

University of Stuttgart

Institute of Machine Components

Reliability Department

Influence of Operating Load Spectra Shapes on Reliability Demonstration Test Planning

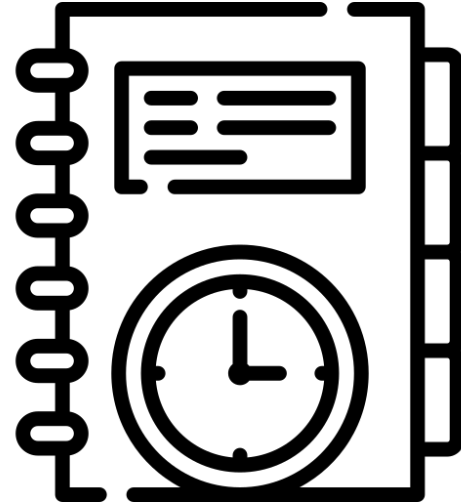
30. June 2022

Achim Benz, M. Sc.



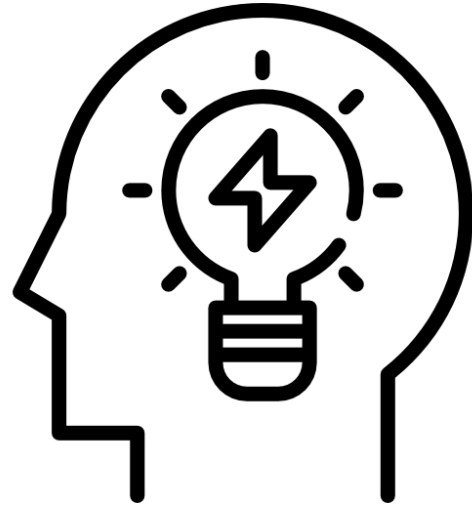
Agenda

- Introduction and Motivation
- Approach
- Case Study
- Summary and Future Work



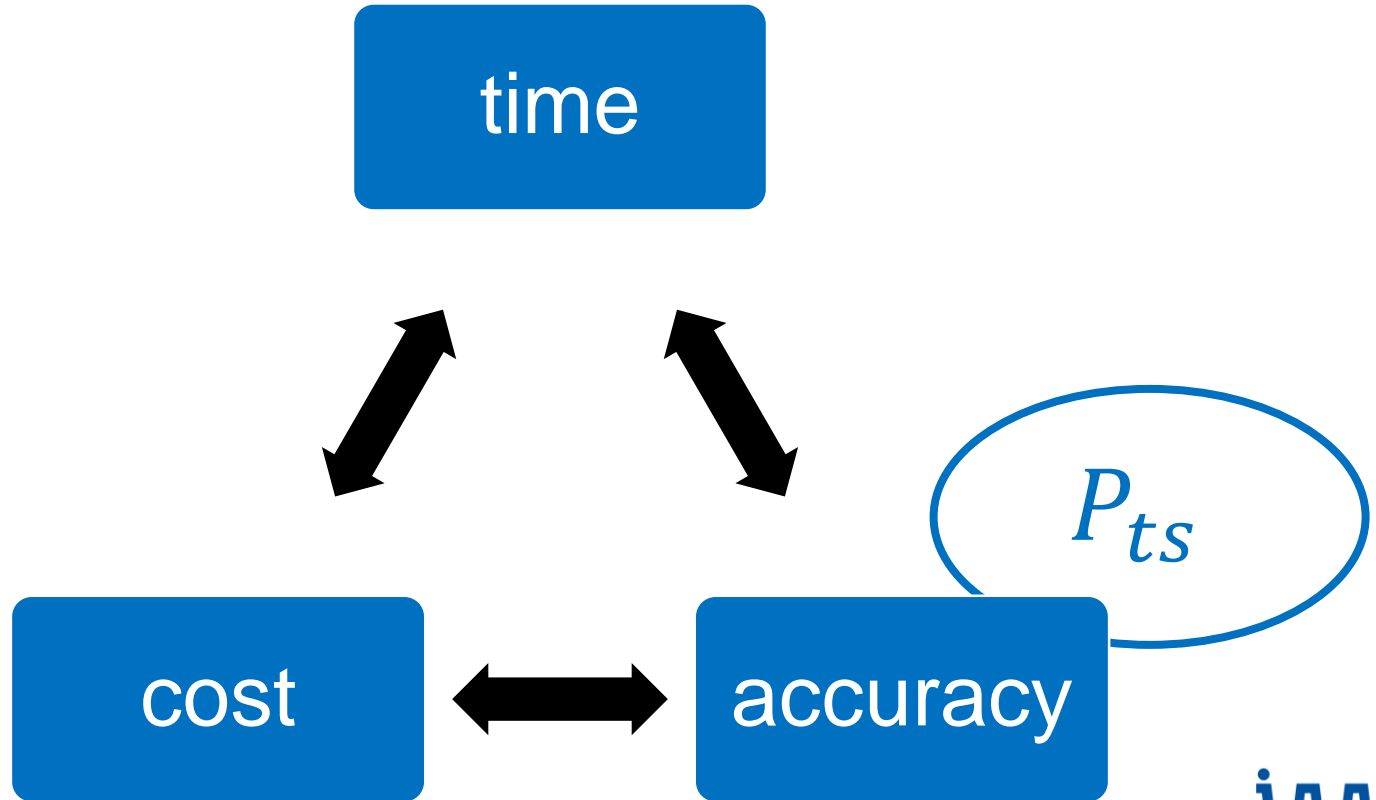
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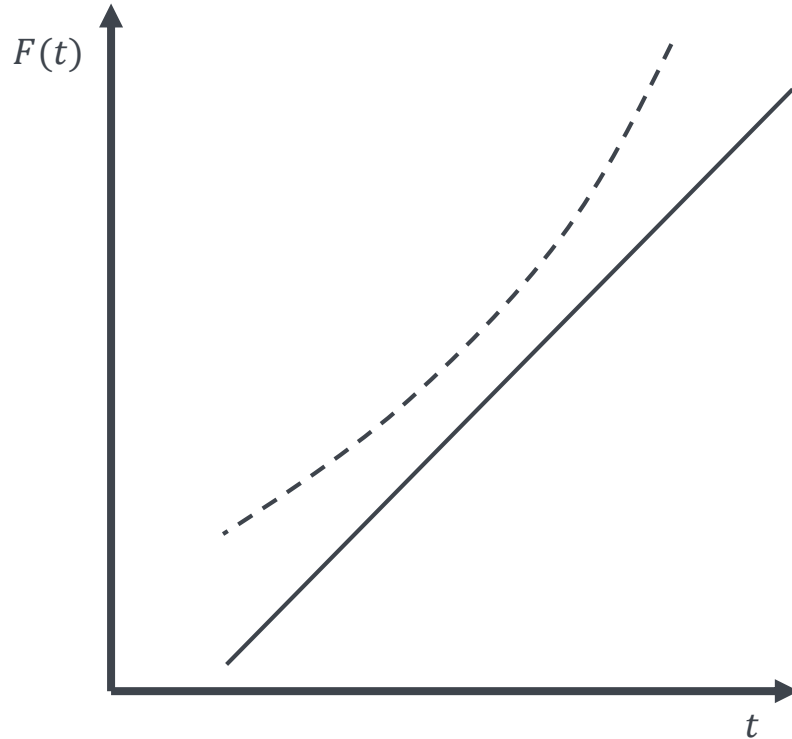
Introduction and Motivation

