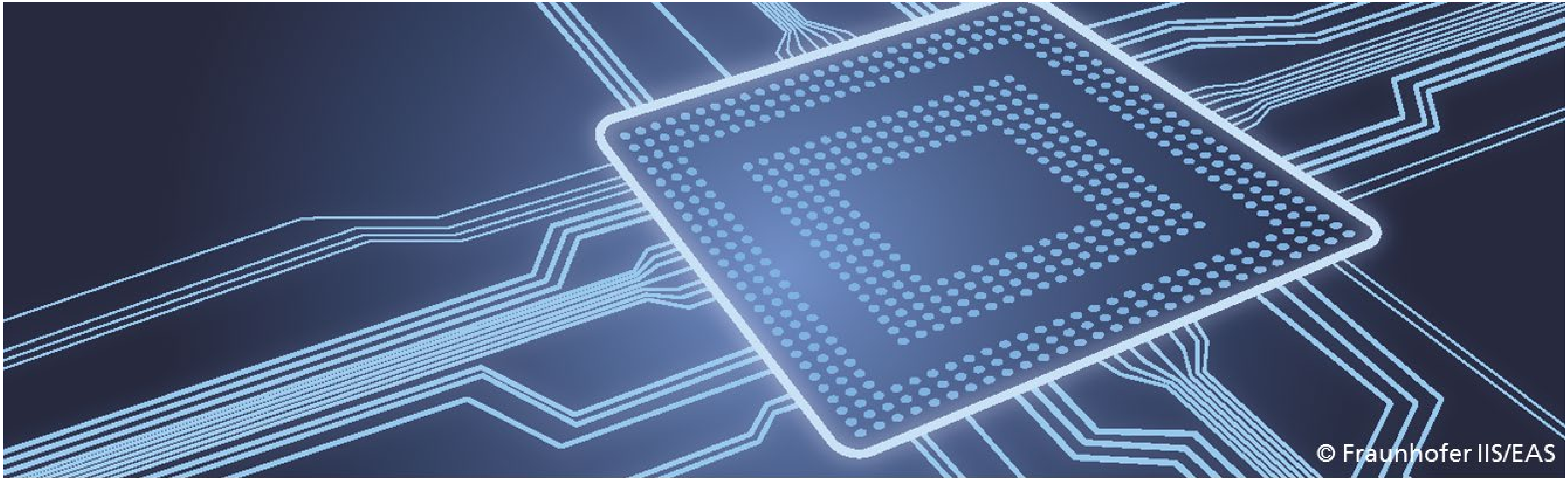
DYNAMIC FAULT INJECTION WITH SYSTEMC AMS FOR QUANTITATIVE SAFETY VERIFICATION

Fraunhofer Institute for Integrated Circuits IIS, Division Engineering of Adaptive Systems EAS
Department Design Methodology



