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University of Stuttgart
Germany
SWE

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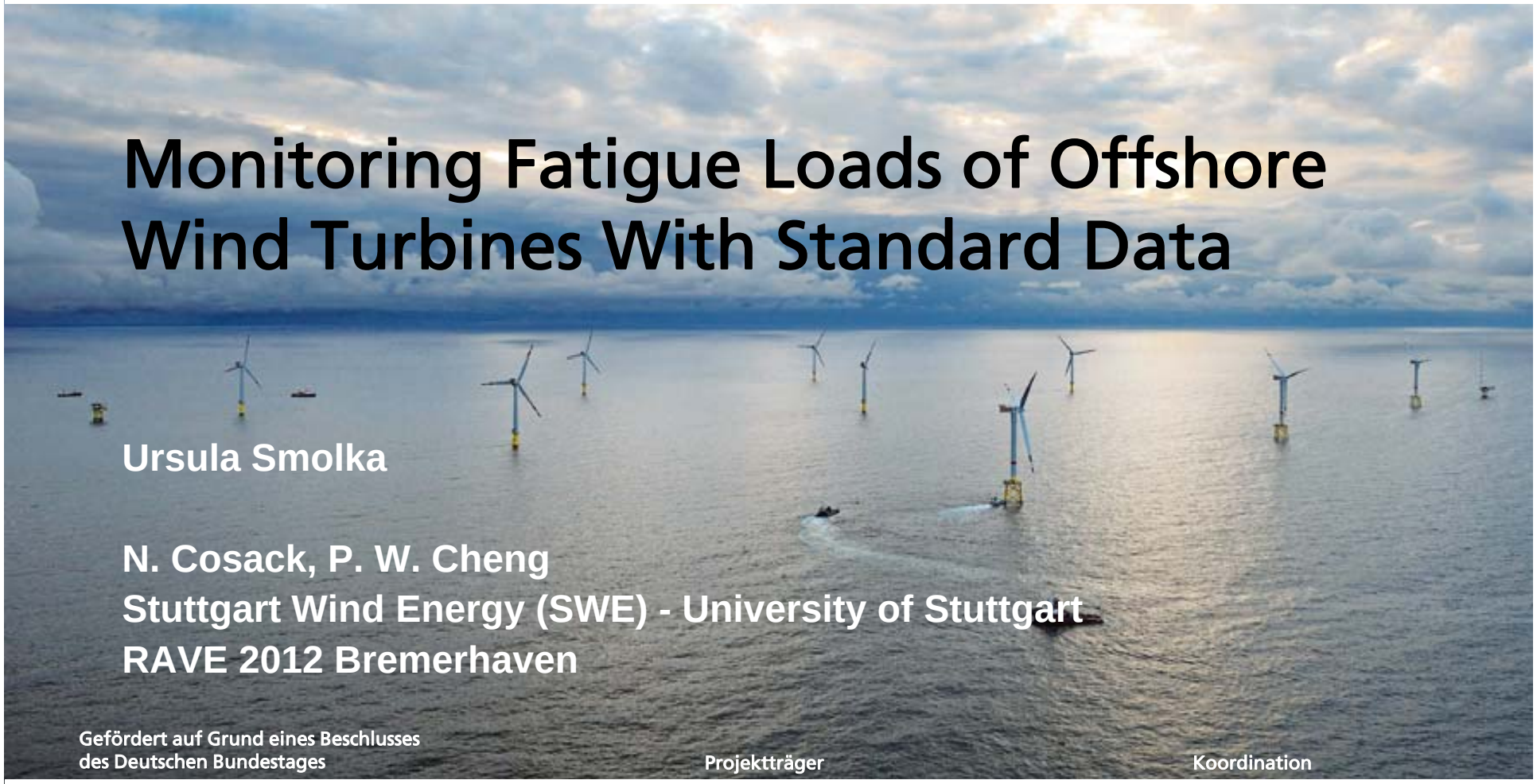
Eine Forschungsinitiative des Bundesumweltministeriums



