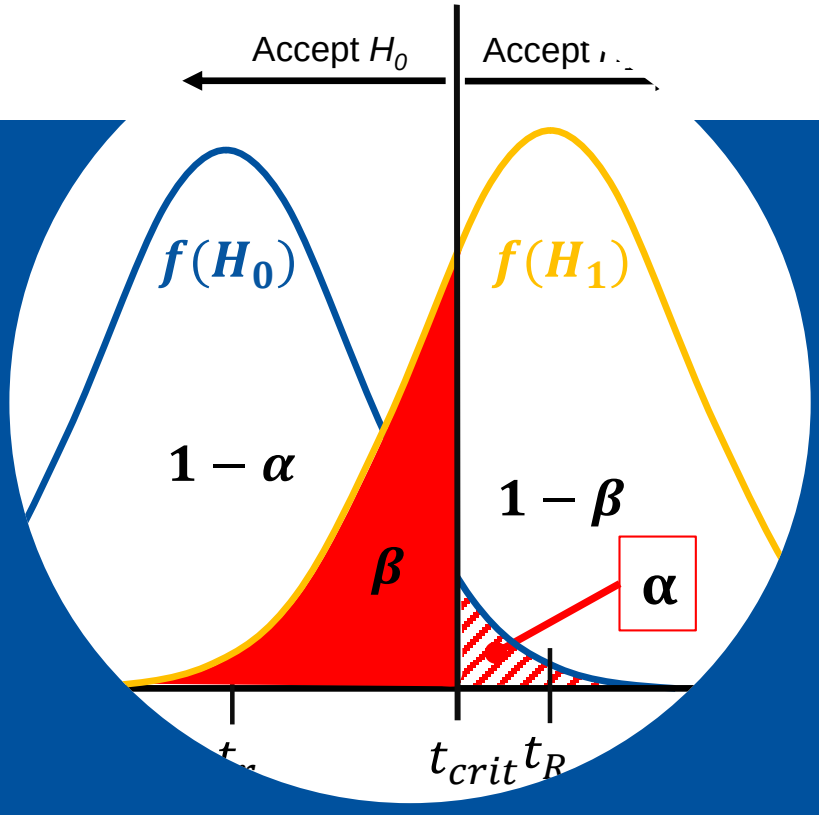
University of Stuttgart
Institut für Maschinenelemente
Forschungsbereich Zuverlässigkeitstechnik

Risk-based Reliability Demonstration Test Planning for Decision Making under Uncertainty



Probabilistic Safety Assessment and Management Conference (PSAM 16)

Dr.-Ing. Martin Dazer

RELTEST SOLUTIONS
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Scope

1. **Reliability research at the University of Stuttgart**
2. Decision making under Uncertainty
3. Risk based test planning procedure
4. Case studies
5. Summary

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Institute of Machine Components

Overview

- Research fields: Reliability Engineering, Sealing Technology, Driveline Technology, Rail Vehicle Technology
- Scientific staff: 2 profs, 5 doctors, about 35 PhD students
- App. 100 bachelor and master theses
- App. 50 publications yearly