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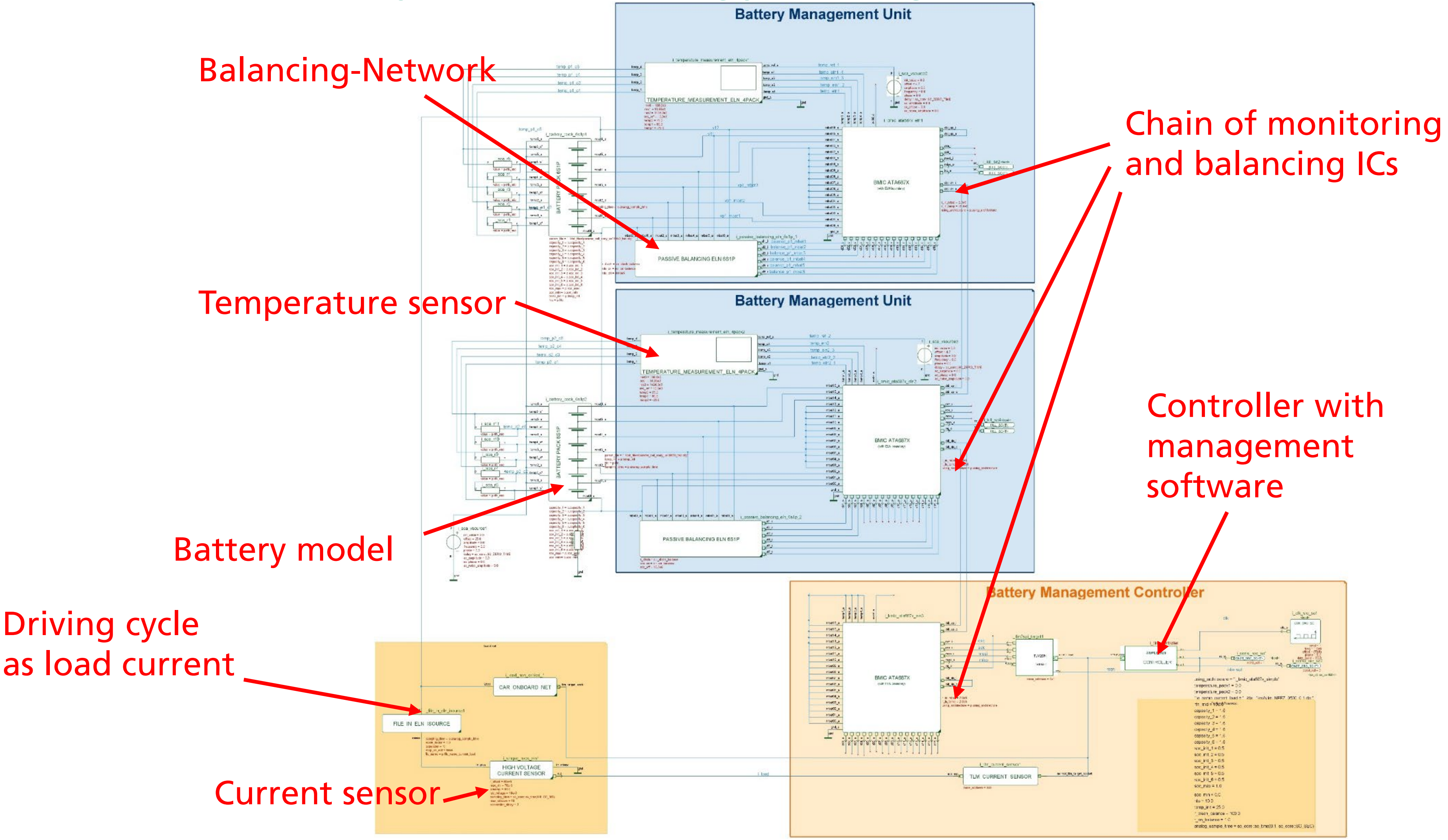
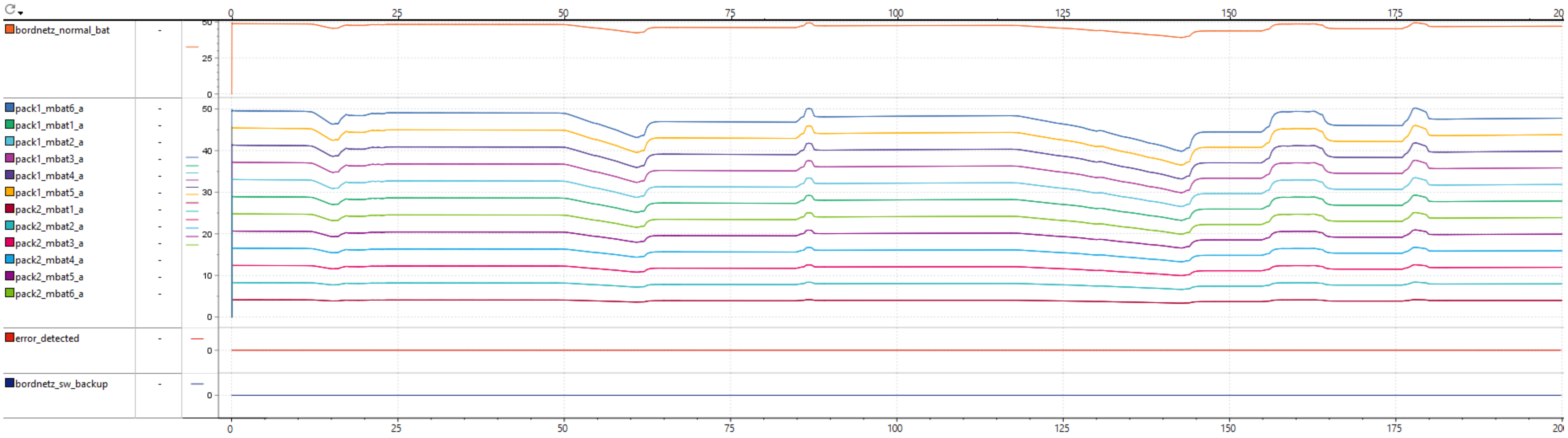
Battery management system (BMS)
As part of the safety critical energy storage item



Battery management system (BMS)
As part of the safety critical energy storage item

- Nominal simulation: based on driving cycle, provided by a project partner
  - No fault occurs
  - Battery cell voltages depend on SOC and load current



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Diagnostic Coverage Determination
FMEDA

- Investigations under Fusa aspects have to be done after functional verification

	Failure rate [FIT]	Safety Relevance Component	Failure Modes	Failure Mode Distribution D_{FMi} [%]	Failure Mode can Violate Safety Goal Directly	Failure Rate λ_i	Coverage by Safety Mechnism	Failure Mode Coverage K_{FMCi} [%]	Single Point Failure Rate $\lambda_{SPF,i}$ [FIT]	Residual Failure Rate $\lambda_{RF,i}$ [FIT]
Battery pack	10	x	Overvoltage	20	x	2	SM1	90	0	0,2
			Undervoltage	30	x	3	SM2	?	0	0
			Voltage changes too fast	10	x	1	SM3	99	0	0,01
			Temperature too low	20	x	2	SM4	95	0	0,1
			Temperature too high	20	x	2	SM4	95	0	0,1
Plug-Connector to main line	15	x	Open	30	x	4,5	SM5	99	0	0,045
			Short to ground	10	x	1,5	SM5	99	0	0,015
			Intermittend contact	60	x	9	SM5	99	0	0,09
Sum total [FIT]	123							Sum total [FIT]	2,2	6,085
Sum safety-relevant [FIT]	123							**SPFM [%]**	**93,3**	
Sum not-safety-relevant [FIT]	0									