Monitoring Fatigue Loads of Offshore Wind Turbines With Standard Data

Ursula Smolka

N. Cosack, P. W. Cheng
Stuttgart Wind Energy (SWE) - University of Stuttgart

RAVE 2012 Bremerhaven

Gefördert auf Grund eines Beschlusses des Deutschen Bundestages

Projektträger

Koordination

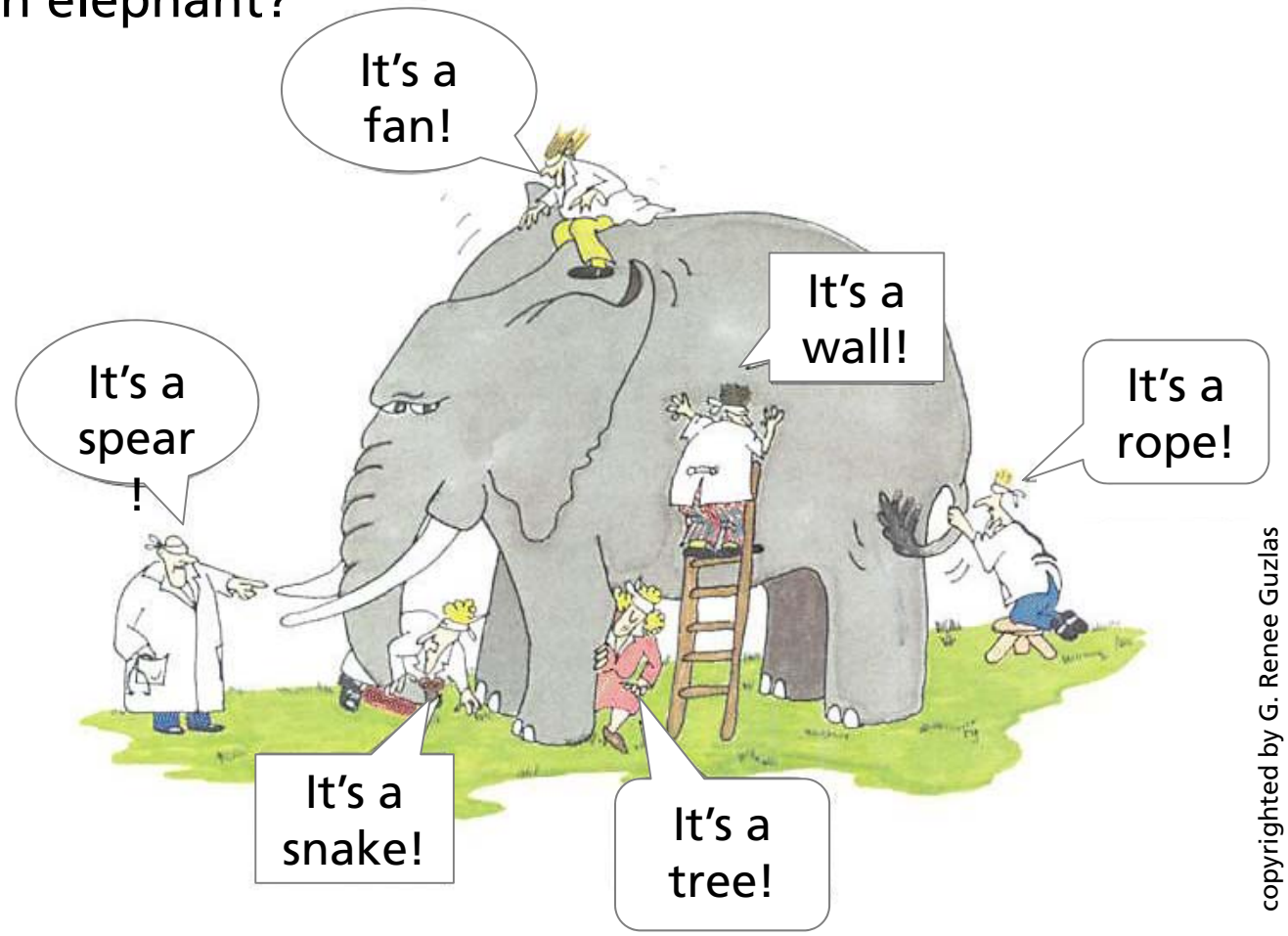
Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

ptj Projektträger Jülich Forschungszentrum Jülich

Fraunhofer IWES

The story of the blind man and the elephant

or: “What is an elephant?”



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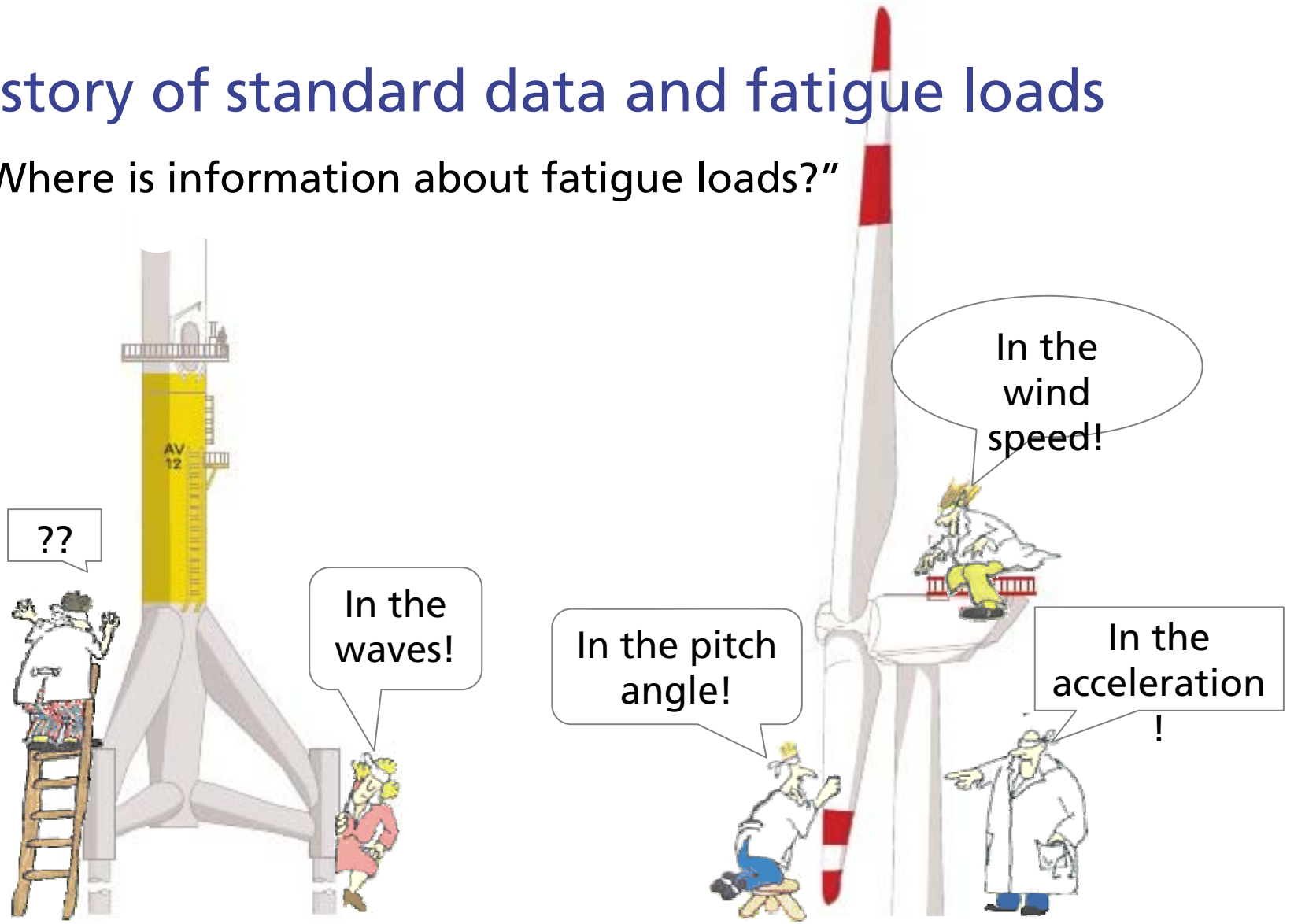
The story of standard data and fatigue loads

or: “Where is information about fatigue loads?”