Decision triangle for reliability demonstration test strategies:



Introduction and Motivation

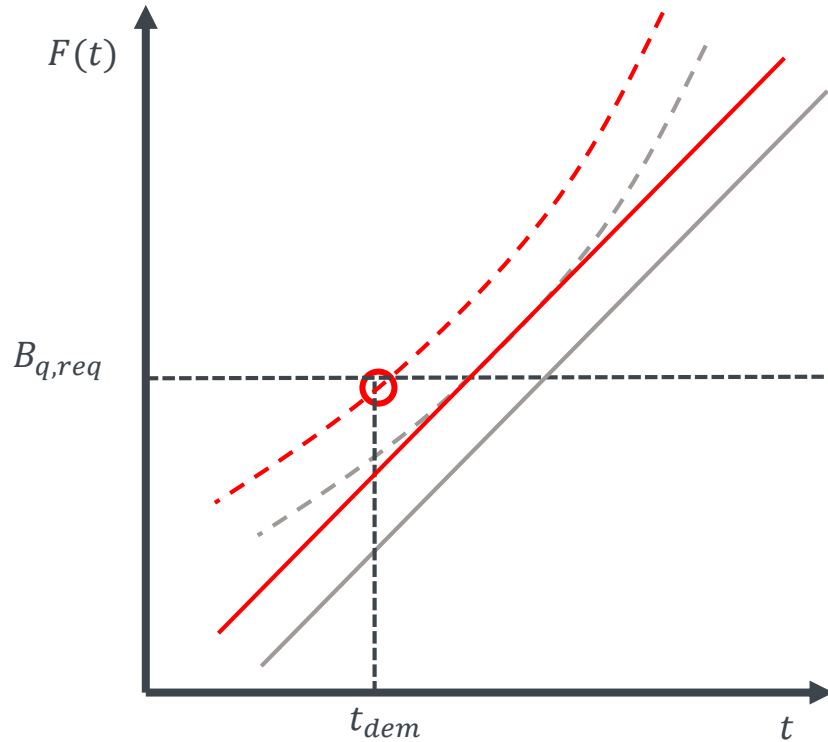
P_{ts} calculation with Monte-Carlo-Simulations



Prior knowledge

Introduction and Motivation

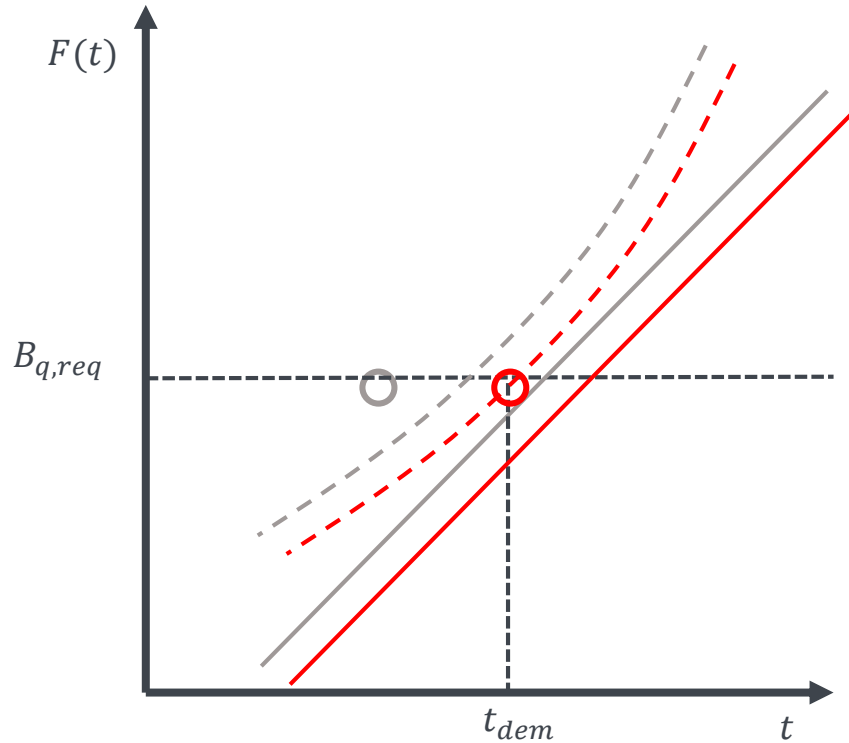
P_{ts} calculation with Monte-Carlo-Simulations