Institute of Machine Components

Research groups

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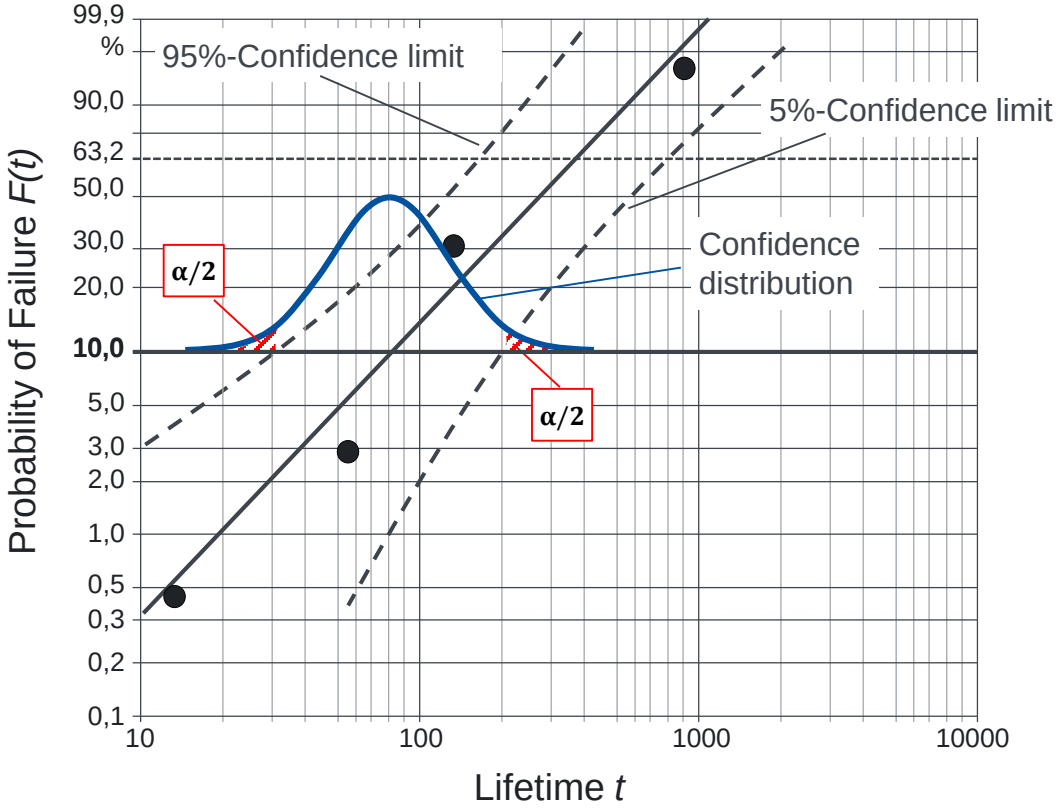
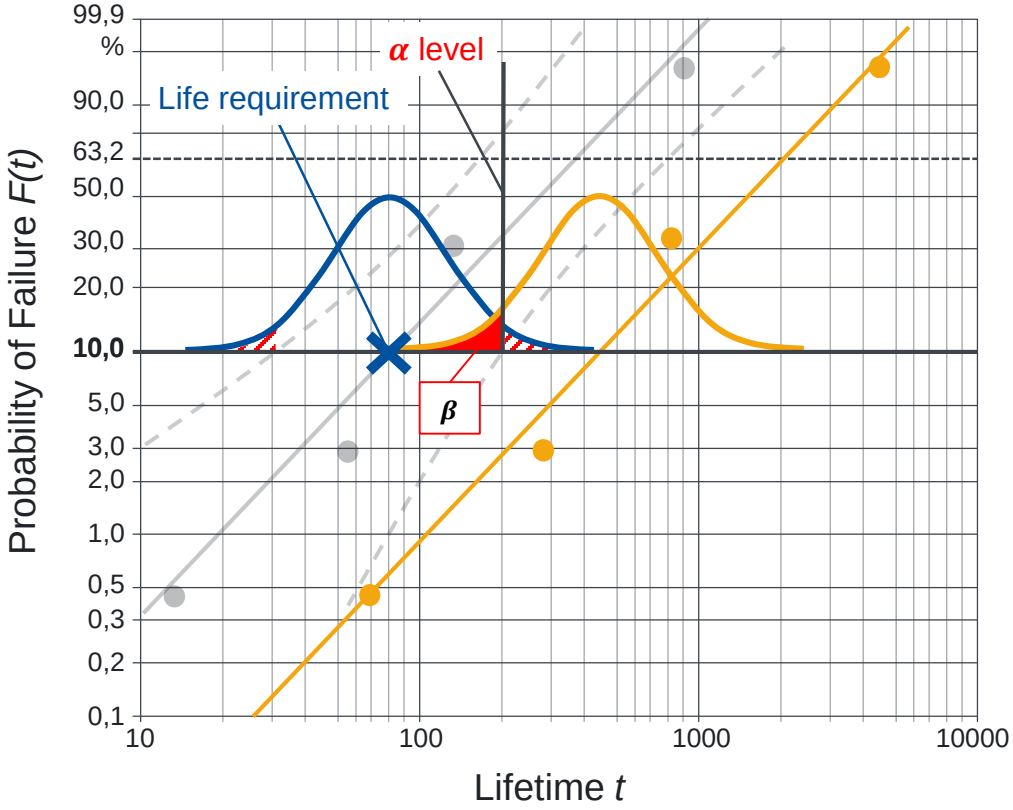
Decision Making under Uncertainty

