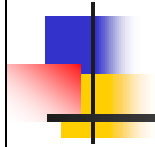


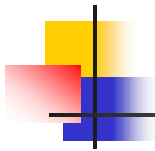
# **Probabilistic Aspects of Fatigue**

## **Introduction**



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**Department of Mechanical and**  
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## Contact Information

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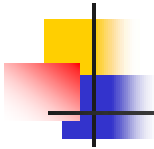
# Fatigue Calculations

The screenshot shows a software interface for fatigue calculations. It consists of three main windows:

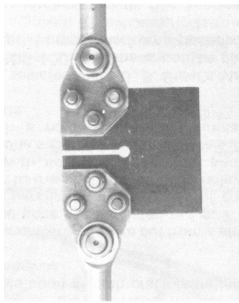
- TSInput1**: Contains a waveform icon and the text "1 Test(s)" and "Display".
- StrainLife1**: Contains an S-N curve icon.
- MetaDataDisplay1**: A table window with buttons for "Clear", "Export...", "Copy", and "Di". The table contains the following data:

ChanNumber	Life	Mode	Inpr
1	6 4.098E 4 Repeats	Damage	Autc
2	7 8840 Repeats	Damage	Autc
3	8 1.585E 4 Repeats	Damage	Autc

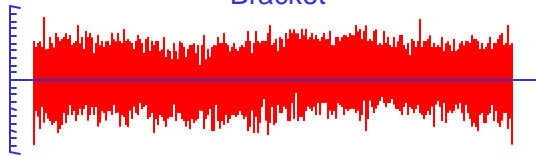
Who really believes these numbers ?