1. Replication

Introduction and Motivation

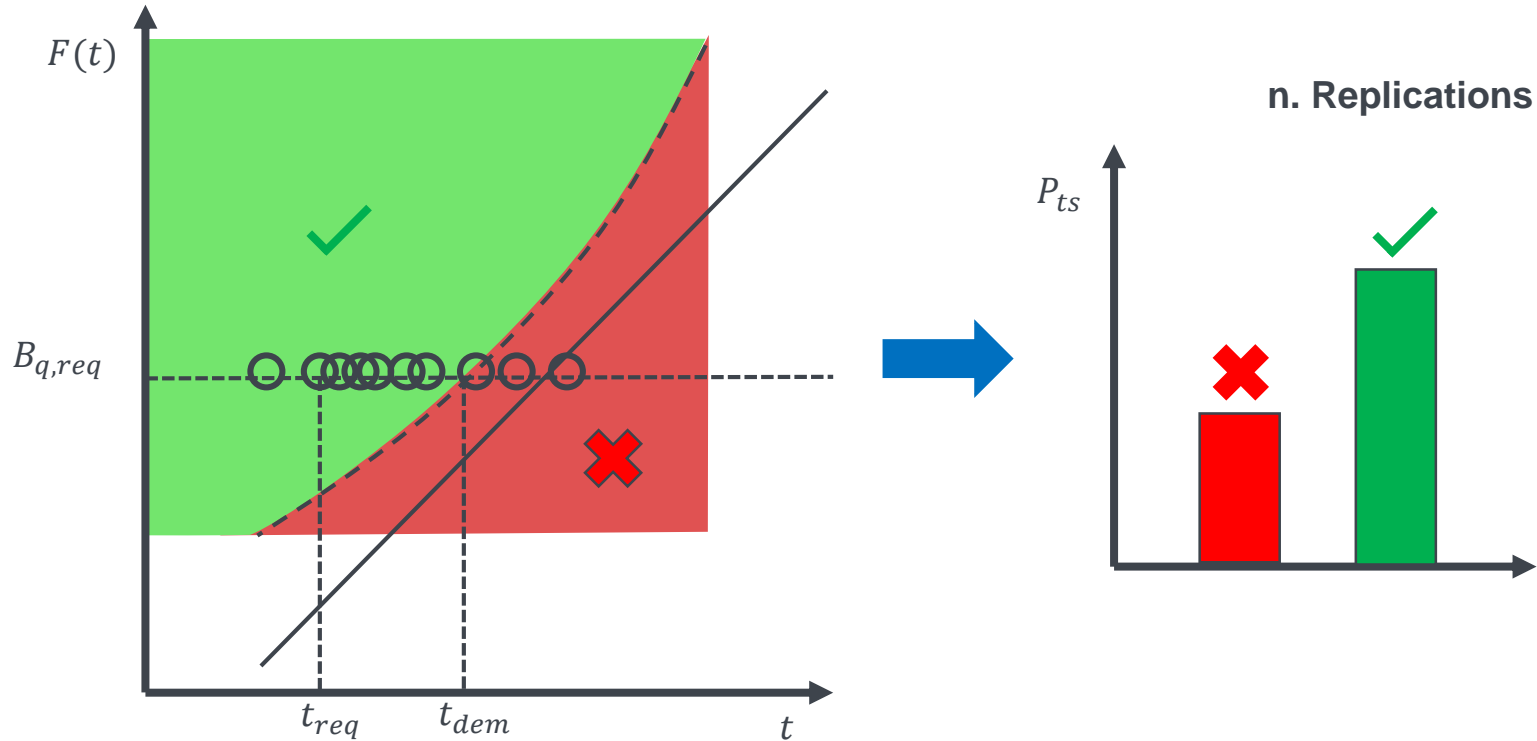
P_{ts} calculation with Monte-Carlo-Simulations



2. Replication

Introduction and Motivation

P_{ts} calculation with Monte-Carlo-Simulations



Introduction and Motivation

New Formula for Probability of test success for damage by applying Miners rule:

$$D_{acc,req} = \sum \frac{n_i}{(1 - S) \cdot t_{real,i}} = \frac{1}{1 - S} \cdot D_{acc,real}$$

$$P_{ts} = \frac{\text{number of } ((D_{acc,req}) \geq D_{acc,virt})}{D_{acc,req}}$$