Challenge



Decision Making under Uncertainty

Challenge



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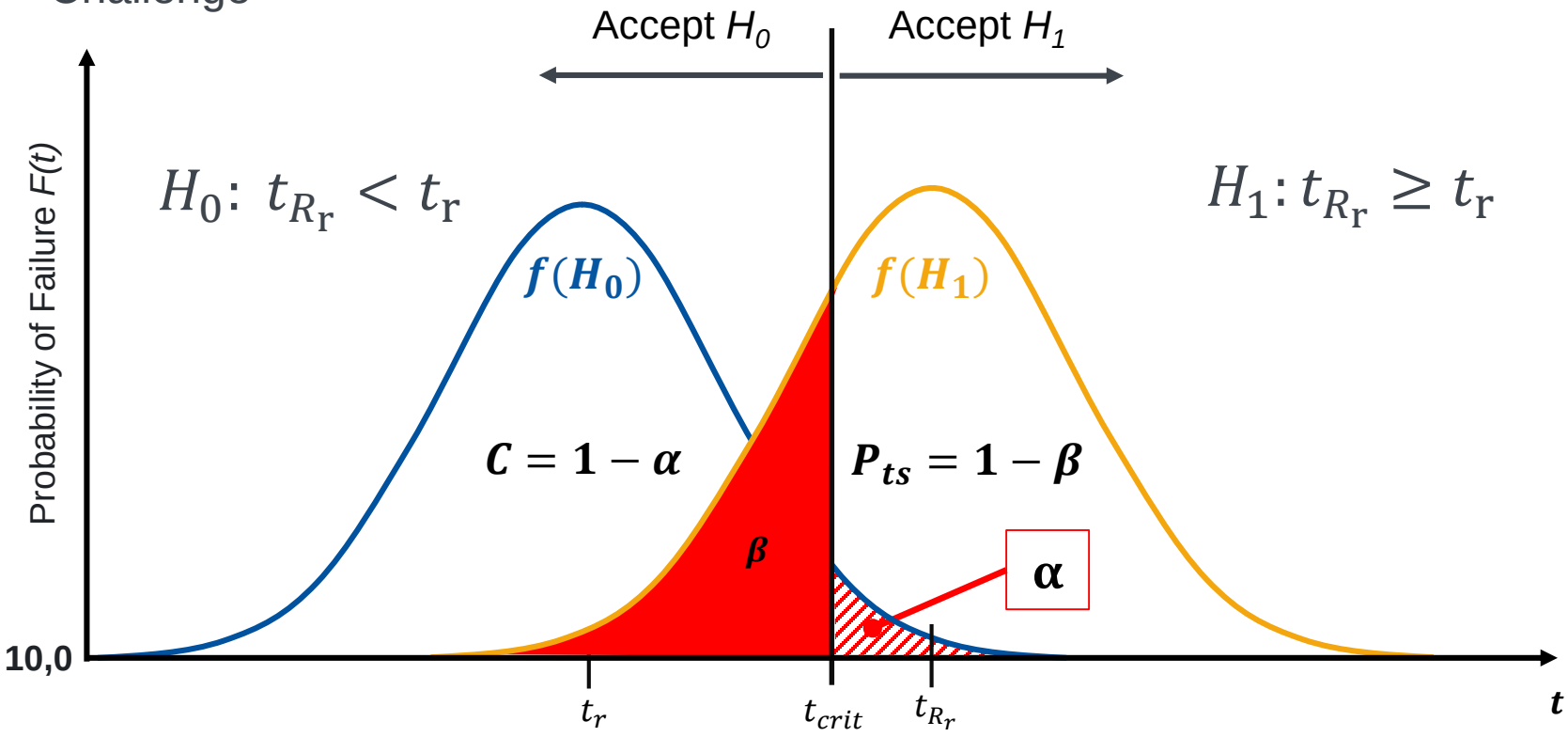
Decision Making under Uncertainty