- Safety mechanism 2: Measure battery voltage and if a drop occurs connect redundant battery

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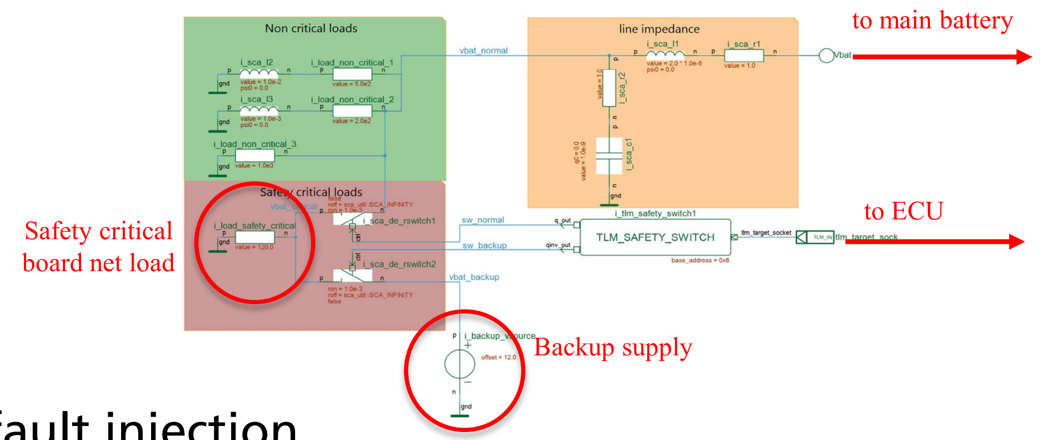
Battery management system (BMS)

Example board net with safety critical loads

- Goal:
  Assessment of safety concepts
  (e.g. supply of safety critical board net loads)
- Switch to backup voltage in case of under voltage



- Under-voltage condition provoked by dynamic fault injection
- ISO26262 compliance proved on time metrics

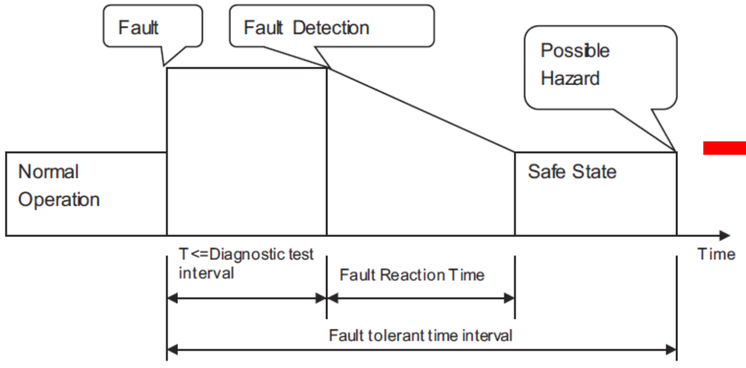
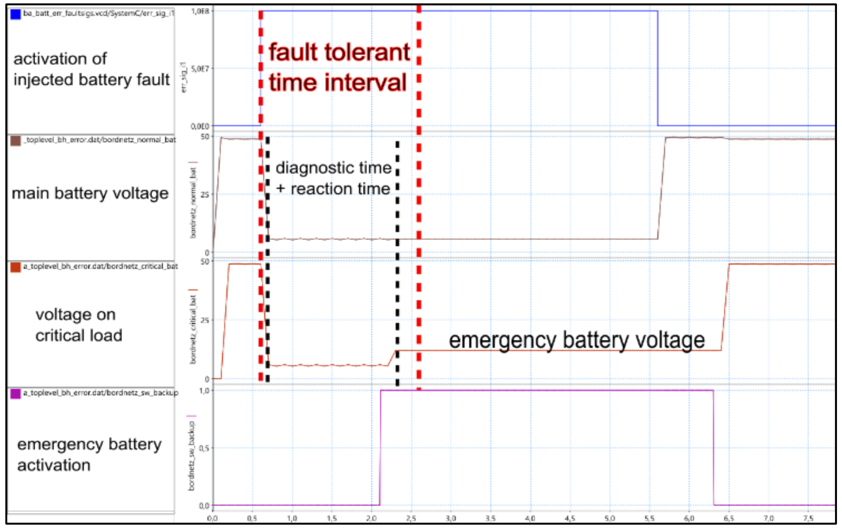
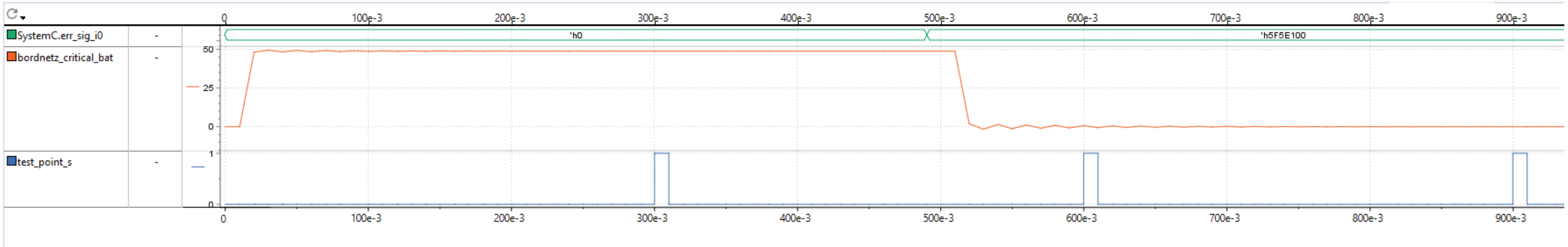


