Industrial Embedded Systems
- Design for Harsh Environment -

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IN2244

Part VI – Safety Architectures

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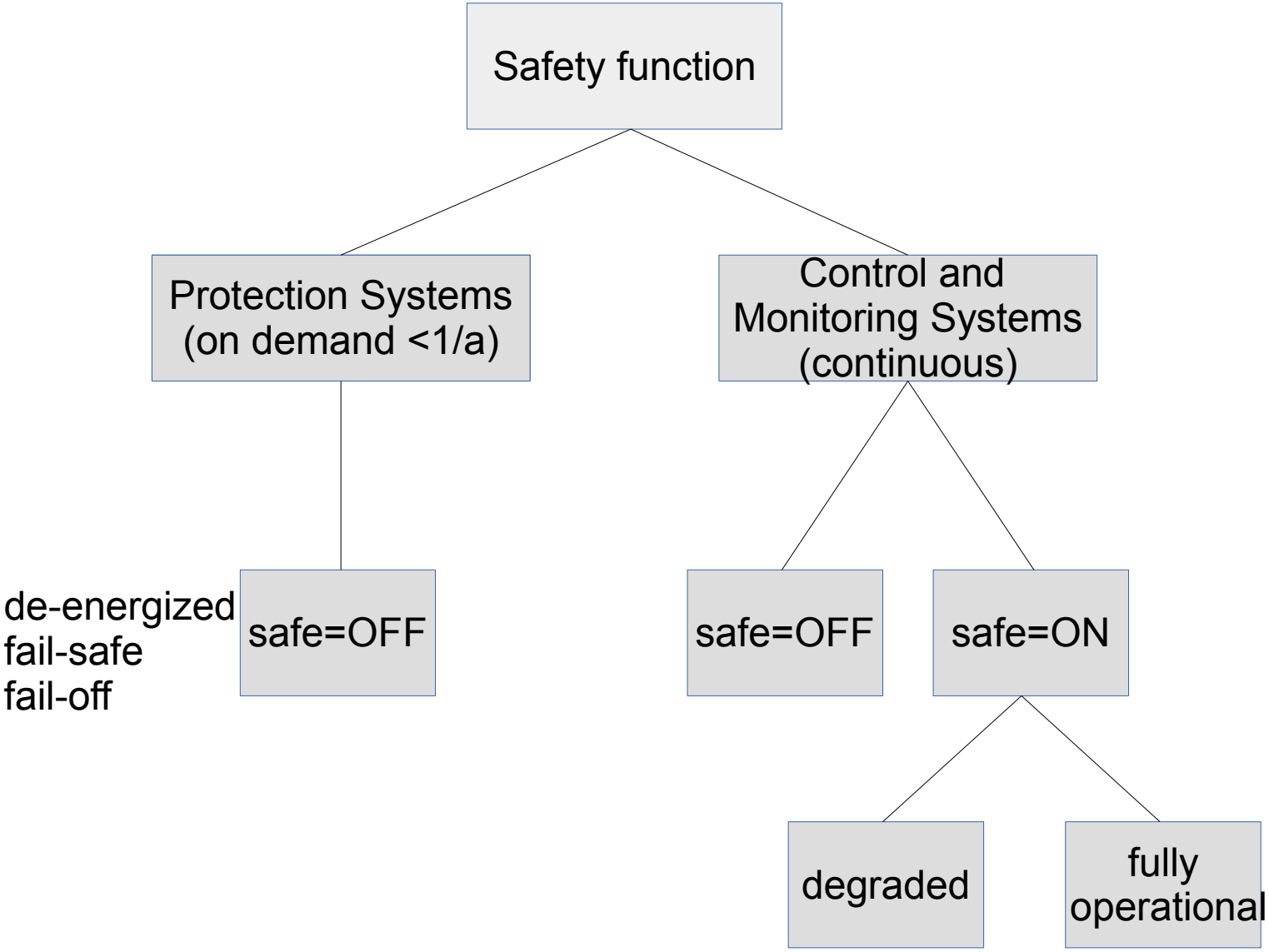
Technische Universität München