Challenge



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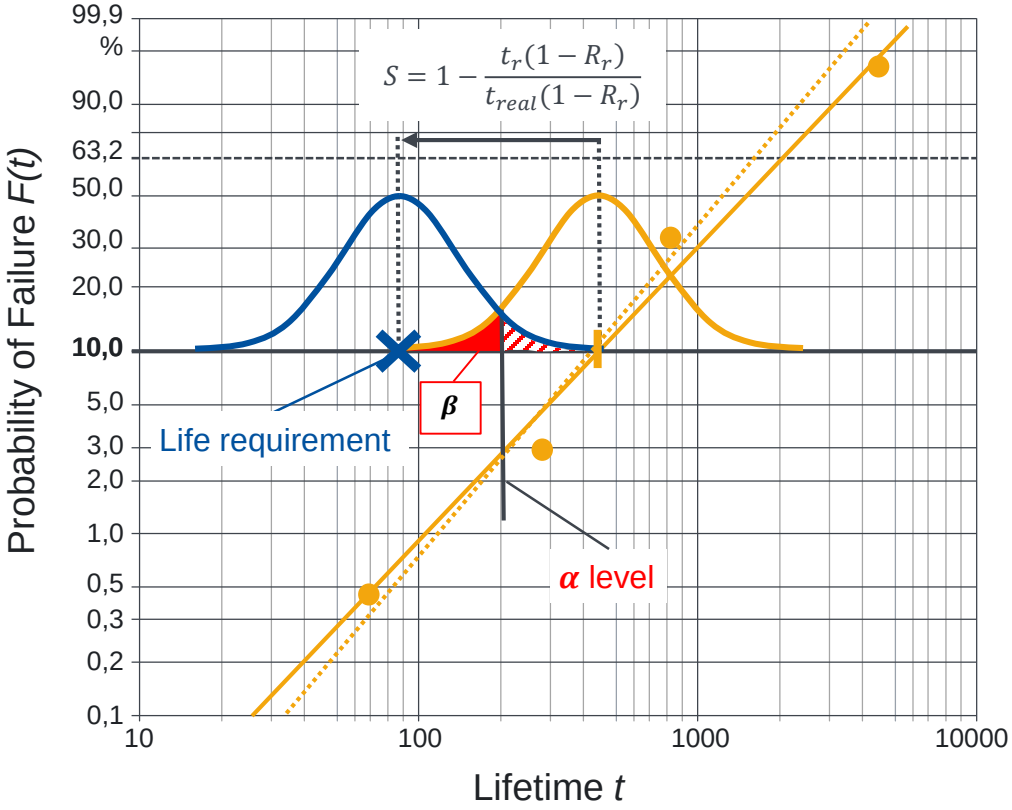
Scope