Figure 4 — Fault reaction time and fault tolerant time interval



Set up a fault injection scenario
Definition of the fault simulation scenario

- Scenario:



  - Suddenly, main battery cannot supply safety critical loads anymore
  - The provider defined a fault tolerant time interval
  - It has to be proven that safety mechanism is able to bring system in stability again fast enough
  - E.g. Check influence of fault occurrence time to this requirement

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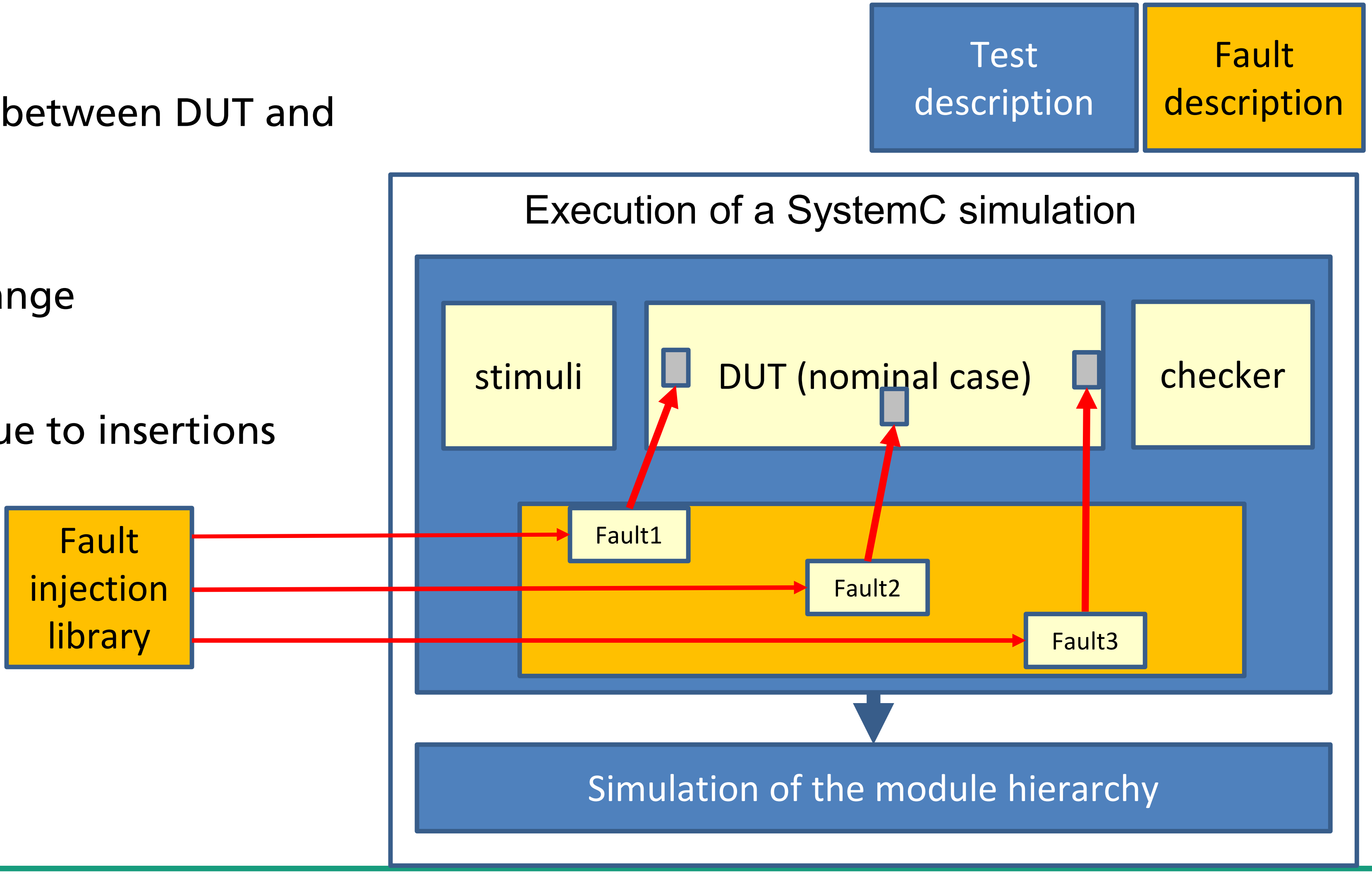
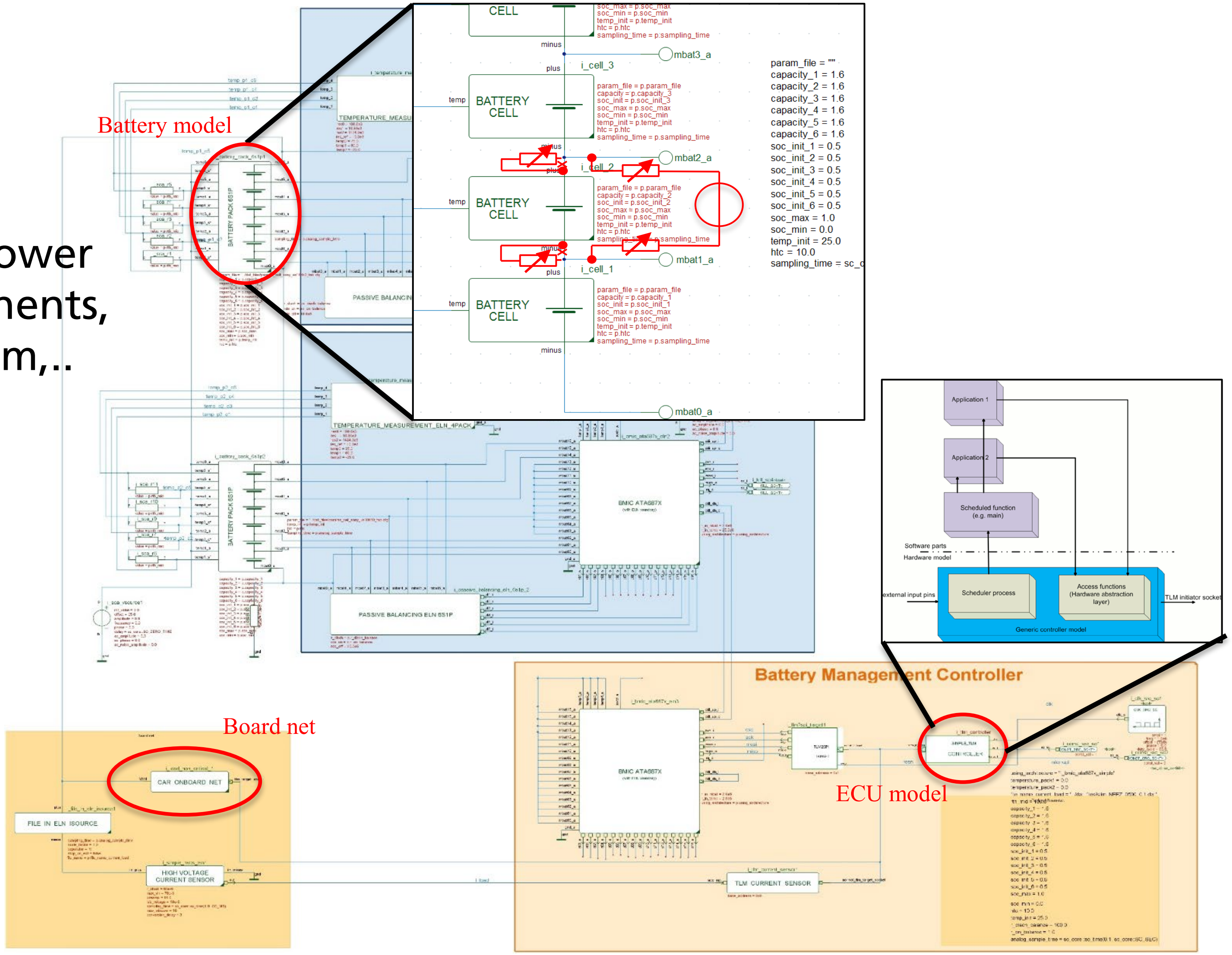
Fault injection approach for SystemC/ SystemC AMS
Principle of the dynamical fault injection