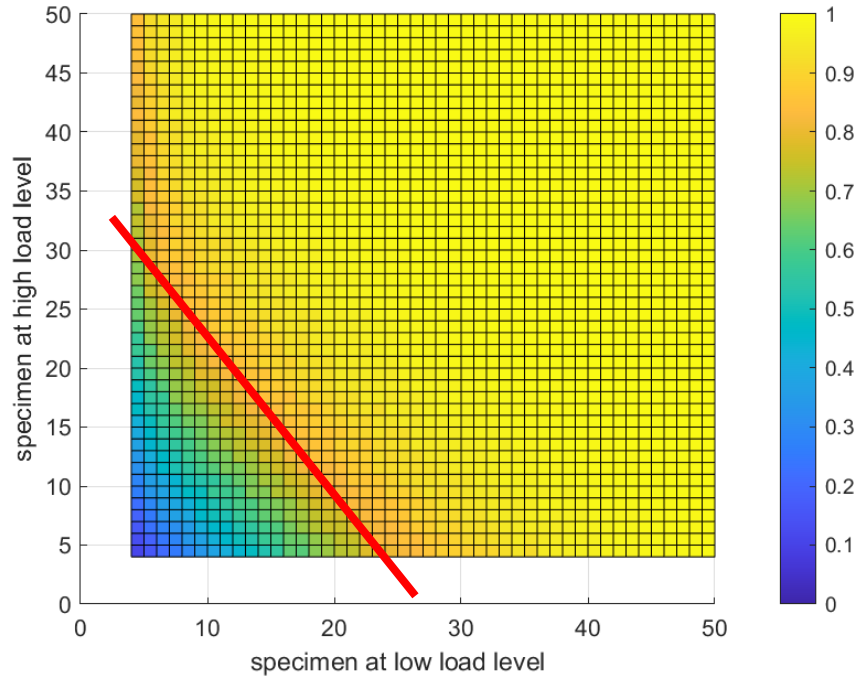
S = Safety Margin

$D_{acc,real}$ from prior knowledge

$D_{acc,virt}$ from simulated reliability test

Introduction and Motivation

P_{ts} for operating load spectra

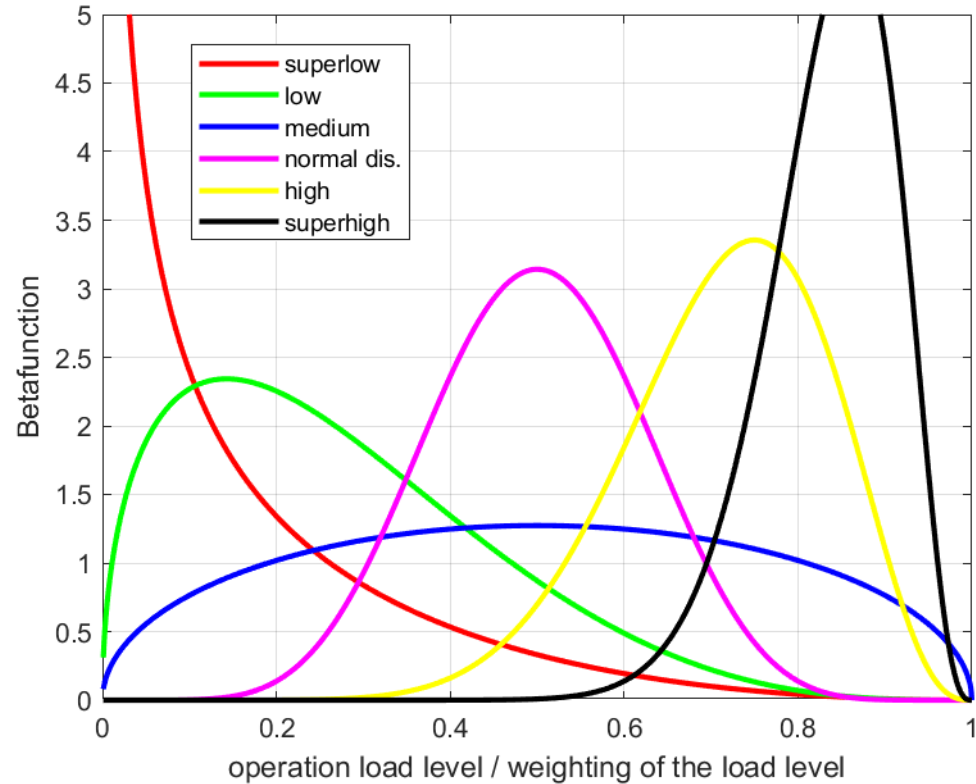


n_L	n_H	P_{ts} [%]	Cost [\$]	time [h]
6	31	90.90	6.6536e+05	67.931
5	35	90.32	6.9216e+05	65.216
5	36	90.82	7.2343e+05	66.579
5	37	90.40	7.4162e+05	66.63
5	38	92.15	7.7184e+05	67.799

Introduction and Motivation

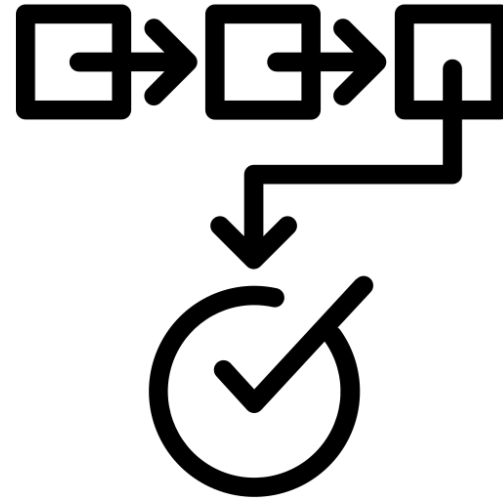
P_{ts} for operating load spectra

- Influence of operating load spectra shapes?