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Outline

- Methods to extract fatigue loading from standard data
- Simulation results and onshore test
- Offshore test case with one year of data
- Conclusions and outlook

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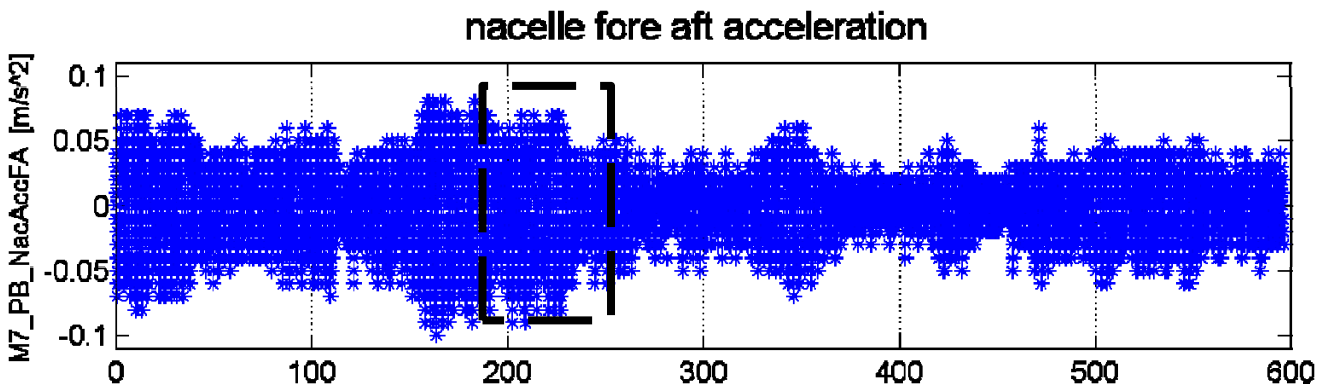
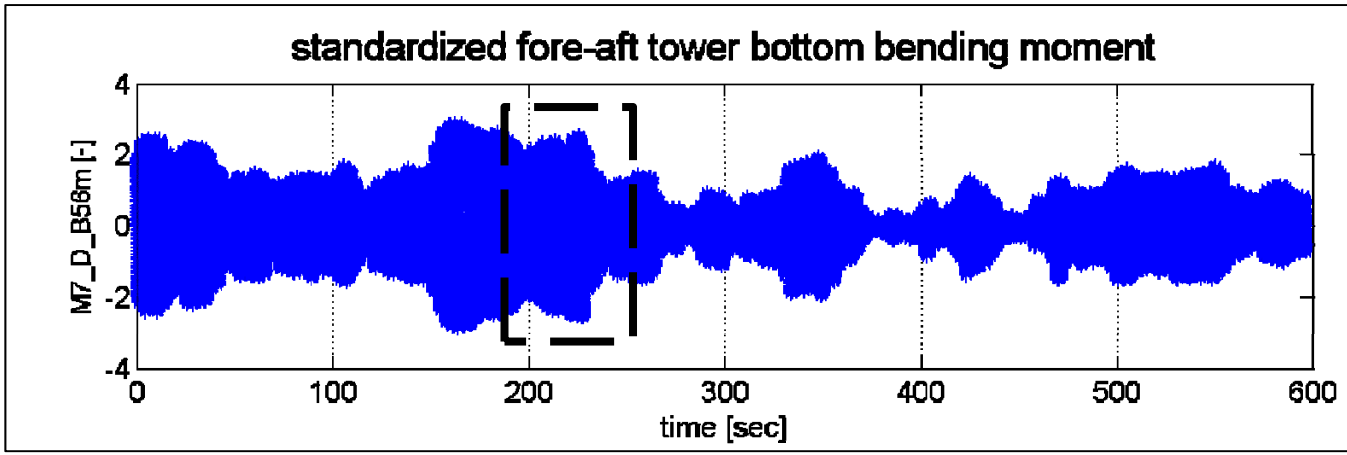
From standard data to fatigue load monitoring

AV07 | 2010 9th May | 11:30 am | idling



monitored
standard signals



monitored
component loading

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From standard data to fatigue load monitoring