- Clear separation between DUT and test description
- No DUT code change
- Avoiding bugs due to insertions of test artifacts



Battery management system (BMS)
Battery fault injection

- Board net as part of a safety-critical system
- Safety concept requires stabil power supply for safety critical components, e.g. ABS, Airbag, breaking system,..
- Safety mechanism is part of the software application



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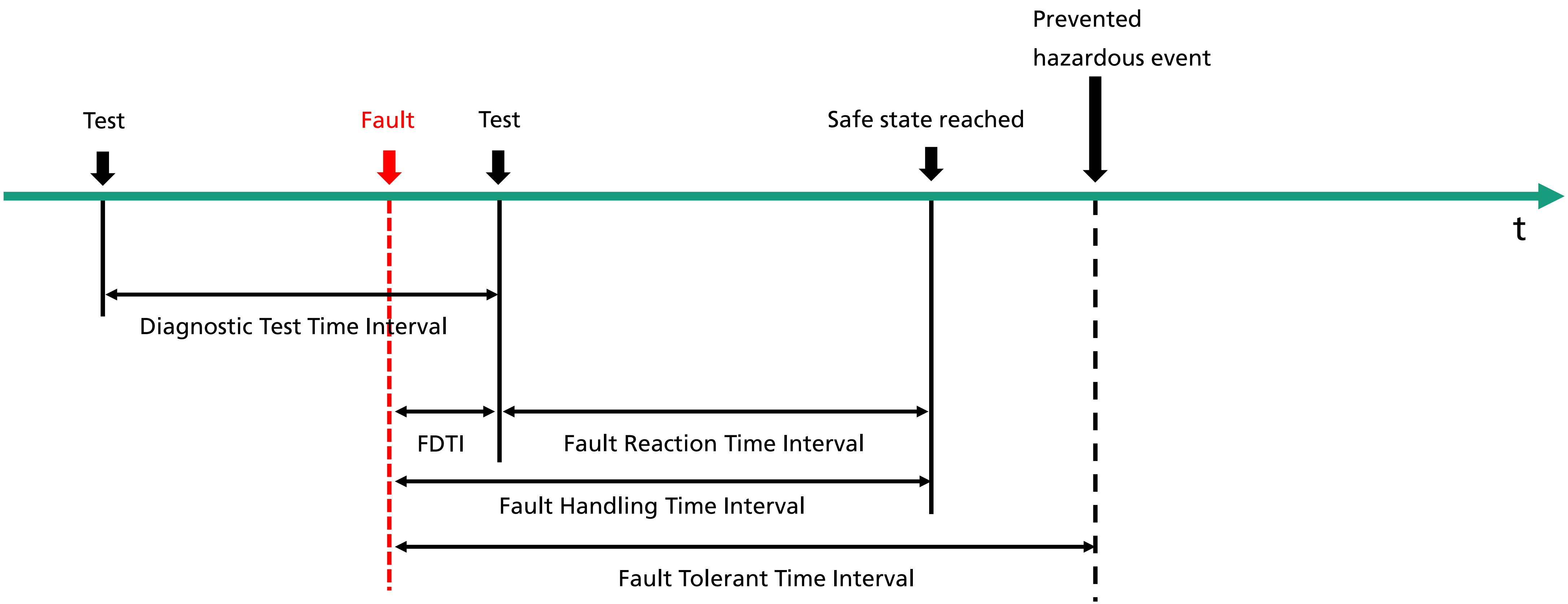
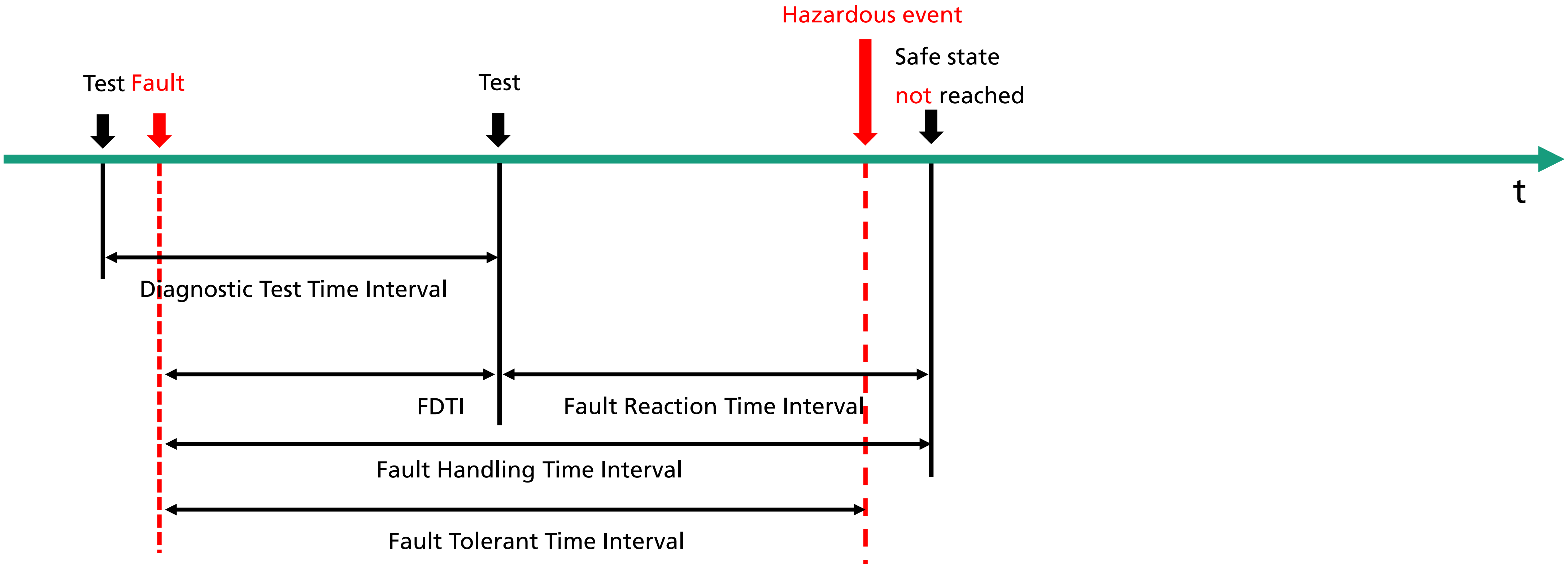
Diagnostic Coverage Determination
Timing limitations for DC