Fail-safe and Fail-operational Systems



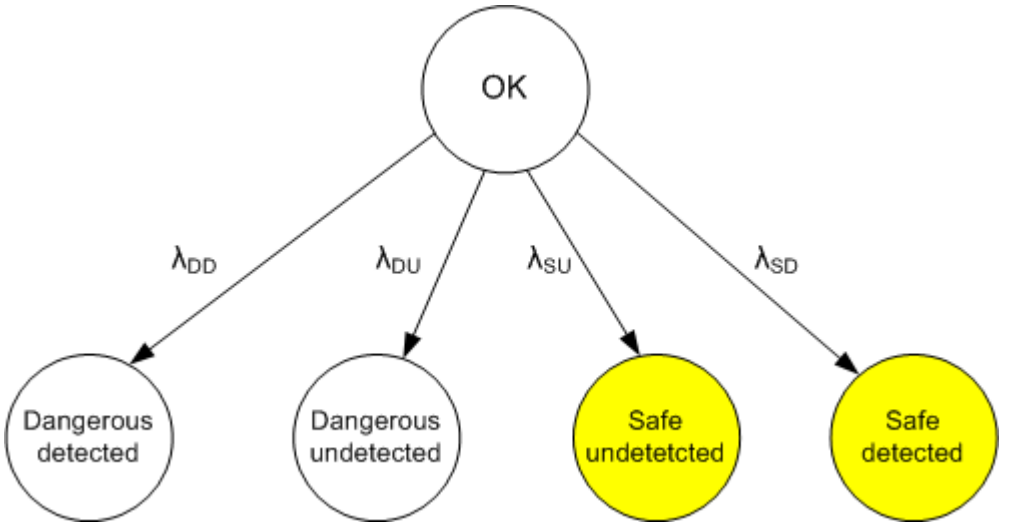
Architecture Constraints

Safe failure fraction	Hardware fault tolerance (see note 2)		
	0	1	2
< 60 %	Not allowed	SIL1	SIL2
60 % – < 90 %	SIL1	SIL2	SIL3
90 % – < 99 %	SIL2	SIL3	SIL4
≥ 99 %	SIL3	SIL4	SIL4
NOTE 1 See 7.4.3.1.1 to 7.4.3.1.4 for details on interpreting this table. NOTE 2 A hardware fault tolerance of N means that N + 1 faults could cause a loss of the safety function. NOTE 3 See annex C for details of how to calculate safe failure fraction.			

Source: IEC61508

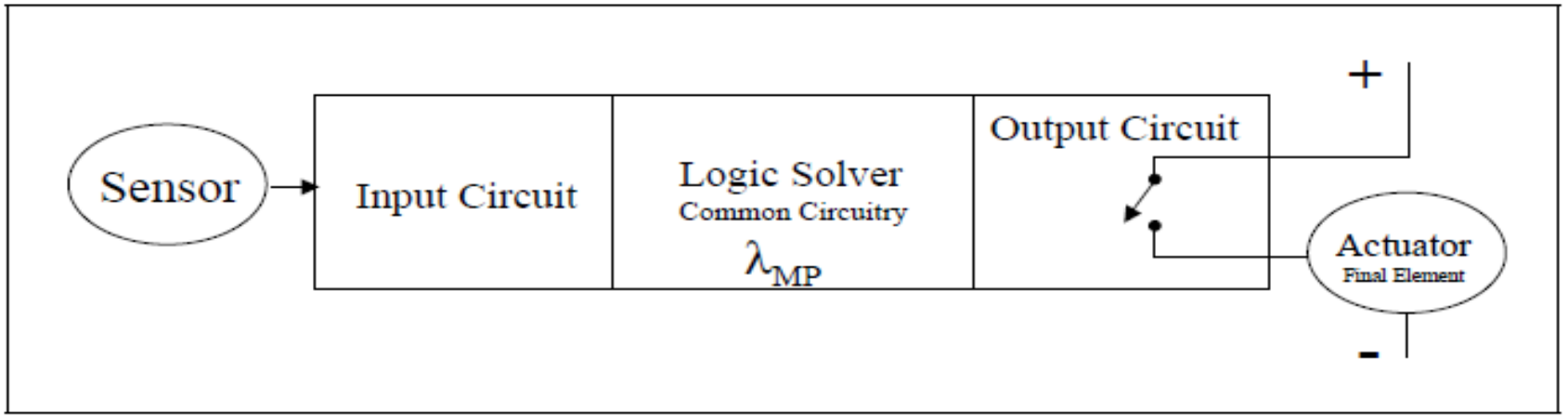
- Besides providing a specific quality (failure rate) a safety function must be hosted by a specific architecture in context of IEC 61508
- Besides architecture constraints also specific fault detection mechanisms must be realized by the final design. This is expressed by the safe failure fraction (SFF)

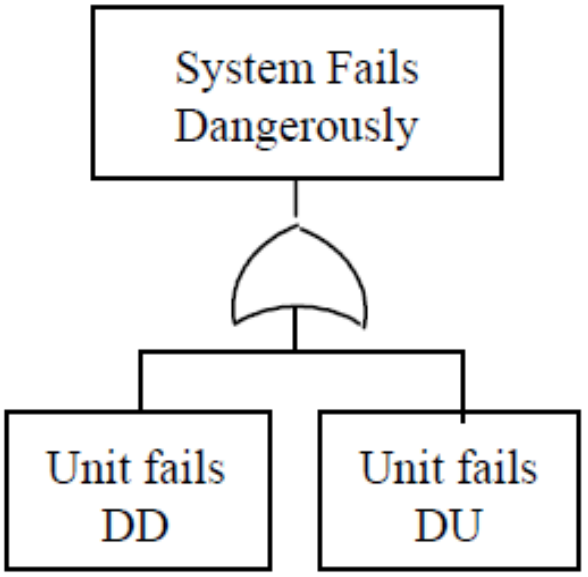
Safe Failure Fraction (SFF)

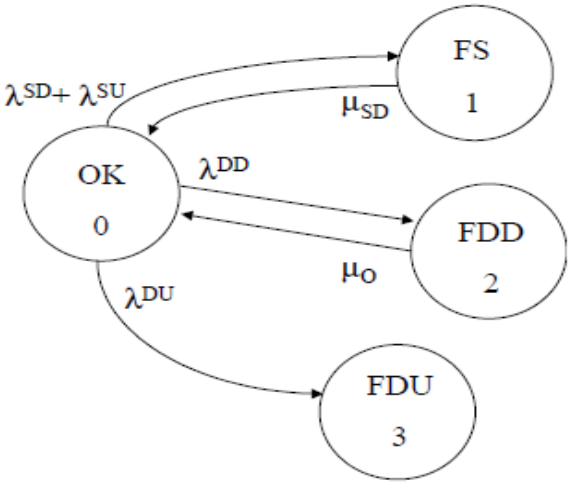


- Failure (this is the same failure rate as in the reliability lecture) can happen in a safe or dangerous way. Detection mechanisms are software enabled in the context of complex systems (involving microcomputers).
- $SFF = 1 - \frac{\lambda_{du}}{\lambda_{total}}$; $\lambda_{total} = \lambda_{du} + \lambda_{dd}\,\lambda_{su} + \lambda_{sd}$