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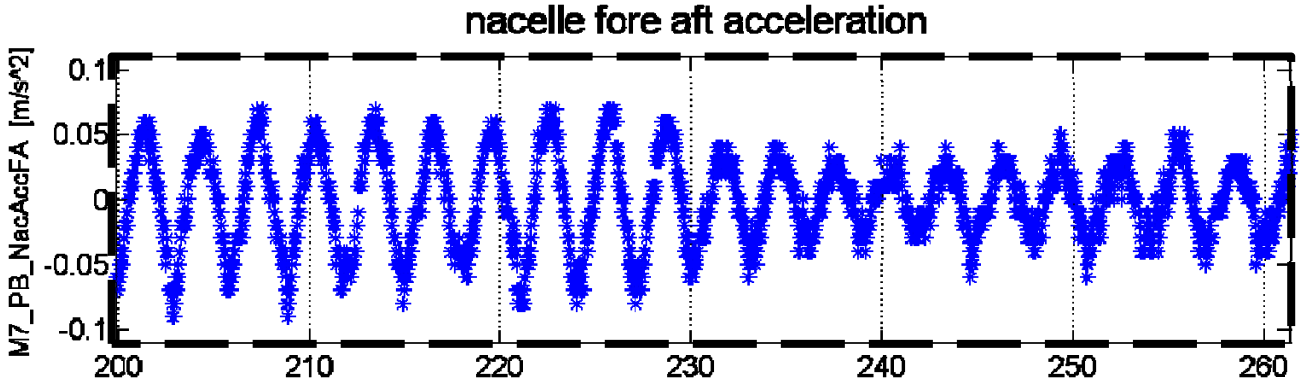
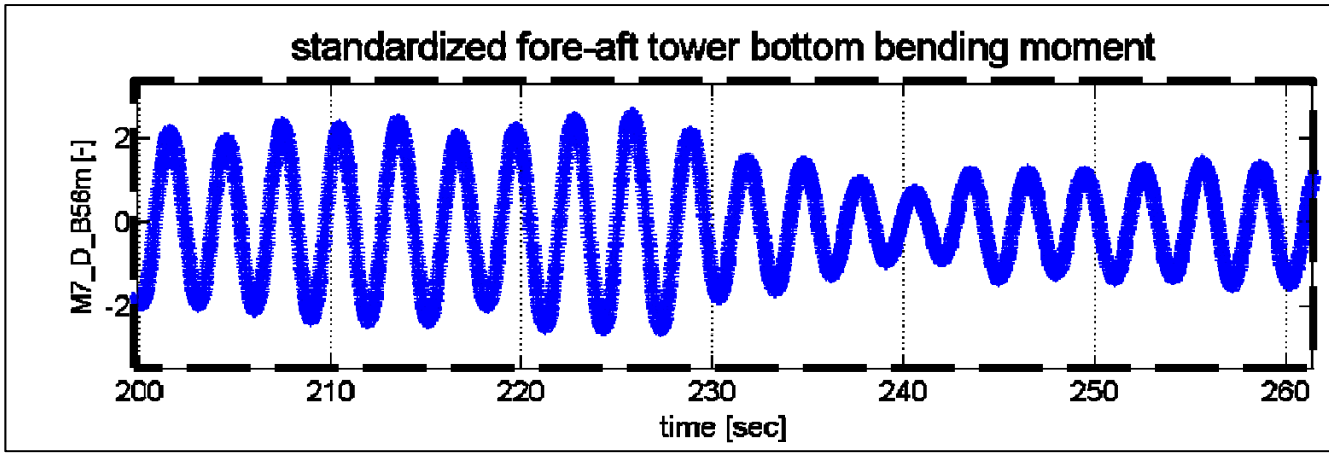


monitored standard signals

? ? ? ?



monitored component loading

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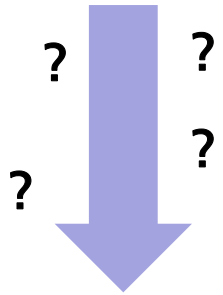
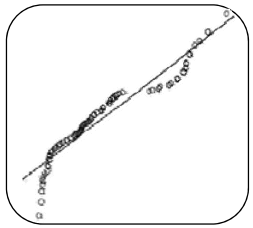
Three methods to estimate fatigue loading

monitored
standard signals



estimated
fatigue loading
Regression Model



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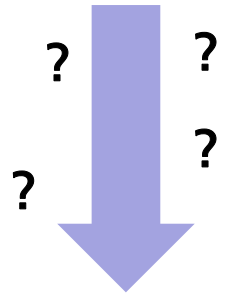
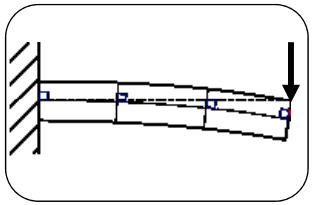
Three methods to estimate fatigue loading

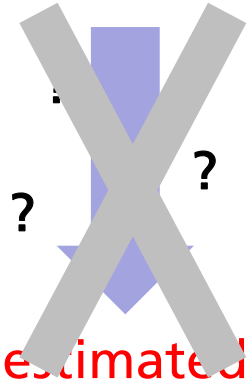
monitored
standard signals



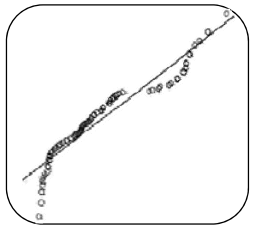
estimated
fatigue loading
Physical Model



monitored
standard signals



estimated
fatigue loading
Regression Model



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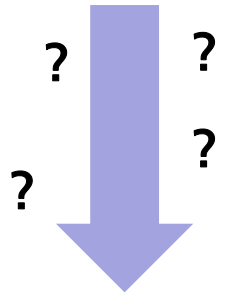
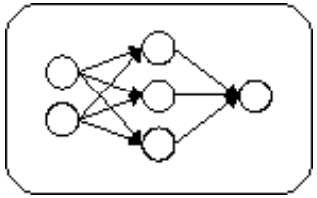
Three methods to estimate fatigue loading

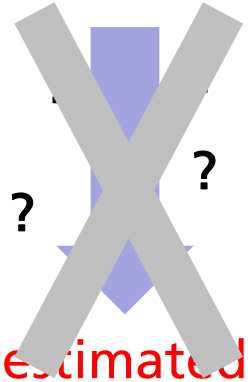
monitored
standard signals



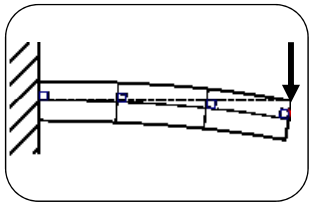
estimated
fatigue loading
Neural Network



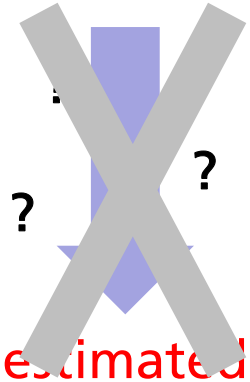
monitored
standard signals



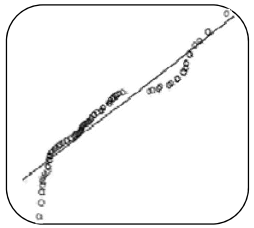
estimated
fatigue loading
Physical Model



monitored
standard signals



estimated
fatigue loading
Regression Model



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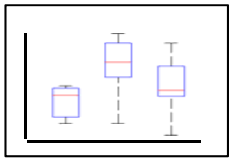
Phase 1/2: creating a database