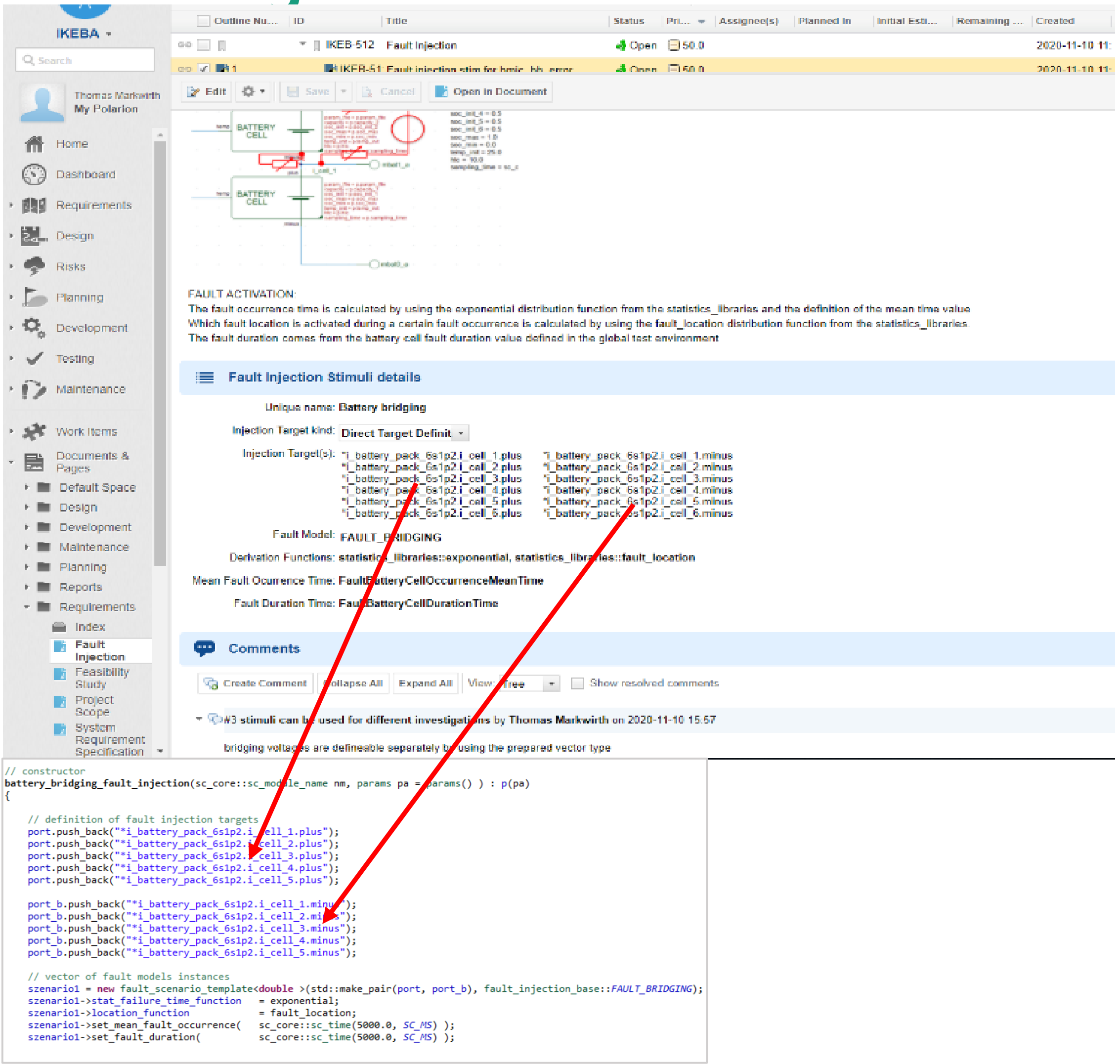
Diagnostic Coverage Determination
Timing limitations for DC



Battery management system (BMS)

Fault description embedded into structured generation flow

- Automated injection flow
  - Safety concept specified in requirement management tool
  - Requirement for fault simulation defined
  - Automated source code and testcase generation
  - Regression



