Reliability of critical components

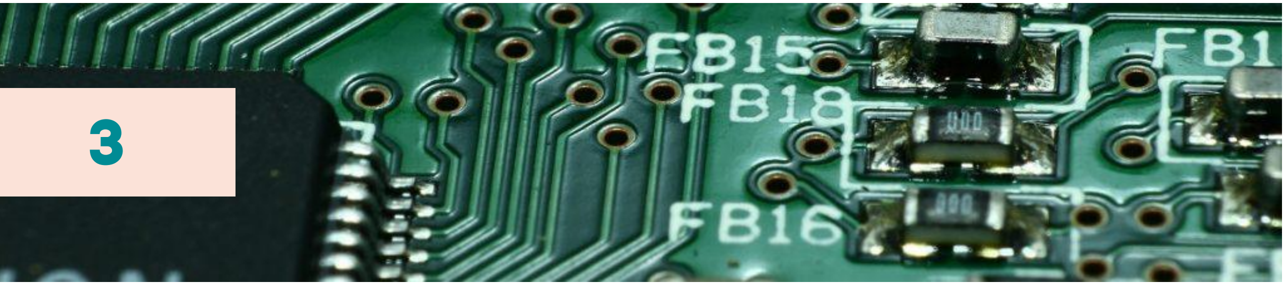
ETIP Ocean Webinar, 2nd of July 2020

Why working with reliability?

“the quality of being trustworthy or of performing consistently well”

“the ocean energy device background gives the market confidence in its reliability”

“the degree to which the result of a measurement, calculation, or specification can be depended on to be accurate”



Noise factors - Five categories of evil…

Identification of uncertenties

1. Wearout
2. External environmental conditions
3. Internal environmental conditions
4. Operational ”behaviour”
5. Manufacturing imperfections

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Different kinds of Uncertainty

We classify sources affecting the prediction uncertenties:

Aleatory uncertainty (or Scatter):

- The inherent **random variation** of the physical phenomenon of interest.
- Can not be reduced.
  (unless large changes are made of the product or in the production)

Epistemic uncertainty:

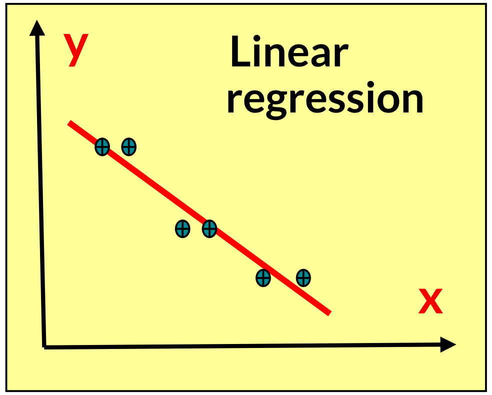
- Caused by **lack of knowledge or information**.
- Can be reduced by better knowledge or more information.
  (e.g. better models or more data)

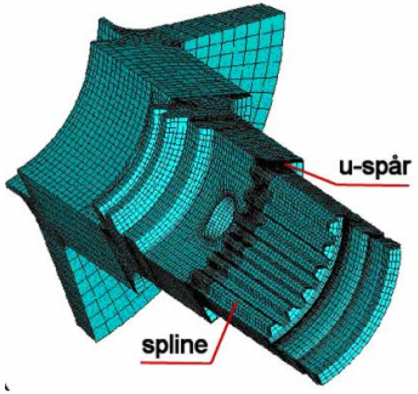
Ref: Melchers, R. (1999): *Structural Reliability Analysis and Prediction*. John Wiley & Sons, 2nd edition.

Different kinds Epistemic Uncertainty

There are many different types of epistemic uncertainties.

Here we make a distinction between two types:





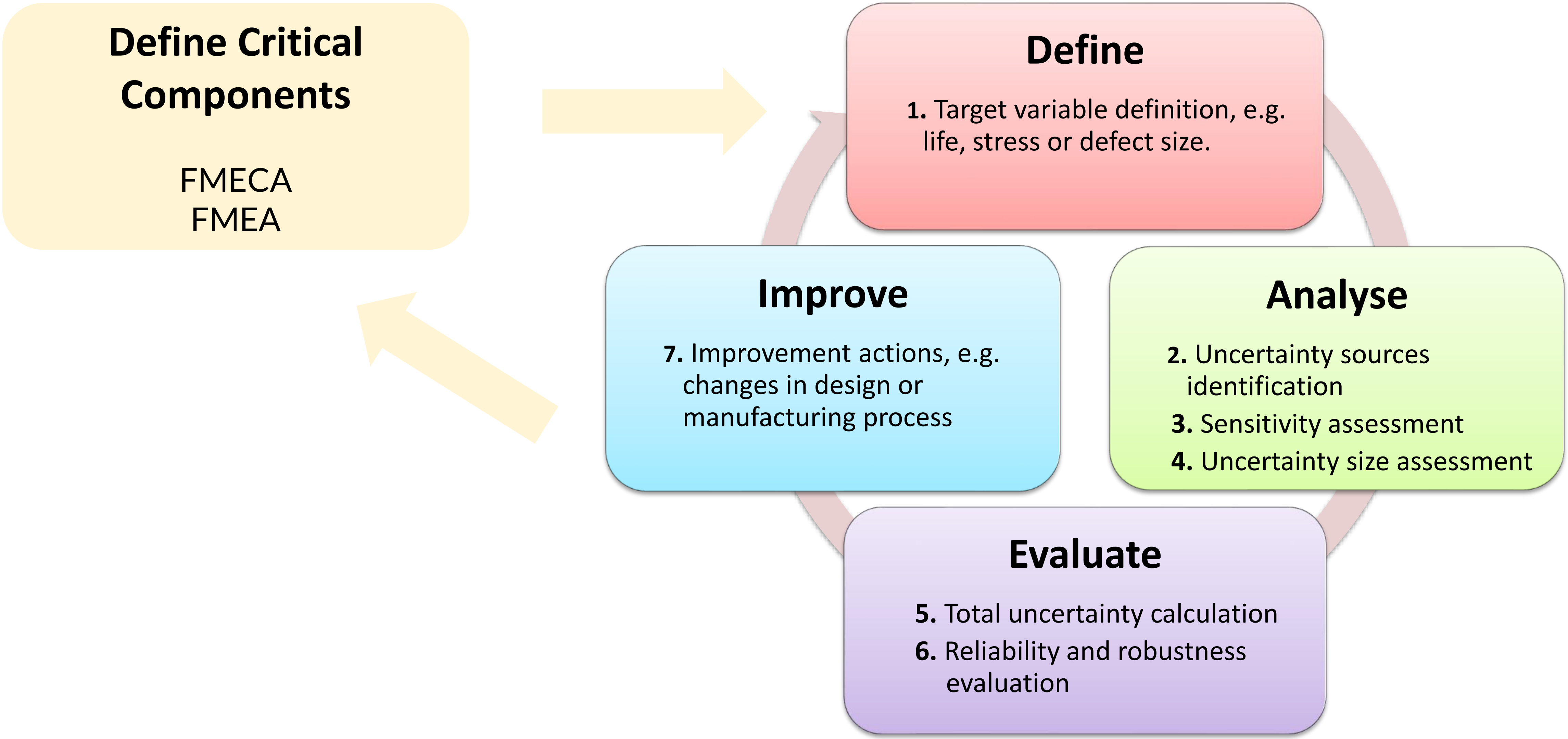
Statistical uncertainty:

- Depends on the limited amount of data available for estimating the model parameters.
- Can be reduced by for example more data, better estimation procedures, or prior information (engineering knowledge).

Model uncertainty:

- Depends on that our model does not perfectly reflect reality, e.g. when a complex phenomenon is modelled by a simple linear relation.
- Can be reduced by for example better or refined models.
  (However often more model parameters are needed. Model complexity!)

Design and Improvement Cycle



VMEA (Variation Mode and Effect Analysis)

Product Development

Concept Phase

Basic

VMEA

Only limited information is available

Design Phase

Enhanced

VMEA

More information is available

Detailed/Optimised Design Phase

Probabilistic

VMEA

Detailed information is available

Product in Use

Monitoring and Maintenance

Predictive Maintenance

VMEA

Monitor loads and/or degradation

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Update uncertainties

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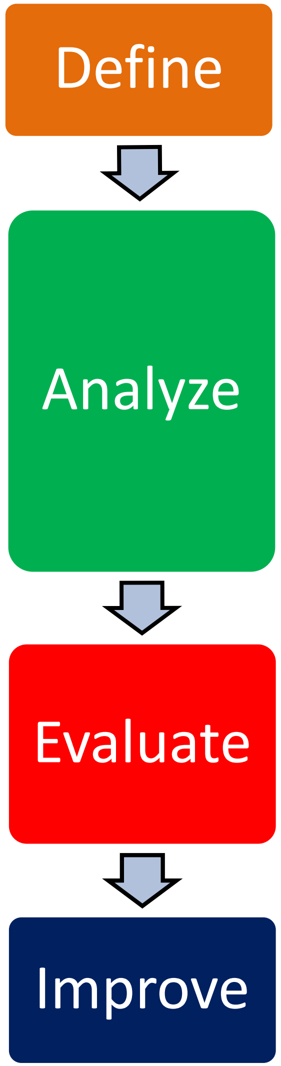
Evaluate reliability and residual life