1oo1 System

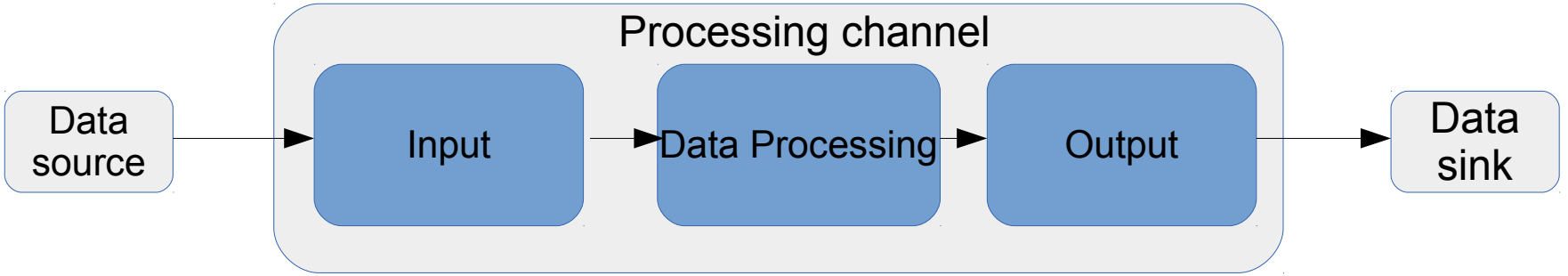






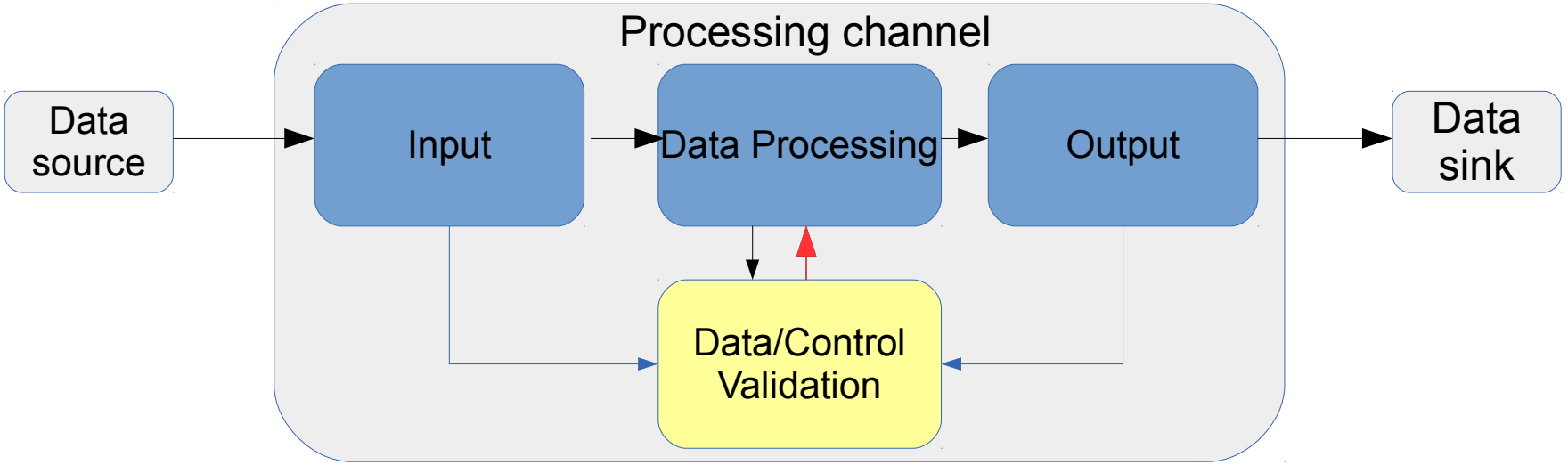
Source:
Goble, Safety instrumented systems verification: practical probabilistic calculation