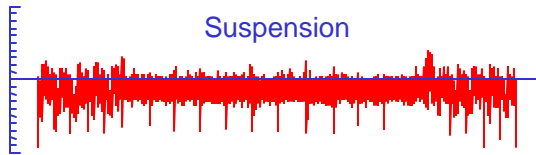
# SAE Specimen



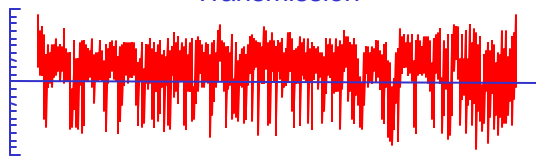
Bracket



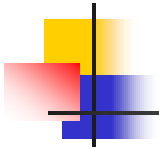
Suspension



Transmission

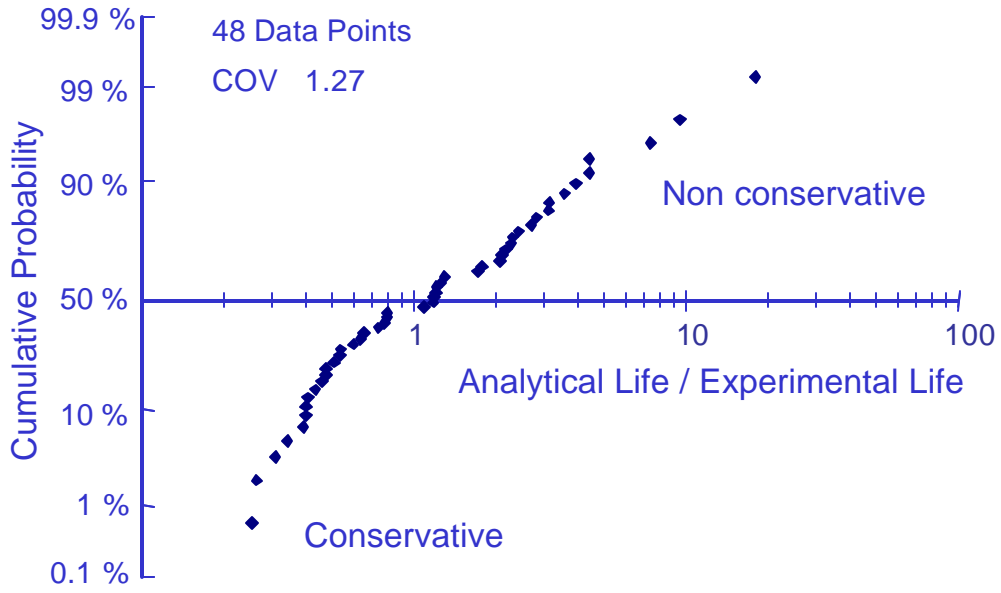


Fatigue Under Complex Loading: Analysis and Experiments, SAE AE6, 1977



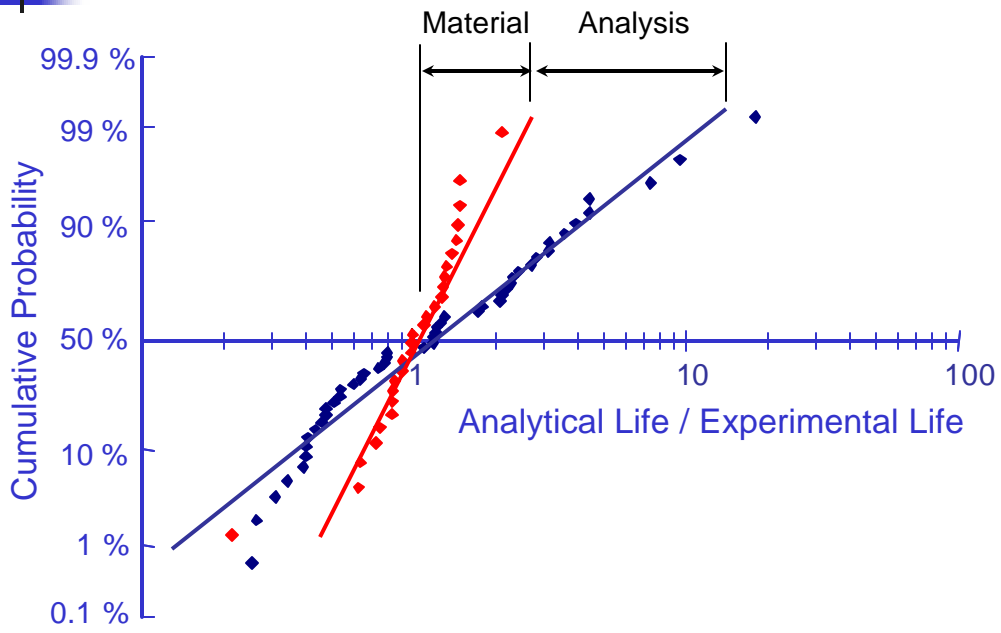
# Analysis Results

Strain-Life analysis of all test data

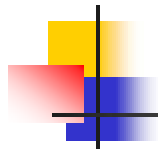




# Material Variability



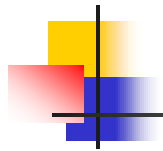
Strain-Life back calculation of specimen lives



## Probabilistic Models

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- Probabilistic models are no better than the underlying deterministic models
- They require more work to implement
- Why use them?



## Quality and Cost

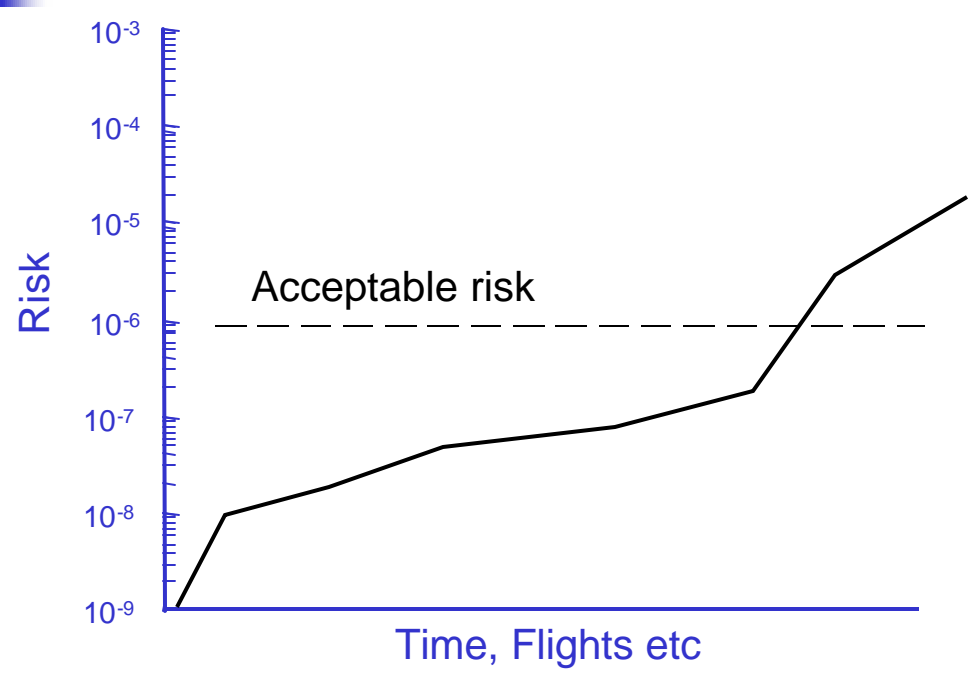
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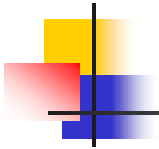
- Taguchi
  - Identify factors that influence performance
  - Robust design – reduce sensitivity to noise
  - Assess economic impact of variation
  
- Risk / Reliability
  - What is the increased risk from reduced testing ?