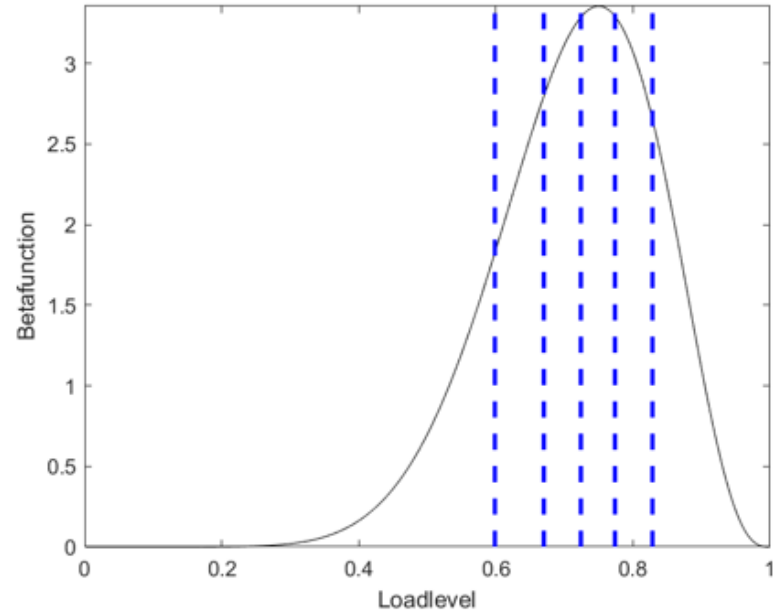
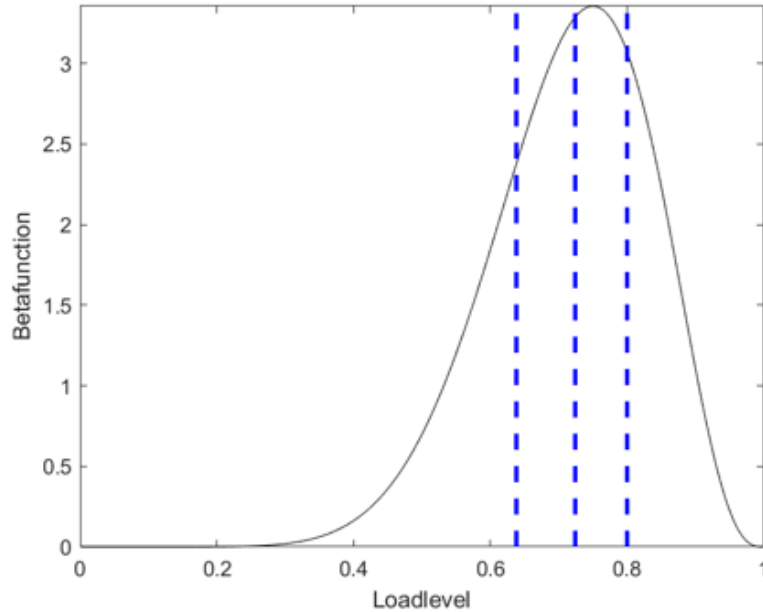
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Approach

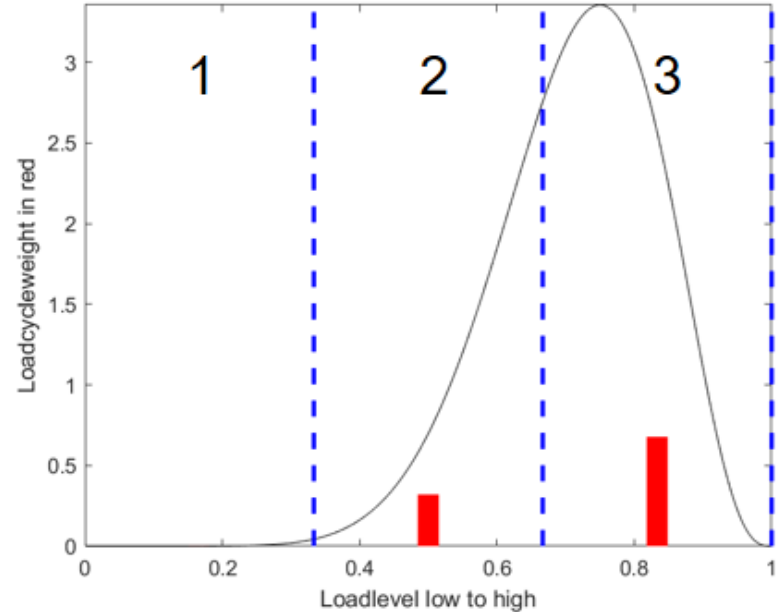
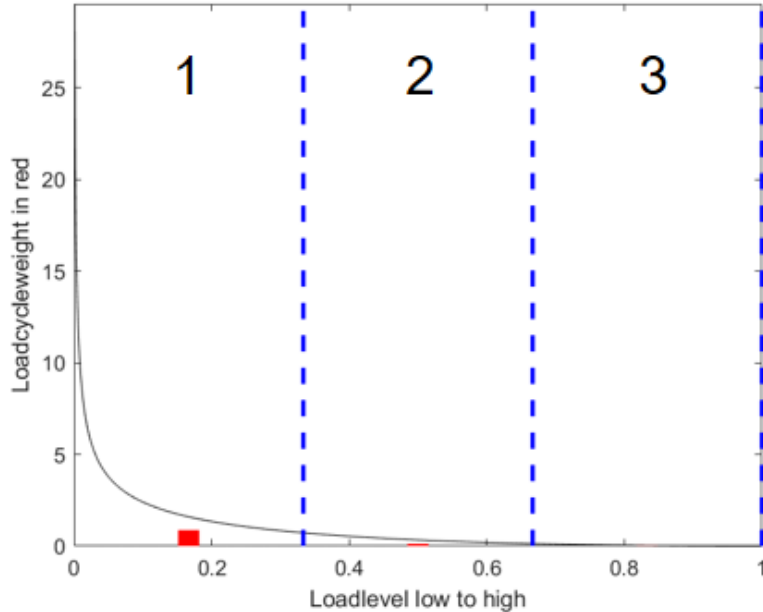
Deriving operating load spectra



- The first betafunction is divided into $X+1$ equal areas. The X intersection points with the x-axis result in the individual load levels of the load spectrum.