1oo1 Software



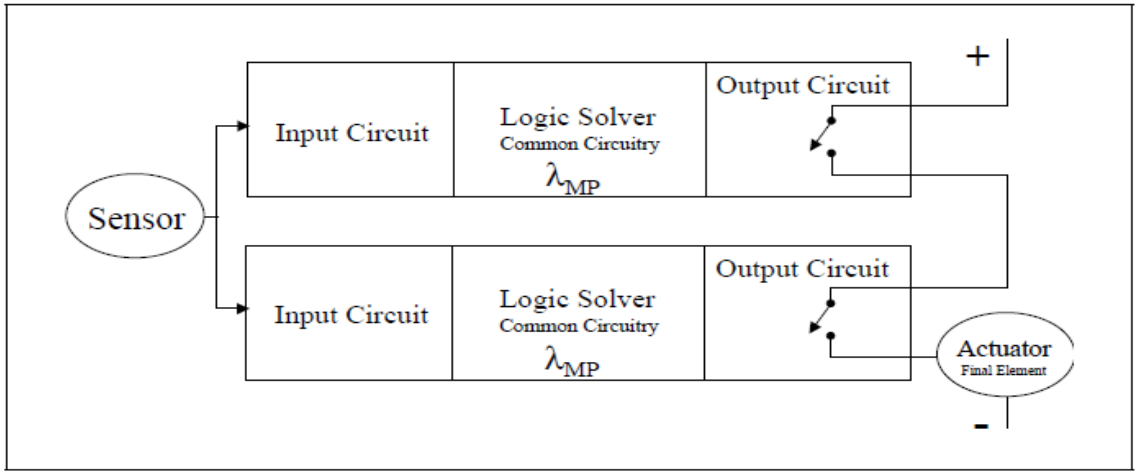
- Reliability (random faults): see previous calculations
- Reliability (systematic faults): highly affected
- Safety: 1oo1 architecture, not used

1oo1 Software



- Still 1oo1.
- Provides some data and control flow checks (self-monitoring)
  - Internal watchdog, acceptance tests
- Use: not used in safety-related applications, reliability increase (depends on application)

1oo2 System



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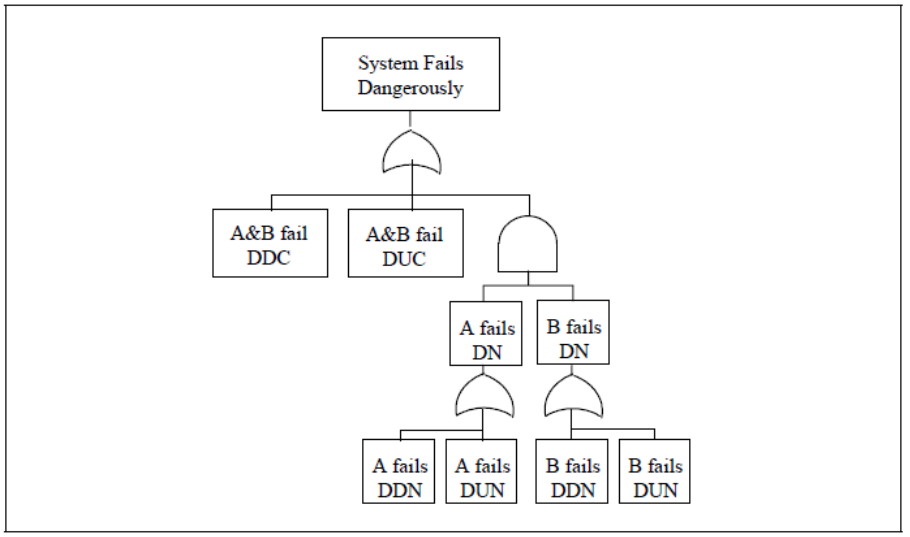
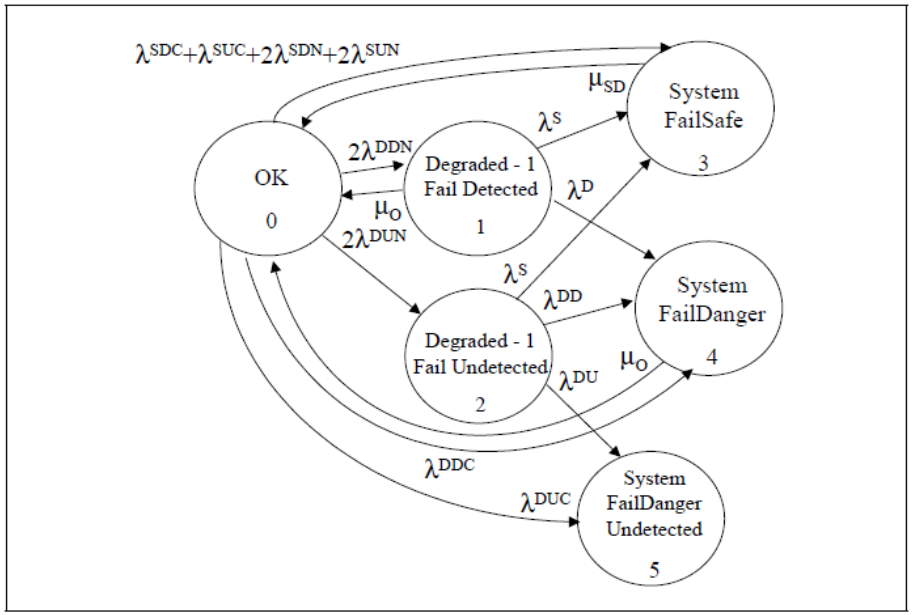
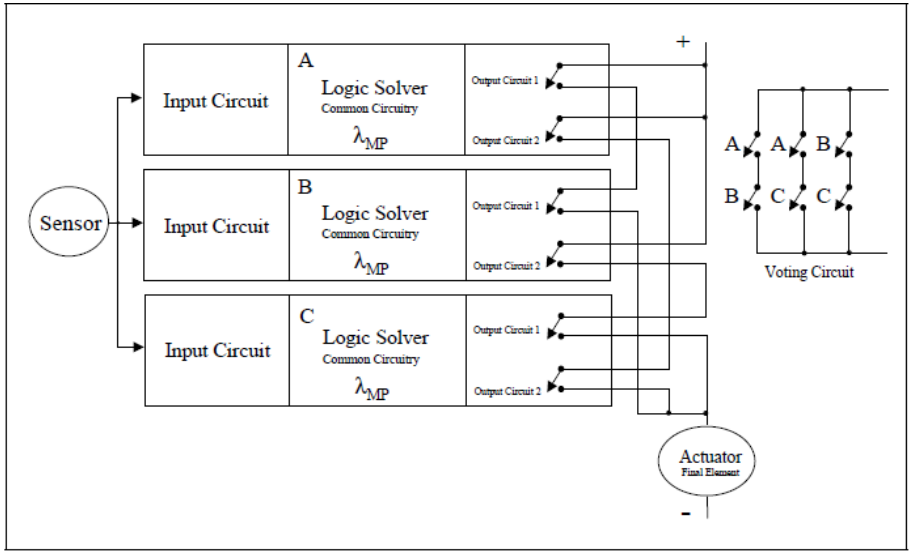
Goble, Safety instrumented systems verification: practical probabilistic calculation