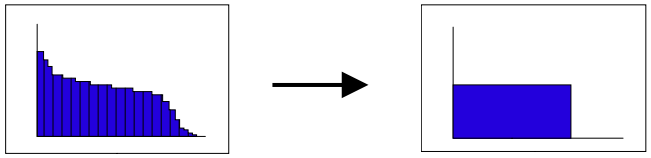
measurement campaign → statistical analysis → data verification

record standard data:

10 min statistical parameters:
mean,
variance,
minima,
maxima…



record overall loads:



multi-stage load cycle distribution

single-stage equivalent load

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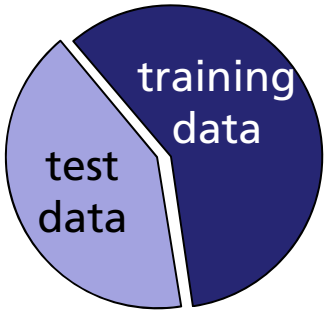
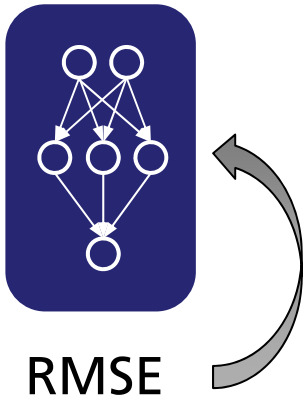
Phase 2/2: train and validate the neural network

input/output subset of interest → iterative network optimization → validation of results



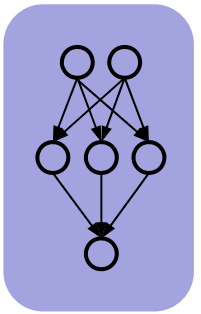
subset of input/output pairs

training input



RMSE (output-estimate)

test input



load estimate

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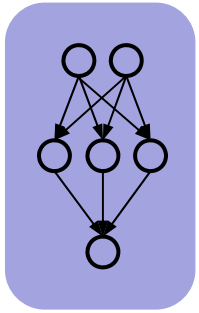
From simulation studies with FLEX 5 to …

input
subset of interest

test data

tower top acceleration
generator speed
electrical power
pitch angle

feed forward
neural network



loads on main componets

rotor torque
rotor thrust
blade bending moments

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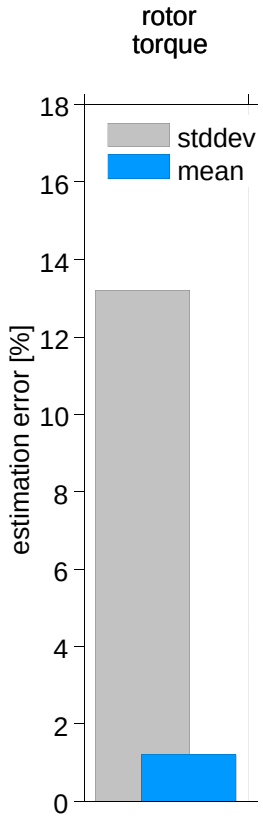
…onshore test case with 150 h of data



[Cosack 2009, m = 10]

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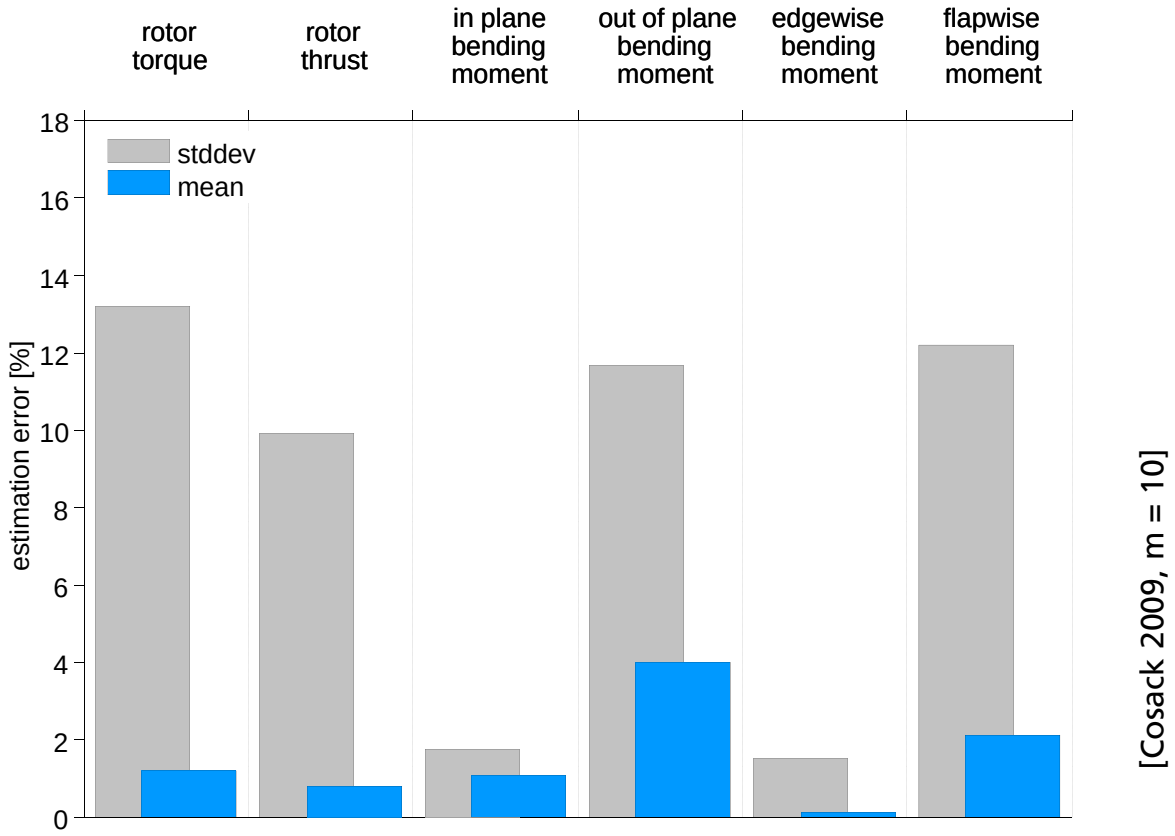
…onshore test case with 150 h of data