Approach

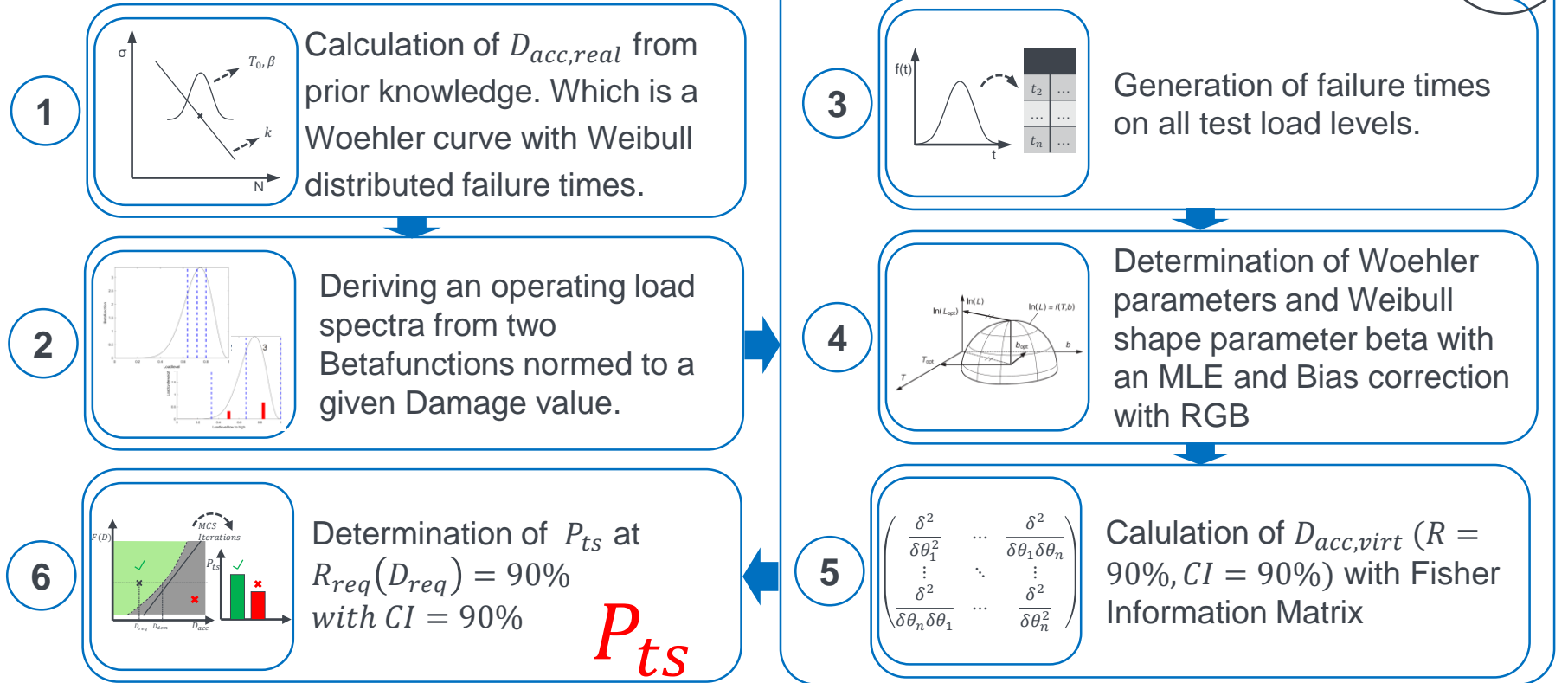
Deriving operating load spectra



- The second beta function is divided into X equal x-axis sections. The X areas give the weighting of the individual load levels of the load spectrum at the damage. Thus, the load level can always be normalized to a damage.

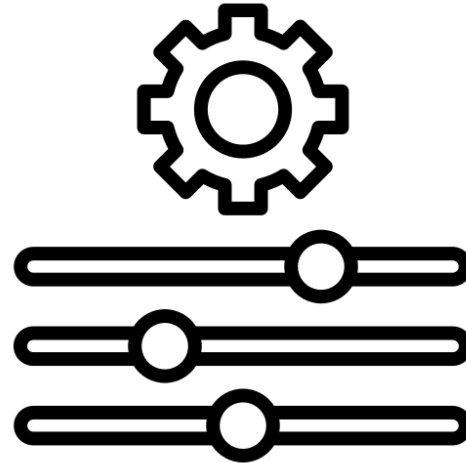
Approach

Simulation Steps:



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Case Study

- How does the shape of the operating load spectra affect the P_{ts} ?
- How does the number of operating load levels affect the P_{ts} for load spectra?