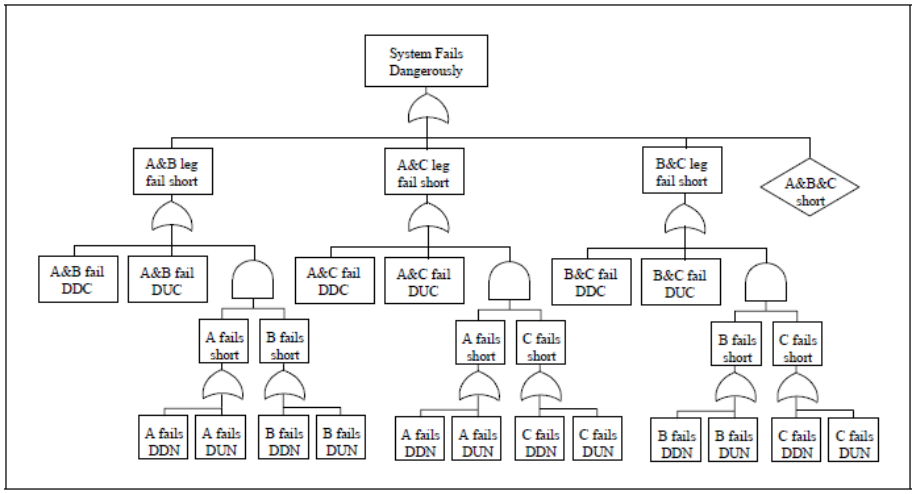


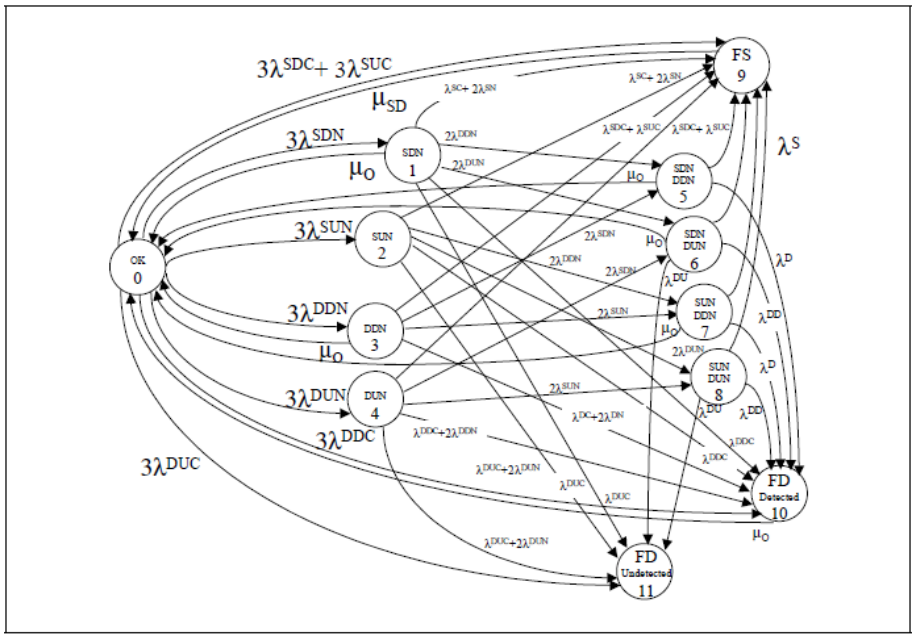


2oo3 System

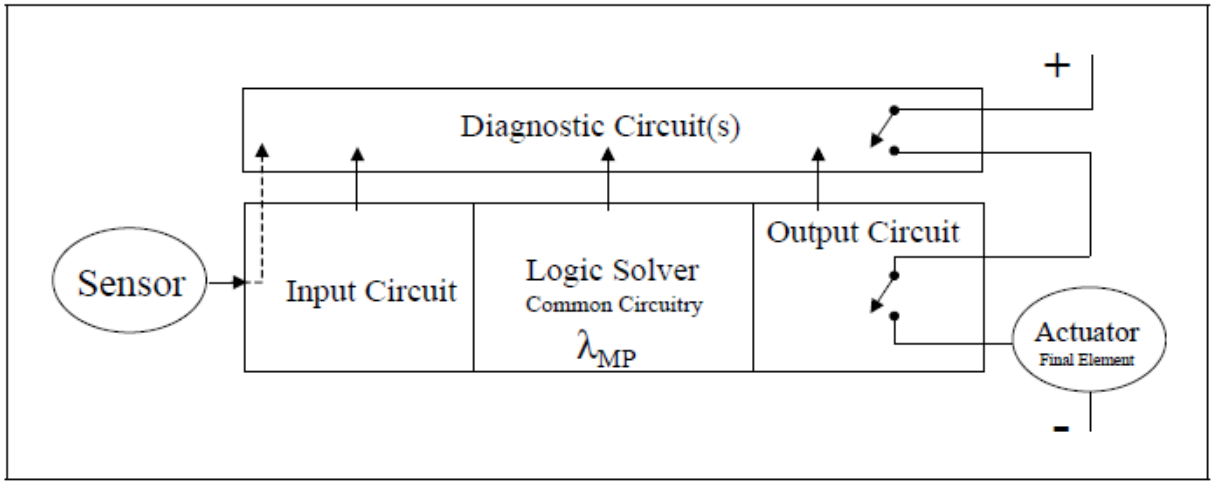


Source:
Goble, Safety instrumented systems verification: practical probabilistic calculation