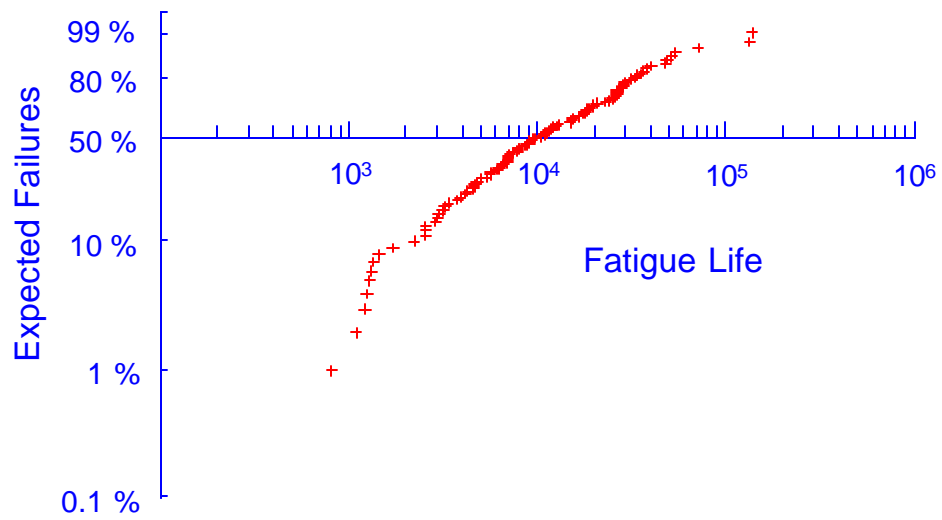


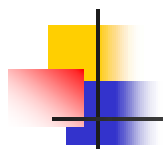
# Risk



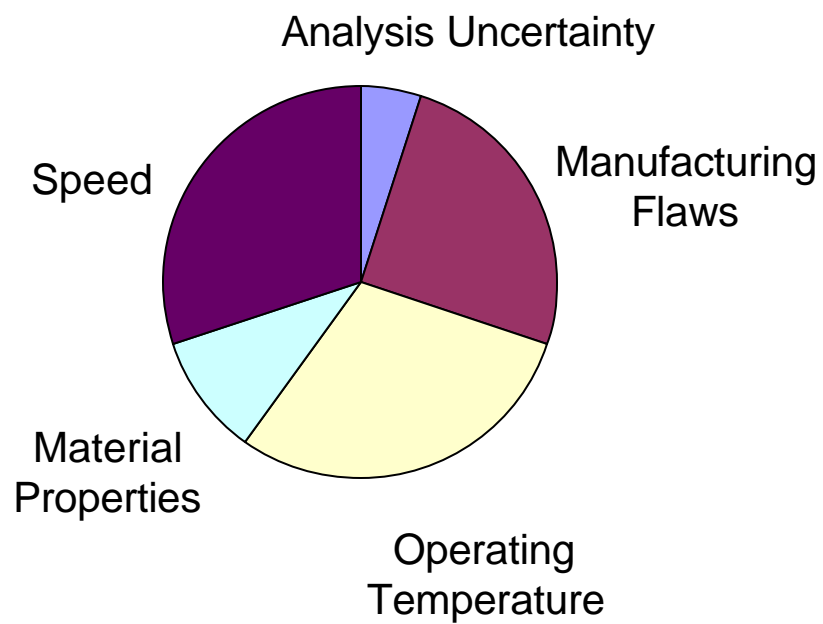


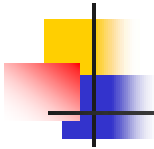
# Reliability





## Risk Contribution Factors





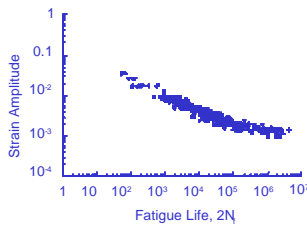
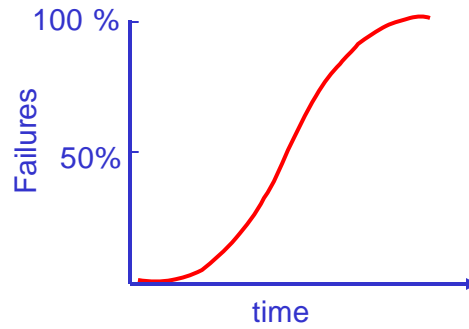
# Uncertainty and Variability