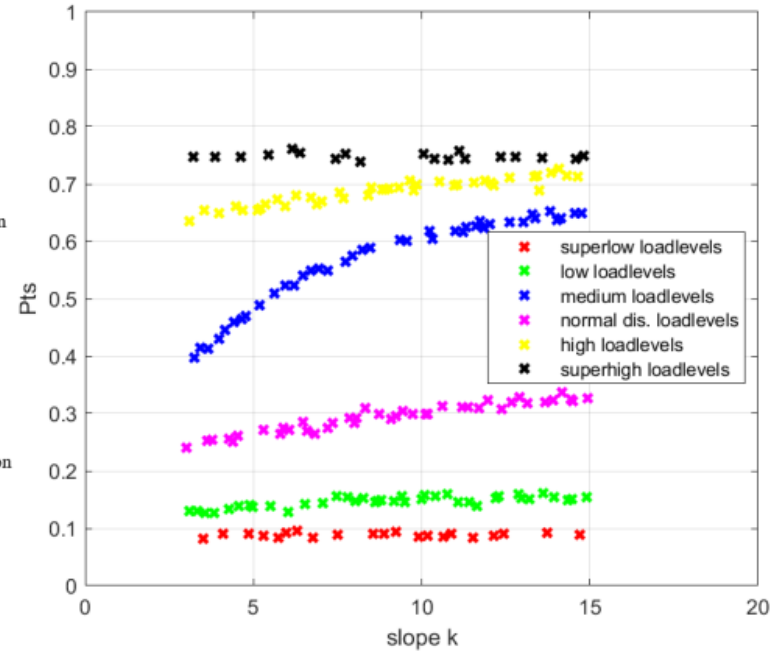
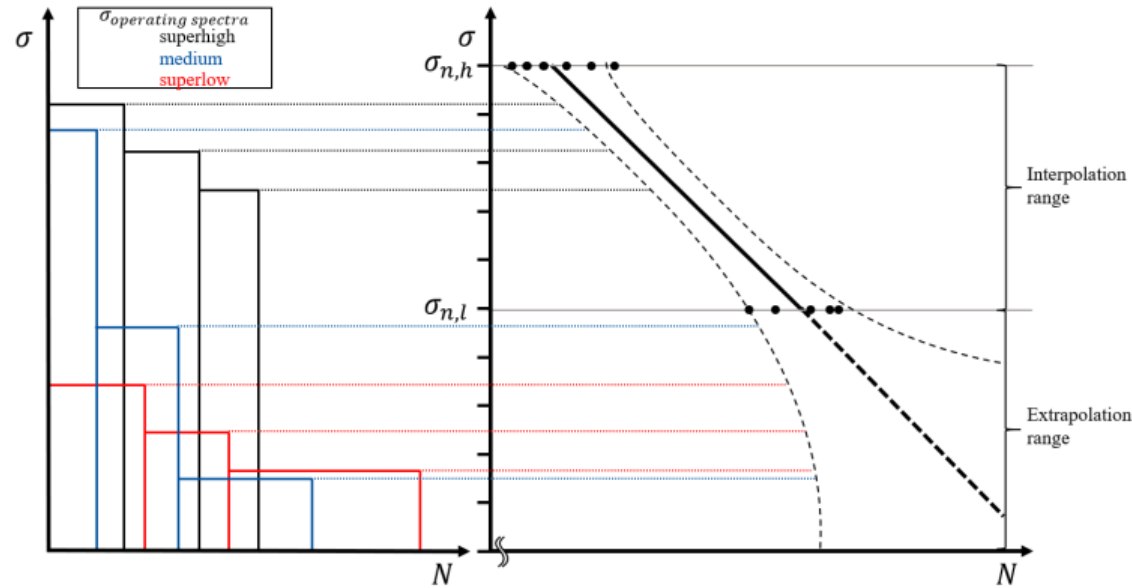


Case Study

	Parameter		Value space
	Changing parameters	Woehler slope k	
specimen on upper test load level n_H		5 - 50	
specimen on lower test load level n_L		5 - 50	
upper test load level σ_H		0.1 - 1	
lower test load level σ_L		0.1 - 0.9	
Amount of operation load level X		2 - 10	
Beta function parameters		superlow	A = 0.5 B = 3
		low	A = 1.5 B = 4
		medium	A = 1.5 B = 1.5
		norm. dist.	A = 8 B = 8
	high	A = 10 B = 4	
	superhigh	A = 20 B = 4	
Constant Parameters	Reliability requirement R		90%
	Confidence level CI		90%
	Woehler location parameter N_D		1
	Safety margin s		0.2
	Damage D		1

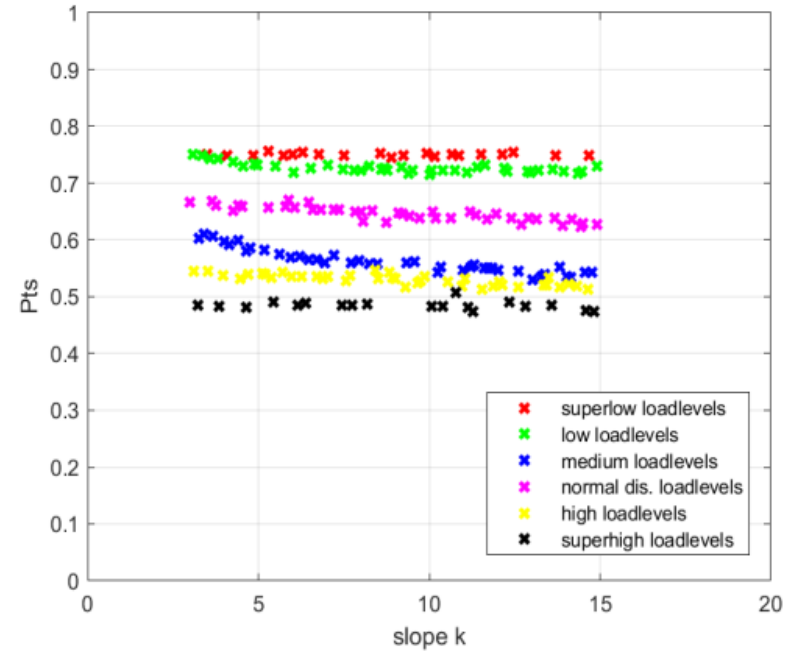
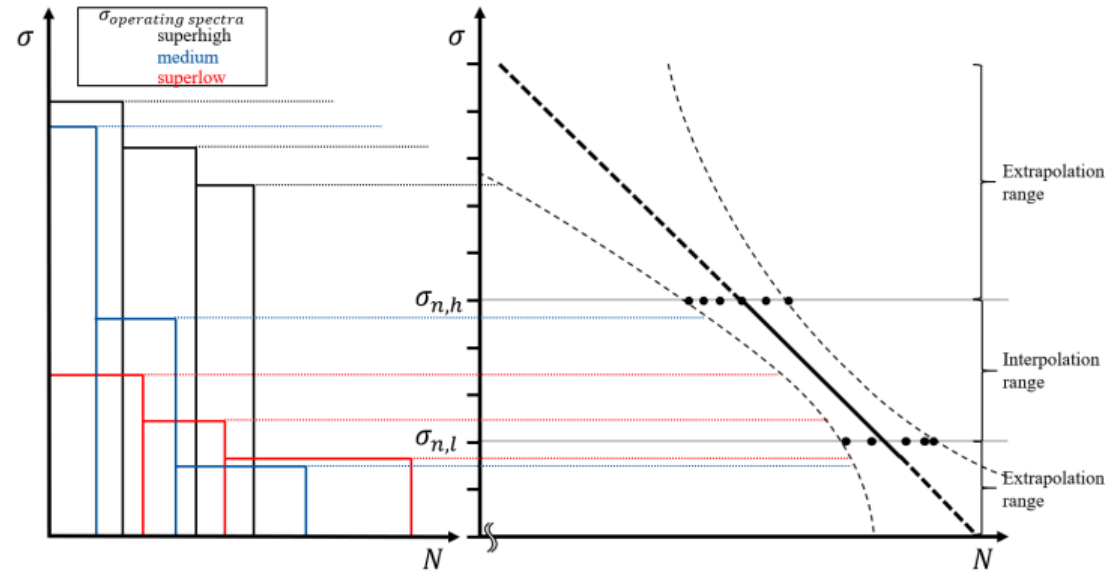
Case Study