[Cosack 2009, m = 10]

Error of single loads < 10%, accumulated loads < 4 %

Standard deviation of estimation errors up to 13 %

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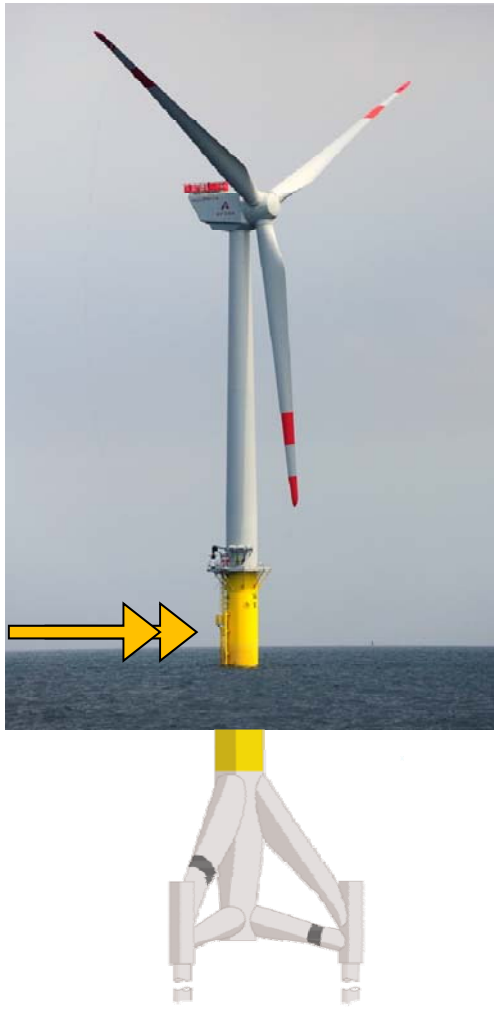
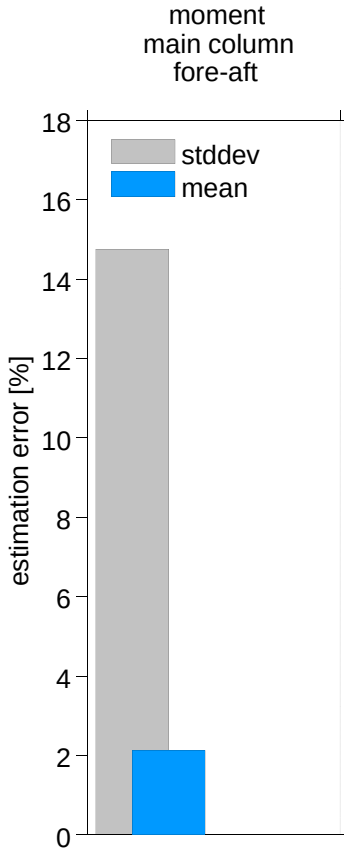
…offshore test case with 8200 h of data