customers



← Stress →

usage

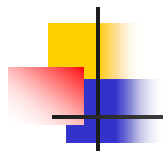


materials

← Strength →

manufacturing



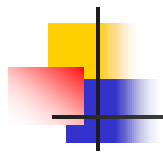


## Deterministic versus Random

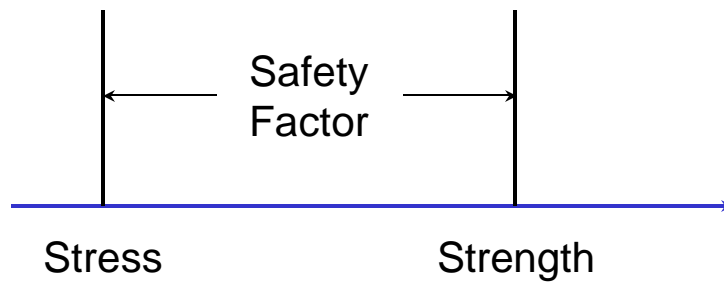
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Deterministic – from past measurements the future position of a satellite can be predicted with reasonable accuracy

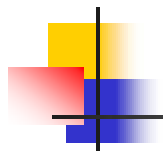
Random – from past measurements the future position of a car can only be described in terms of probability and statistical averages



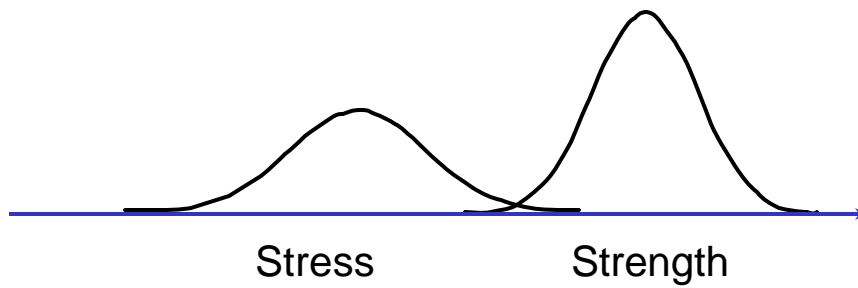
## Deterministic Design



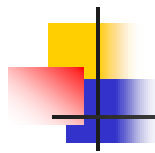
Variability and uncertainty is accommodated by introducing safety factors. Larger safety factors are better, but how much better and at what cost?



## Probabilistic Design



$$\text{Reliability} = 1 - P(\text{Stress} > \text{Strength})$$



## 3 $\sigma$ Approach

3 $\sigma$  contains 99.87% of the data

$$P(s < S) = 2.3 \cdot 10^{-3}$$

If we use 3 $\sigma$  on both stress and strength

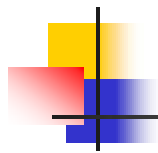
$$P(\text{failure}) = P(\Sigma \geq s \cap s \leq S) = 5.3 \cdot 10^{-6} \approx 4.5 \sigma$$

The probability of the part with the lowest strength having the highest stress is very small

For 3 variables, each at 3 $\sigma$ :

$$P(\text{failure}) = 1.2 \cdot 10^{-8} \approx 5.7 \sigma$$

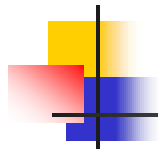




## Benefits

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- Reduces conservatism (cost) compared to assuming the “worst case” for every design variable
- Quantifies life drivers – what are the most important variables and how well are they known or controlled ?
- Quantifies risk



## Probabilistic Aspects of Fatigue

- Introduction
- Basic Probability and Statistics
- Statistical Techniques
- Analysis Methods
- Characterizing Variability
- Case Studies
- [FatigueCalculator.com](http://FatigueCalculator.com)
- [GlyphWorks](http://GlyphWorks.com)