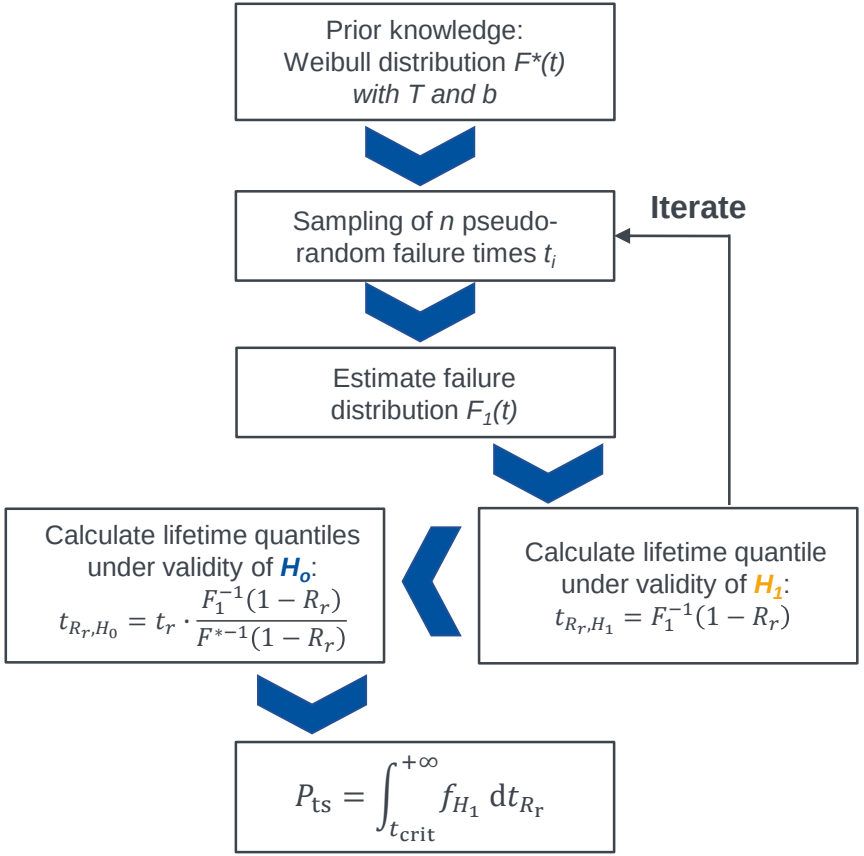
3 Risk based test planning procedure

- End-of-Life Test planning
- Accelerated End-of-Life Test planning
- Zero Failure Testing

Risk based test planning procedure

End-of-Life Testing





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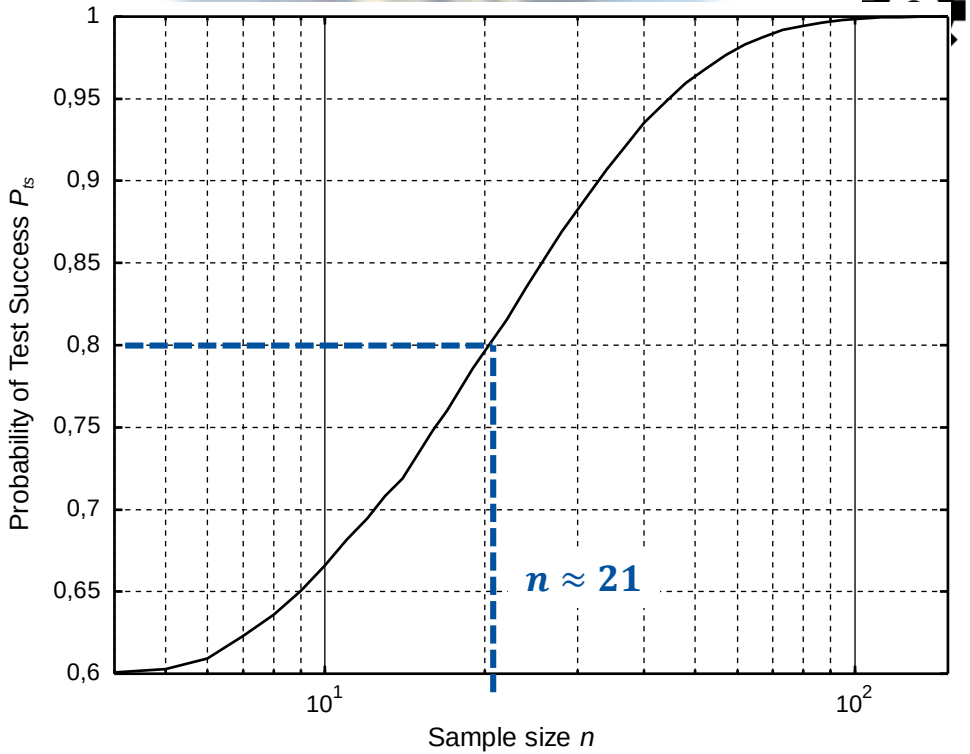
Risk based test planning procedure