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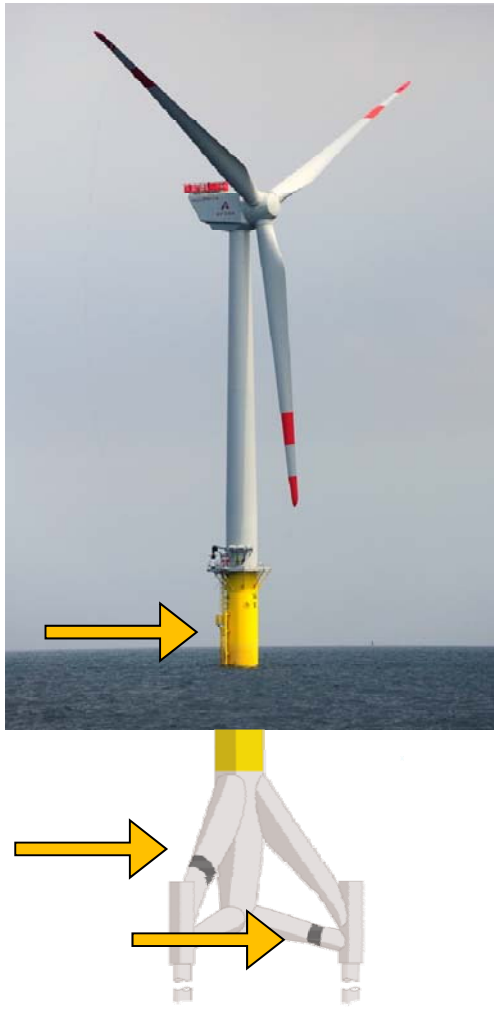
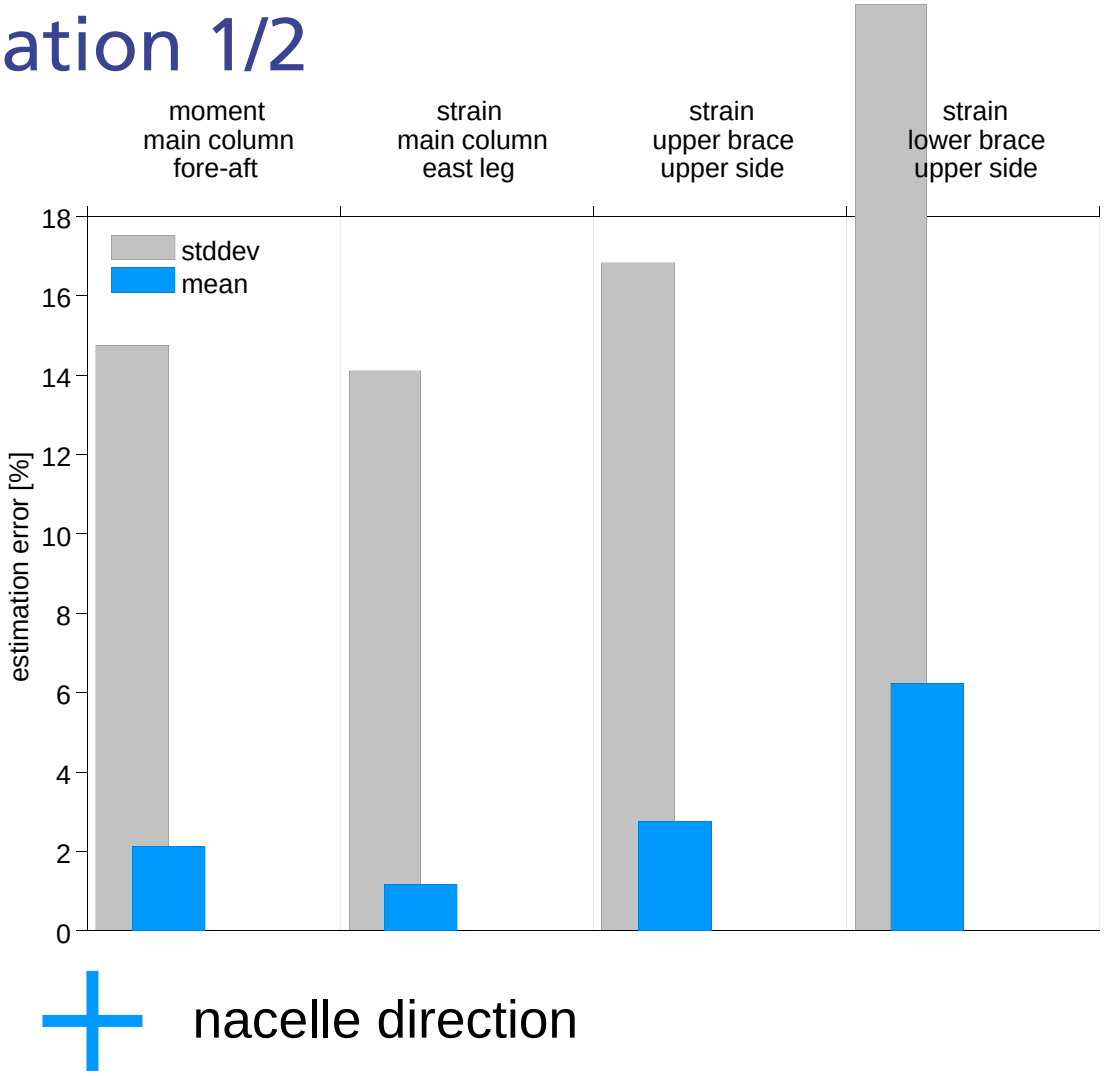
Local load estimation 1/2





+ nacelle direction

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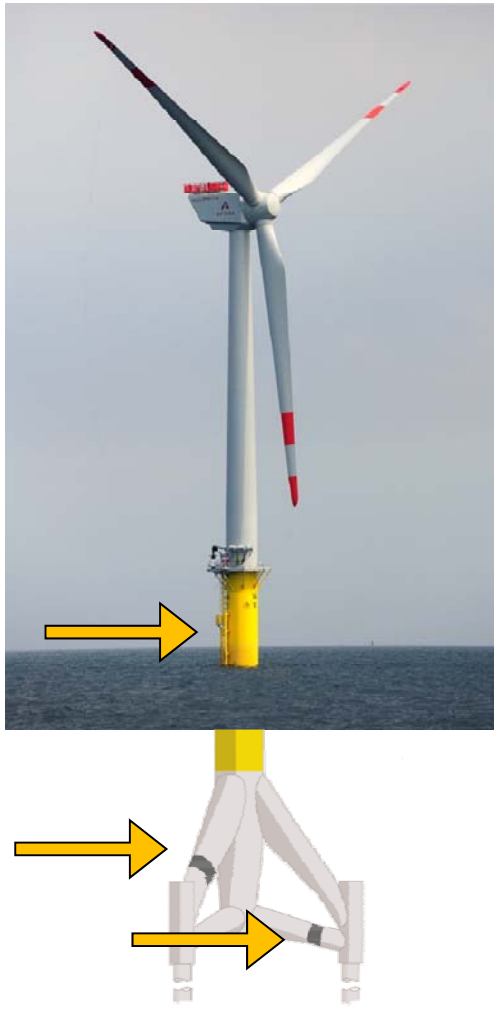
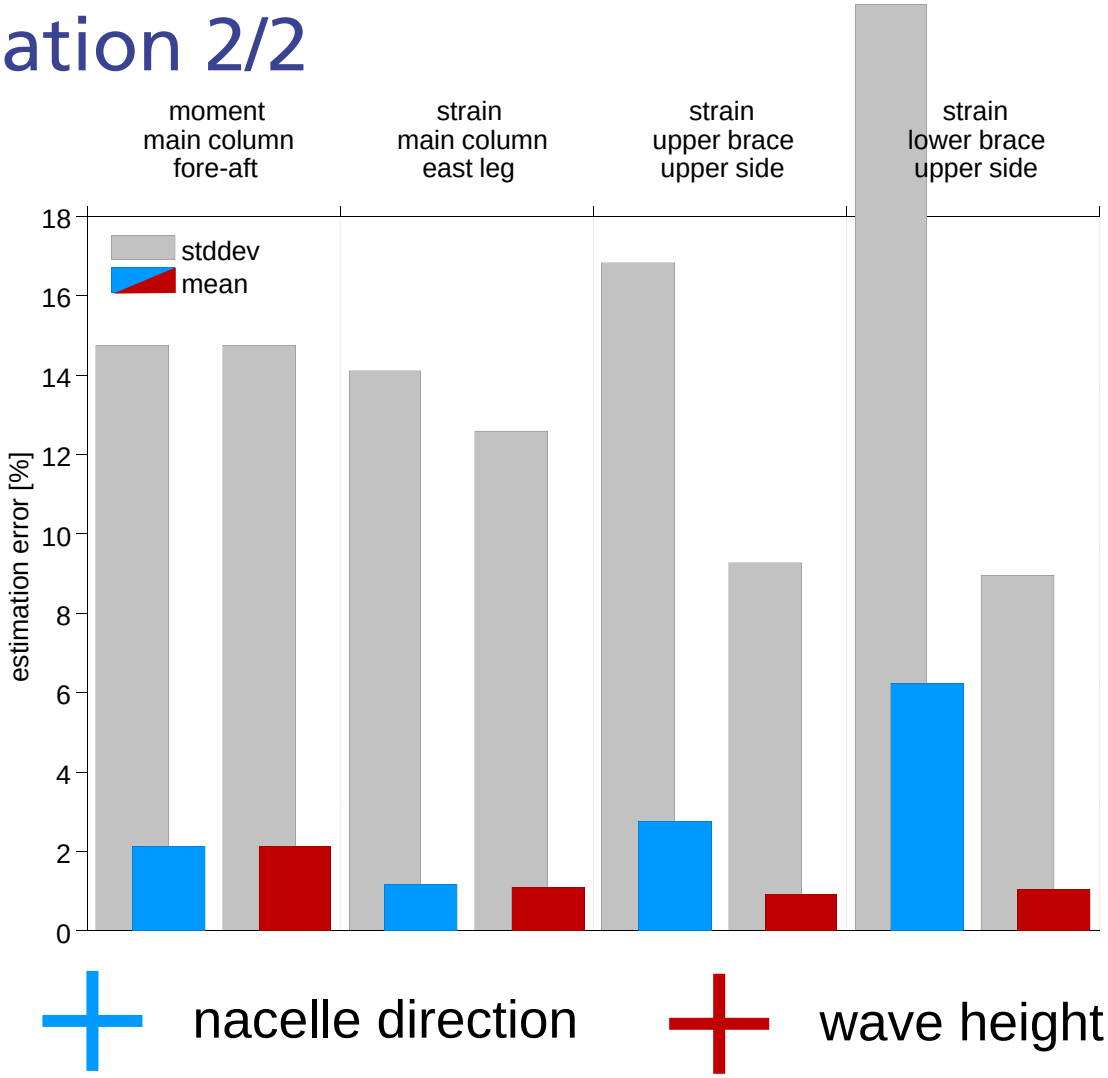
Local load estimation 2/2