1oo1D System



Source:
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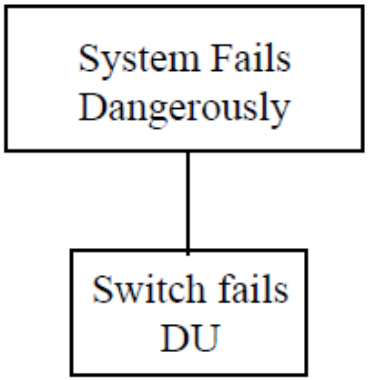
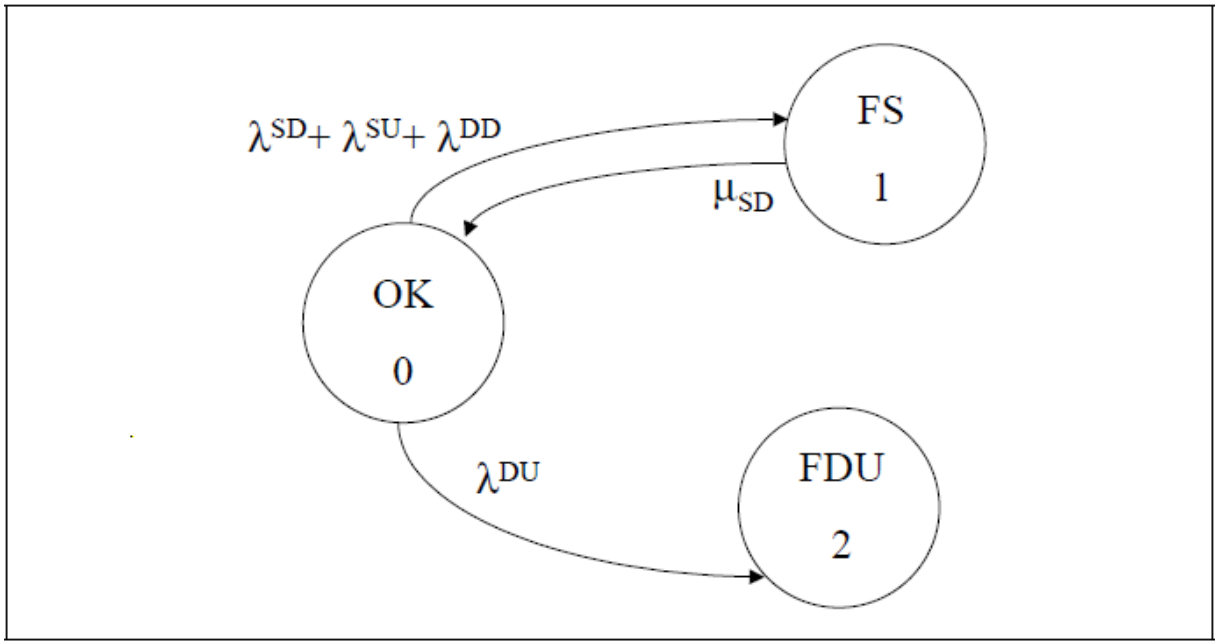