End-of-Life Testing Case Study

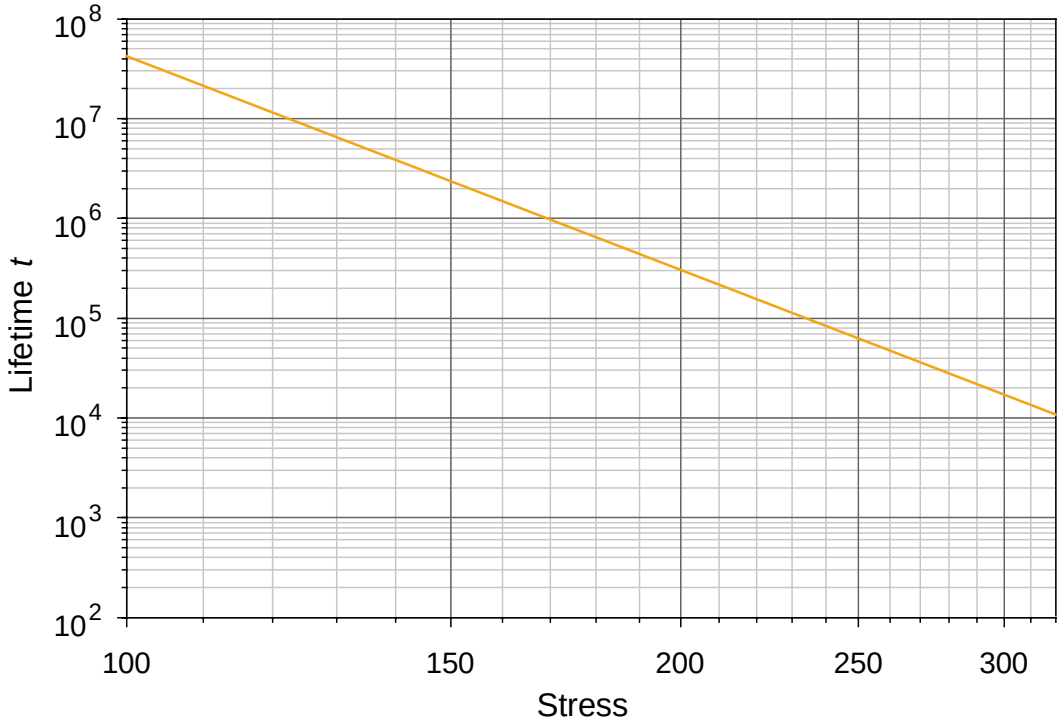
Requirements	
Reliability	90 %
Confidence	90 %
Lifetime	$2 \cdot 10^6$ revolutions

Prior knowledge	
Shape *b*	3
Scale *T*	$6.06 \cdot 10^6$ revolutions



Risk based test planning procedure

Accelerated End-of-Life Testing



Life model:

$$\ln(T) = \ln(m_2) - \ln(B) \cdot m_1$$

$$\ln L = \sum_{i=1}^{n} \ln\left(\frac{b}{m_2 \cdot B^{-m_1}} \cdot \left(\frac{t_i}{m_2 \cdot B^{-m_1}}\right)^{b-1} \cdot e^{-\left(\frac{t_i}{m_2 \cdot B^{-m_1}}\right)^{b}}\right)$$

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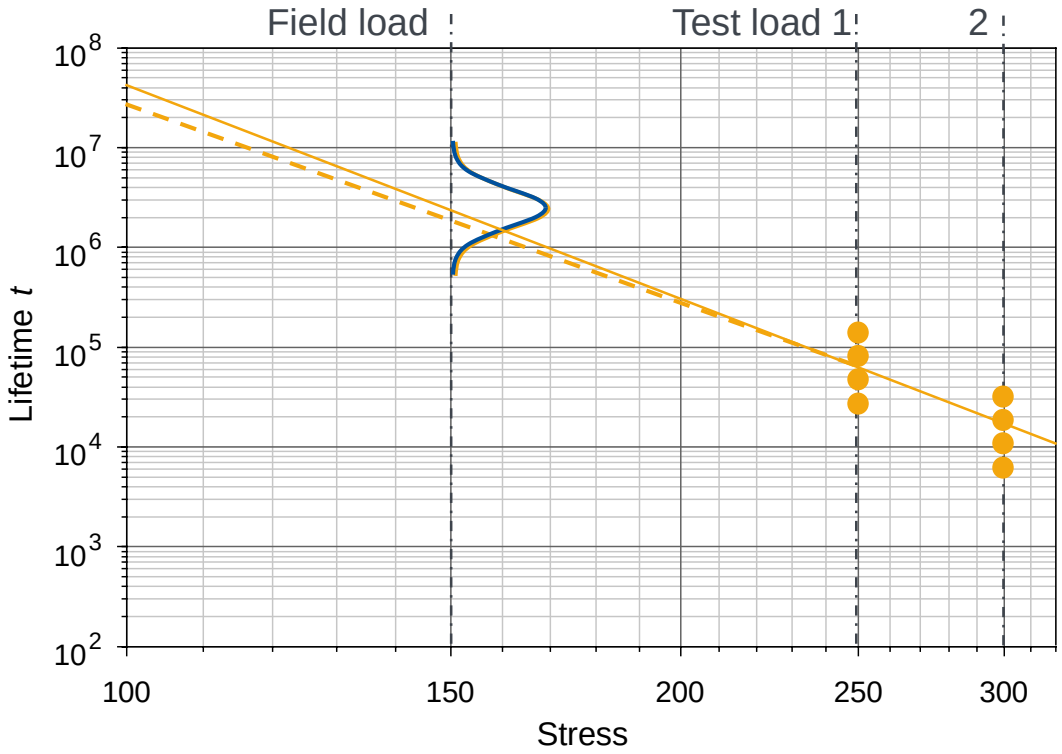
Risk based test planning procedure

