ISO 26262 Road vehicles



Källa: www.euromation.se

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More to read …

www.iec.ch/functionalsafety
(the web site of the International Electrotechnical Commission includes ”A basic guide” och FAQ)

http://www.sp.se/en/index/research/safeprod/Sidor/default.aspx
(SafeProd - a research project on functional safety in complex products)

DS-håndbog 148:2004, *Functional Safety* at DKK 712,-.
(www.ds.dk)

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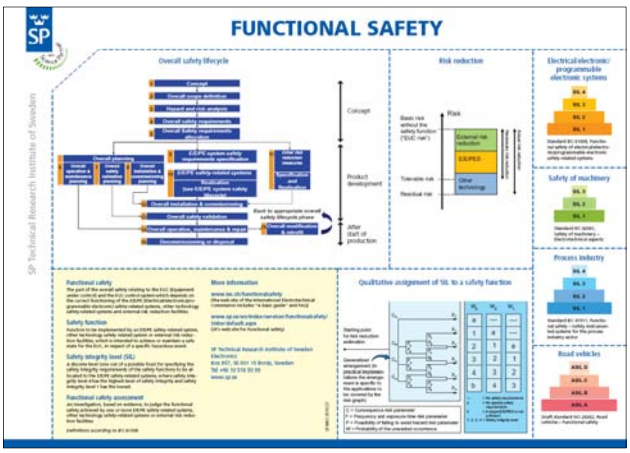
Functional Safety poster

- Download SP INFO 2010:27 at http://www.sp.se/en/publications/Sidor/Publikationer.aspx
- 

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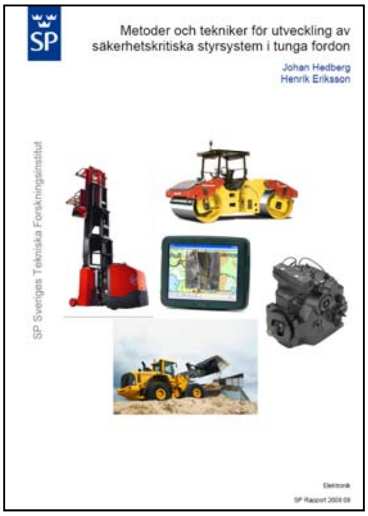
Download on Heavy Vehicles

- SP Report 2008:08
- ”Metoder och tekniker för
- utveckling av säkerhetskritiska
- styrsystem i tunga fordon ”

- at
- http://www.sp.se/en/publications/Sidor/Publikationer.aspx

- (only available in Swedish)



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Download the AutoVal reports

SP reports no
2007:13
2007.14
2007:15

(only no 2007:13 available on paper)

- To be found at www.sp.se under ”Publications” and ”Electronics and ICT”

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