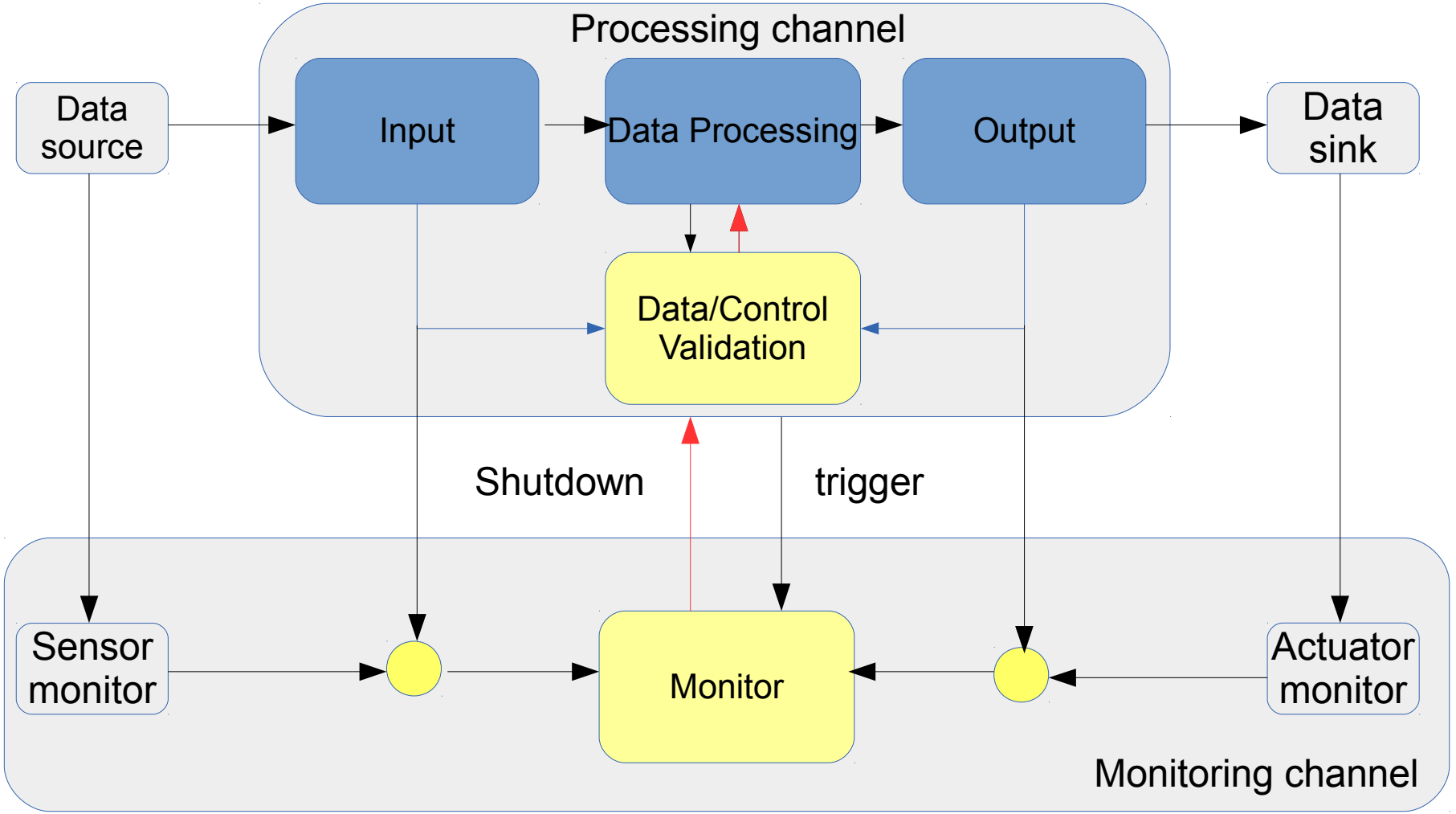
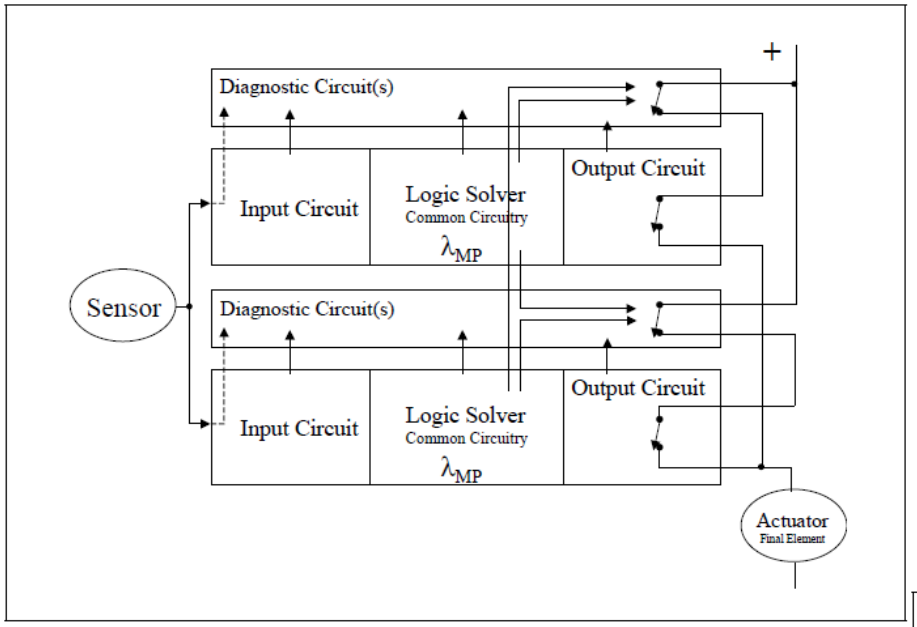




External Diagnostics (MooND Architectures)