Accelerated End-of-Life Testing



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Prior knowledge:
Weibull distribution *F*(t)*
with T and b
Lifetime model parameters:
Slope m_1
Baseline m_2

Simlar procedure to EoL

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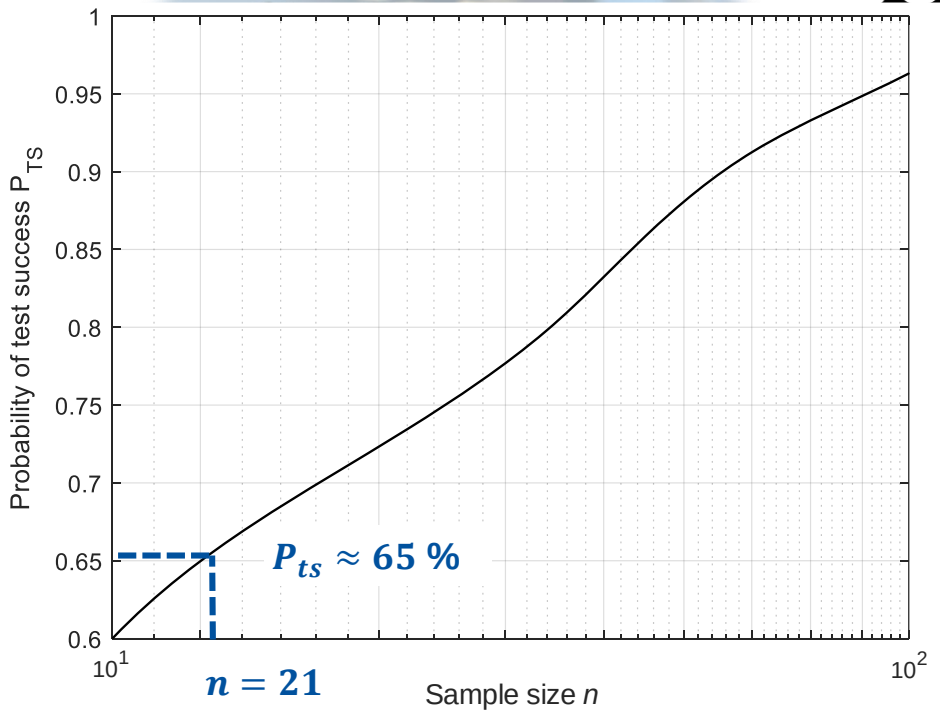
Risk based test planning procedure