VMEA Work Procedure



1. **Target Function Definition.**
   For example, life of a component, maximum stress or largest defect.
2. **Uncertainty Sources Identification.**
   Identify all sources of uncertainty (scatter, statistical, model).
3. **Sensitivity Assessment.**
   Evaluate the sensitivity coefficients of the sources of uncertainty.
4. **Uncertainty Size Assessment.**
   Quantify the size of the different sources of uncertainty.
5. **Total Uncertainty Calculation.**
   Combine the contributions from all uncertainty sources.
6. **Reliability and Robustness Evaluation.**
   Find the dominating uncertainties or derive safety factors.
7. **Improvement Actions.**
   Identify uncertainty sources that are candidates for improvement actions.

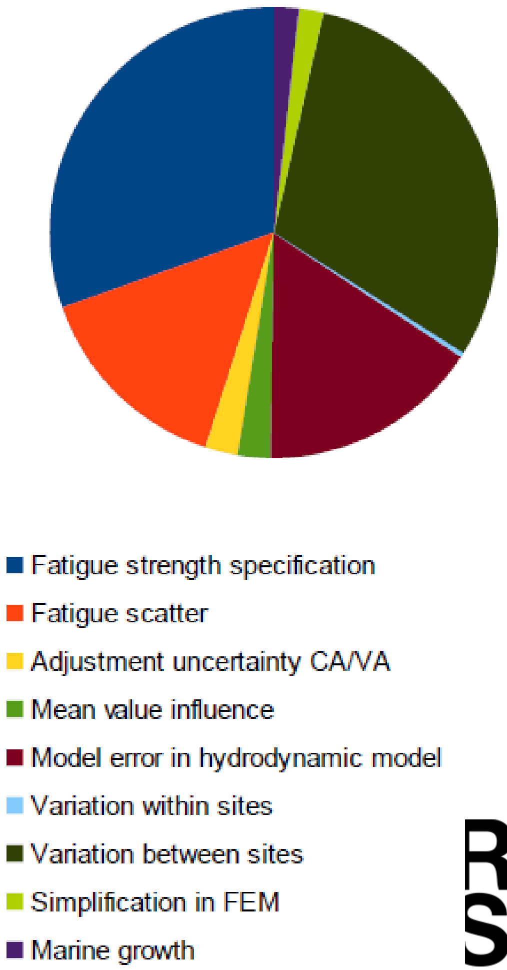
Result: VMEA table

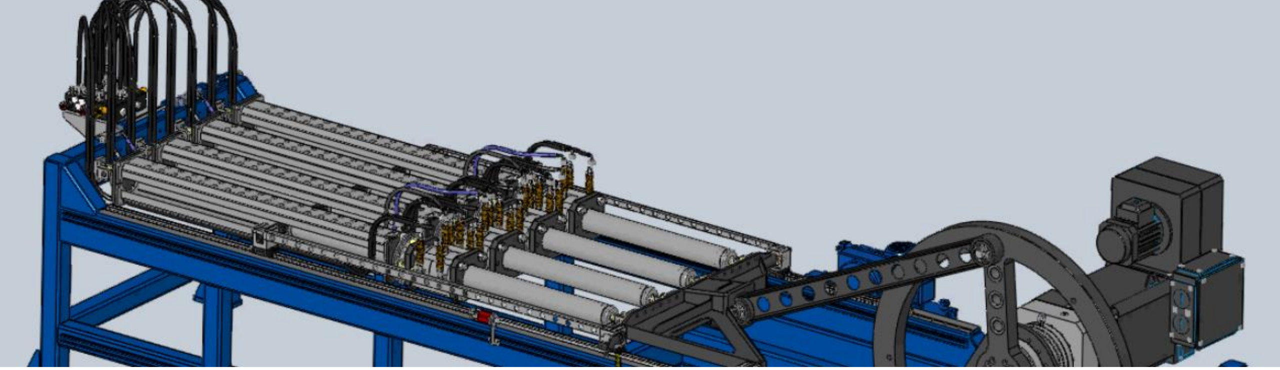
Table of uncertainties influencing the fatigue life:

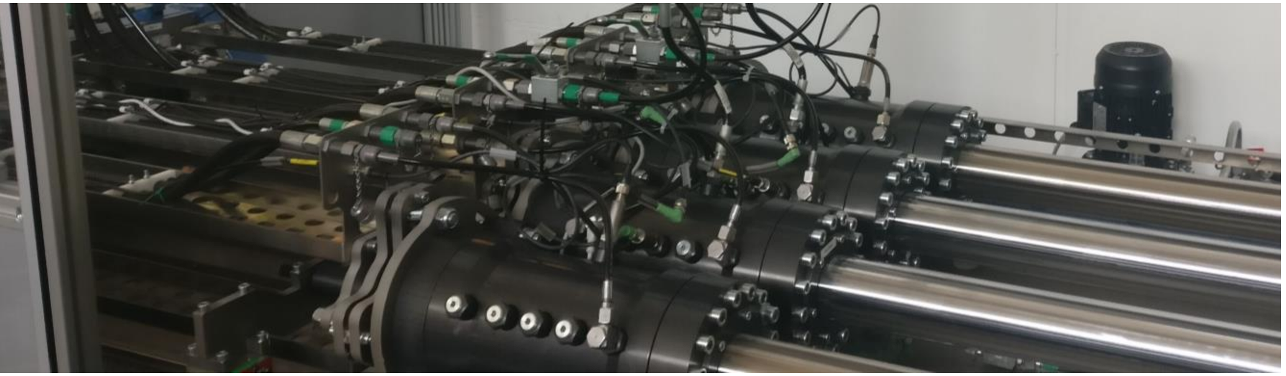
- *material and geometry uncertainties*
- *model uncertainties*
- *load uncertainties*

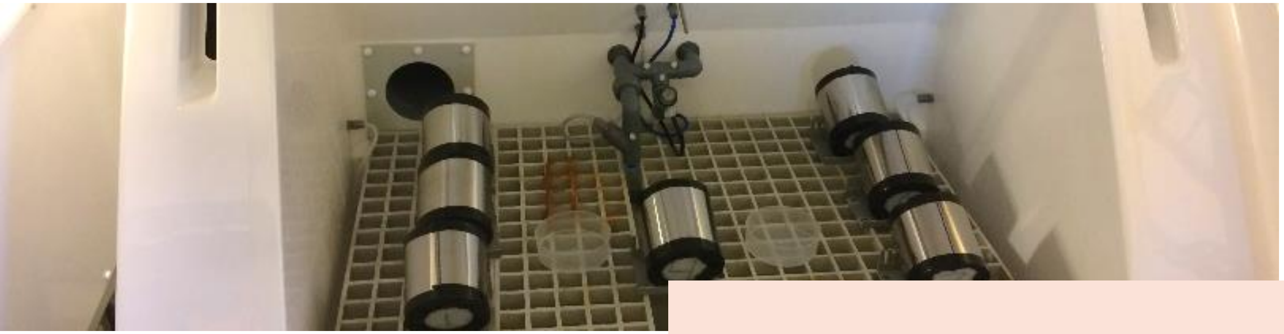
- Which uncertainties dominate?
- How can uncertainties be decreased?
- What are the safety factors?

Input					Result		
Uncertainty components	scatter	uncert.	Sensitivity coefficient c	standard deviation s	Scatter	Uncertainty	Total
Strength							
Fatigue strength specification		x	3,000	0,120		0,360	
Fatigue scatter	x		1,000	0,250	0,250		
Adjustment uncertainty CA/VA		x	1,000	0,100		0,100	
Mean value influence		x	1,000	0,100		0,100	
Total Strength uncertainty					**0,250**	**0,387**	**0,461**
Load							
Model error in hydrodynamic model		x	3,000	0,087		0,261	
Variation within sites	x		3,000	0,012	0,036		
Variation between sites	x		3,000	0,120	0,360		
Simplification in FEM		x	3,000	0,029		0,087	
Marine growth		x	3,000	0,029		0,087	
Total Load uncertainty					**0,362**	**0,289**	**0,463**
Total uncertainty					**0,440**	**0,483**	**0,653**









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Lesson Learnt

- Start reliability work in early design stages (FMECA / B-VMEA)
- Important with systematic and coherent reliability methodologies from component to system level in relation to LCOE
- More accelerated life time testing on critical components is crucial and corrolated with the marine environment for potential commercial deployment sites
- Established supply chain underestimates the challenges with different requirements in the ocean energy sector.

Thank you!

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