Results P_{ts} with test levels: $\sigma H=1$; $\sigma L=0.8$



Case Study

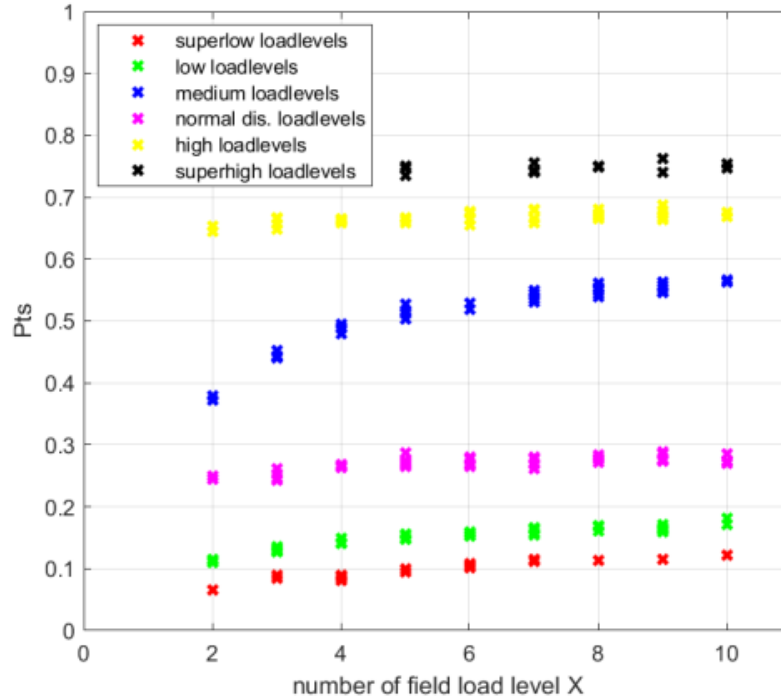
Results P_{ts} with test levels: $\sigma H=0.5$; $\sigma L=0.2$



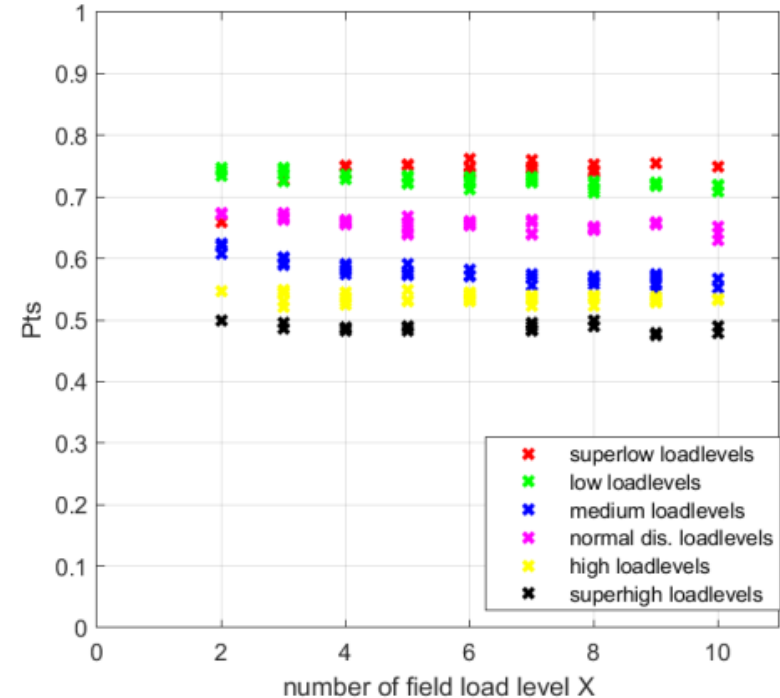
Case Study

Influence of number of operating load levels

left: $\sigma_H=1; \sigma_L=0.8;$

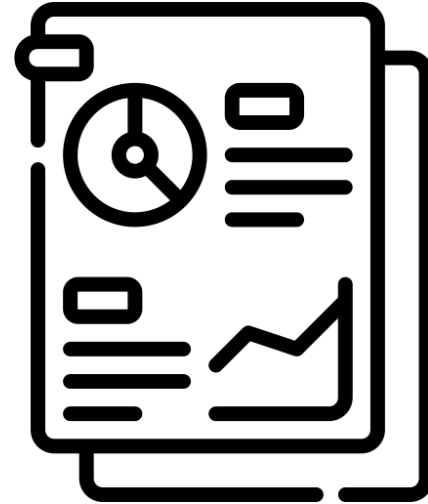


right: $\sigma_H=0.5; \sigma_L=0.2;$



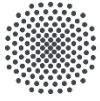
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Summary and Future Work

- Summary:
 - The test load levels interact with the operating load spectrum directly through the confidence level of the life model.
 - This shows that the more loads of the operating load spectrum lie within the narrow confidence level between the two test loads, the higher the P_{ts} .
- Further work:
 - Performing a larger parameter study and training a NN with the results.
 - Use of more than 2 test load levels might be used to optimize P_{ts} .



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Thank you!



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