Accelerated End-of-Life Testing Case Study

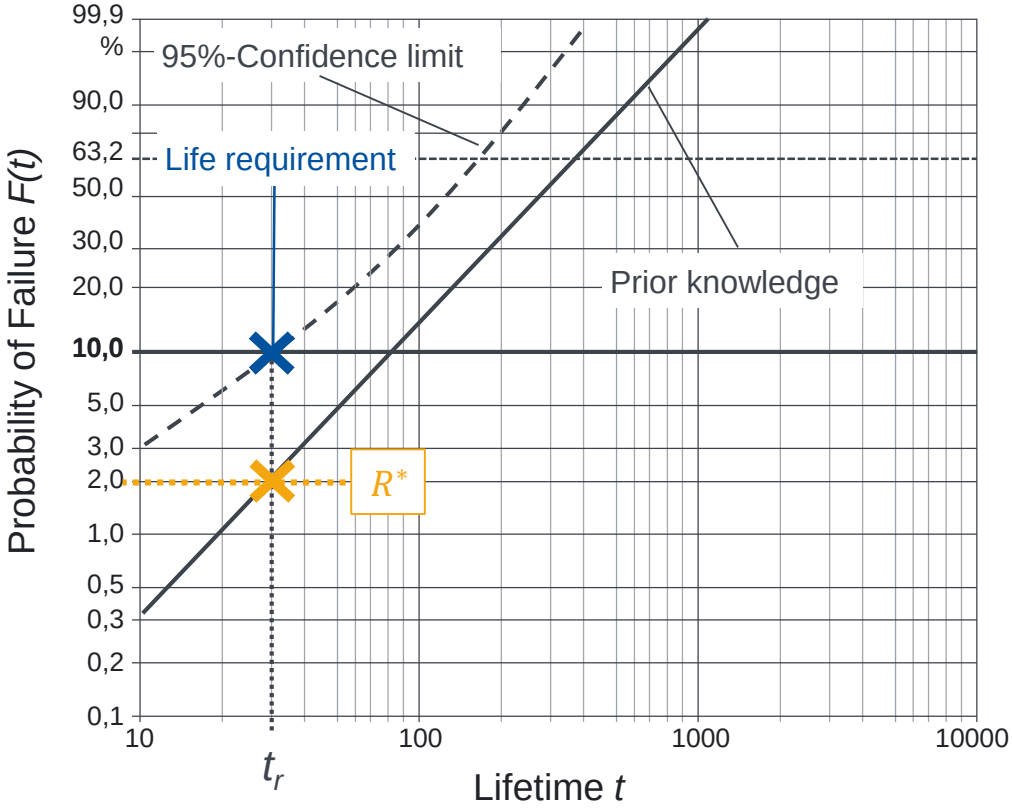
Requirements	
Reliability	90 %
Confidence	90 %
Lifetime	$2 \cdot 10^6$ revolutions

Prior knowledge	
Shape *b*	3
Scale *T*	$6.06 \cdot 10^6$ revolutions
Slope *k*	5



Risk based test planning procedure

Zero Failure Testing



$$H_0\colon R(t_r) < R_r(t_r)$$

$$H_1\colon R(t_r) \geq R_r(t_r)$$

$$C = 1 - \sum_{i=0}^{f} \binom{n_{SR}}{i} \cdot \left(R_r(t_r)\right)^{n_{SR}-i} \cdot \left(1 - R_r(t_r)\right)^{i}$$

$$P_{ts} = \sum_{i=0}^{f} \binom{n_{SR}}{i} \cdot \left(R^*(t_r)\right)^{n_{SR}-i} \cdot \left(1 - R^*(t_r)\right)^{i}$$

$$P_{ts} = \left(R^*(t_r)\right)^{n_{SR}} \quad \text{with} \quad R^*(t_r) \approx e^{-\left(\frac{t_r}{T^*}\right)^{b^*}}$$

Risk based test planning procedure

Zero Failure Testing

Requirements	
Reliability	90 %
Confidence	90 %
Lifetime	30,000 cycles

Prior knowledge	
Shape *b*	3
Scale *T*	96,000 cycles

$$C = 1 - \sum_{i=0}^{f} \binom{n_{SR}}{i} \cdot \left(R_r(t_r)\right)^{nSR^{-i}} \cdot \left(1 - R_r(t_r)\right)^{i}$$

$$n_{SR} = \frac{\ln(1-C)}{\ln\left(\left(R_r(t_r)\right)\right)} = 22$$

$$R^*(t_r) \approx e^{-\left(\frac{t_r}{T^*}\right)^{b^*}} = e^{-\left(\frac{30{,}000}{96{,}000}\right)^{3}} \approx 97\ \%$$

$$P_{ts} = \left(R^*(t_r)\right)^{n_{SR}} = (0{,}97)^{22} \approx 51\ \%$$

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Summary

- Reliability test planning and reliability demonstration always take place under uncertainty.
- Decisions have to be made with minimum risk
- The P_{ts} quantifies the entrepreneurial risk of a failed reliability test
- All known reliability test strategies can be evaluated
- Possibility to identify the best possible test strategy for the individual use case just before decision making

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Institute of Machine Components
Reliability Department

Thank you!

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