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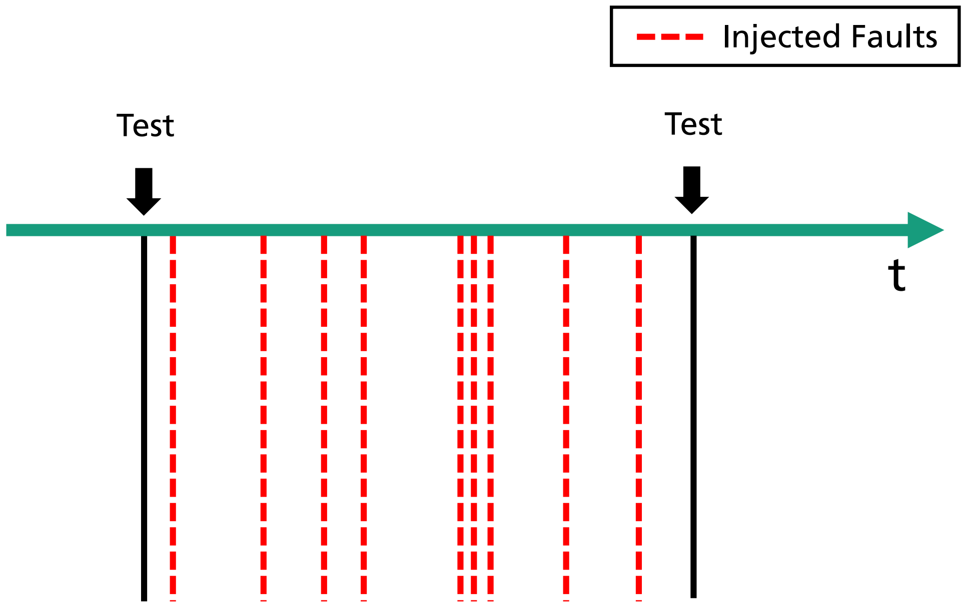
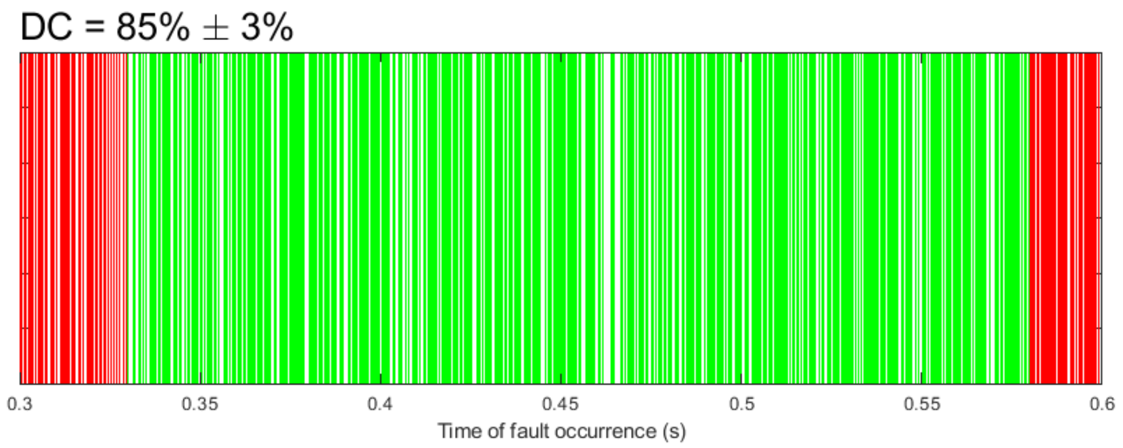
Diagnostic Coverage Determination
Monte-Carlo Simulations

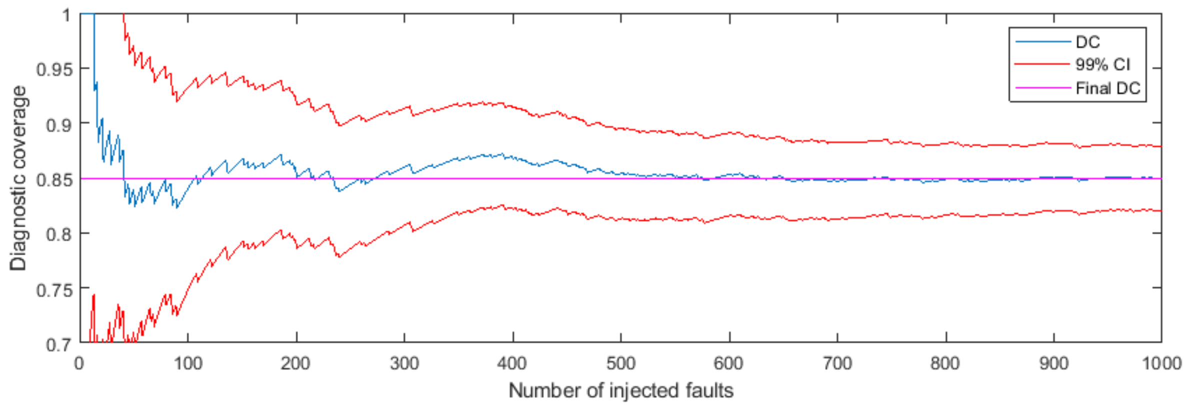
- Define parameter space(s) – e.g. DTTI
- Inject fault at random points
- Estimate DC from ratio of faults with prevented hazardous event to all injected faults
- Advantages:
  - Best efficiency for many parameter spaces
  - Can map whole parameter space
- Disadvantages:
  - Normally not sensible for one parameter space and required accuracy
  - Complicated to set up compared to other approaches



Example: 9 randomly injected faults – low accuracy

Diagnostic Coverage Determination
Monte-Carlo Simulations - Results





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Diagnostic Coverage Determination

FMEDA

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			Temperature too high	20	x	2	SM4	95	0	0,1
Plug-Connector to main line	15	x	Open	30	x	4,5	SM5	99	0	0,045
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			Intermittend contact	60	x	9	SM5	99	0	0,09
Sum total [FIT]	123							Sum total [FIT]	2,2	6,535
Sum safety-relevant [FIT]	123							SPFM [%]	92,9	
Sum not-safety-relevant [FIT]	0									

- Safety mechanism 2: Measure battery voltage and if a drop occurs connect redundant battery

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Diagnostic Coverage Determination
Sum up

- SystemC/ SystemC AMS is usable for a quantitative safety verification
- Could be demonstrated, that dynamic fault injection approach is very efficient for this task
- But…
  - No standardized interchange formats, e.g. for fault descriptions, metrics, … ,simulation results as e.g. FMEDA input
  - Mainly “own” libraries for fault injection, statistics, interfaces… used

THANK YOU FOR YOUR ATTENTION
YOUR CONTACT PARTNER

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