1oo2D System



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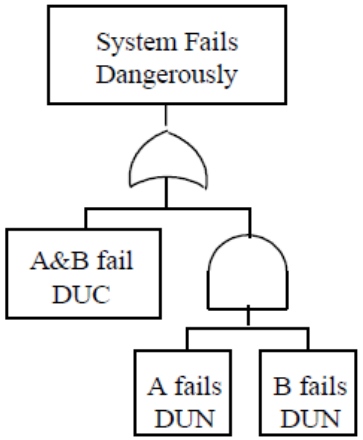
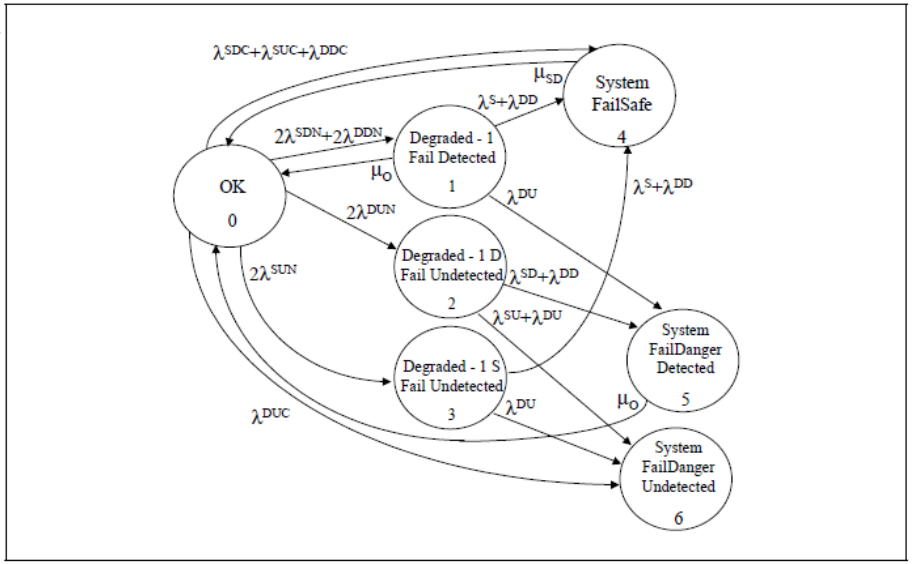
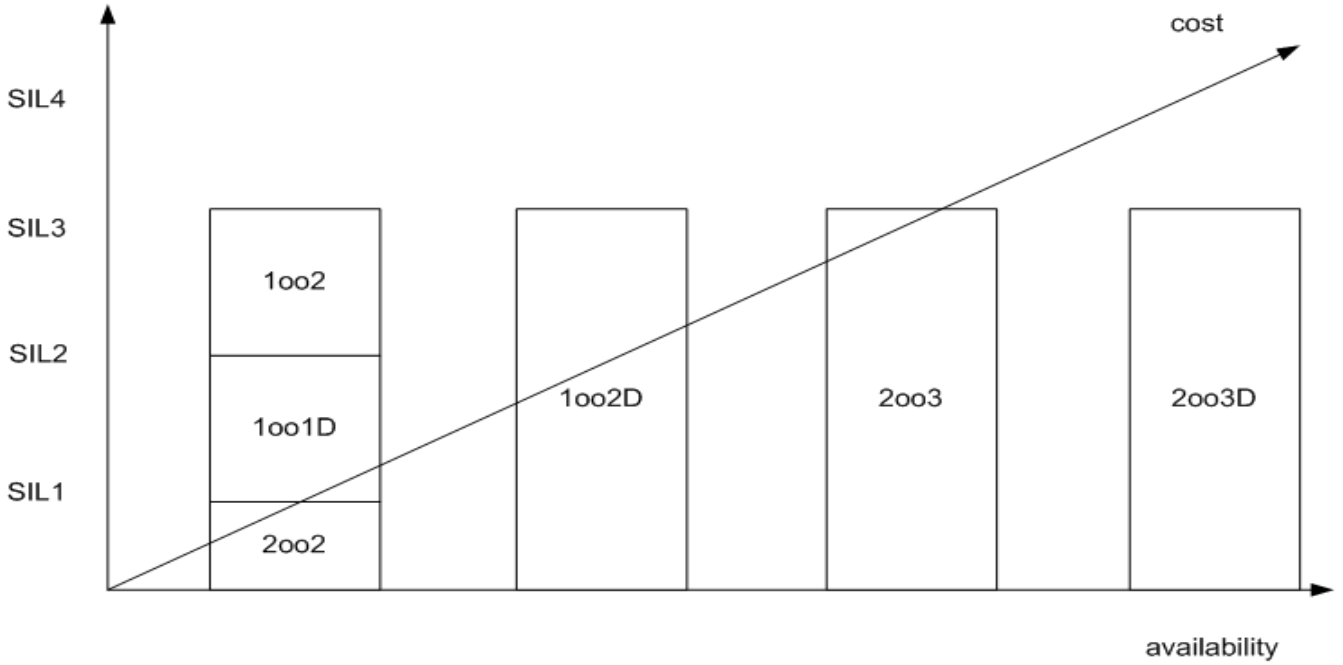




Architectures and Cost



Architecture	Number of units	Output Switches	Objective
1oo1	1	1	Base unit
1oo2	2	2	High Safety
2oo2	2	2	Maintain output
1oo1D	1	2	High Safety
2oo3	3	6	Safety and Availability
2oo2D	2	4	Safety and Availability
1oo2D	2	4	Safety and Availability – biased toward Safety

Source:
Goble, Safety instrumented systems verification: practical probabilistic calculation

Systematic Failures

- Architecture: common cause failures, dependency failures
  - Freedom from interference
  - Look at common cause failures in previous Markov diagrams
- Software: SIL for software renamed to systematic capability (SC) in IEC61508 Edition 2.0
  - SC N supports a safety function of SIL N