nacelle direction + wave height

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Within the scope of the OWEA project…

… a **load monitoring method** based on statistical parameters of standard wind turbine signals has been **developed.**

… a **general layout** of a load estimation system has been **defined.**

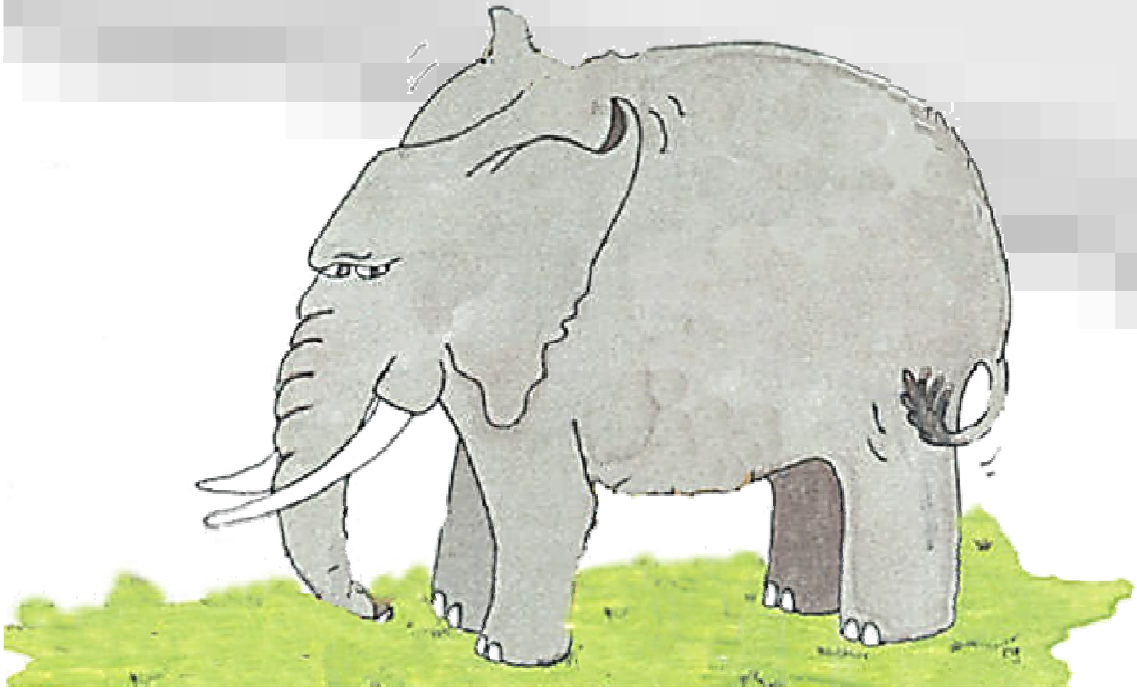
… for onshore and offshore test cases the **feasibility was proven.**

… an **acceptable accuracy** of <4% has been achieved.

… even **local loads** on the support structure were **well estimated.**

… **sea state** measurements were shown to **enhance the accuracy.**

Outlook

- Enhance accuracy of **cumulated fatigue load estimation**
- Define a **minimal robust set of standard signals** that covers all operational and inflow conditions
- Develop methods that **reduce** the required duration of the initial **measurement campaign**

Thanks
for your attention!