



# Superelement approach in Sesam and Bladed

## Coupled analysis for offshore wind turbines

**DNV GL**

28 September 2017

# Topics of this seminar

- Introduction to Bladed and Sesam
- Superelement vs integrated analysis
- Demonstration of superelement process
- Superelement verification



# Quick introduction to Sesam and Bladed

## Offshore wind – combining DNV GL competencies



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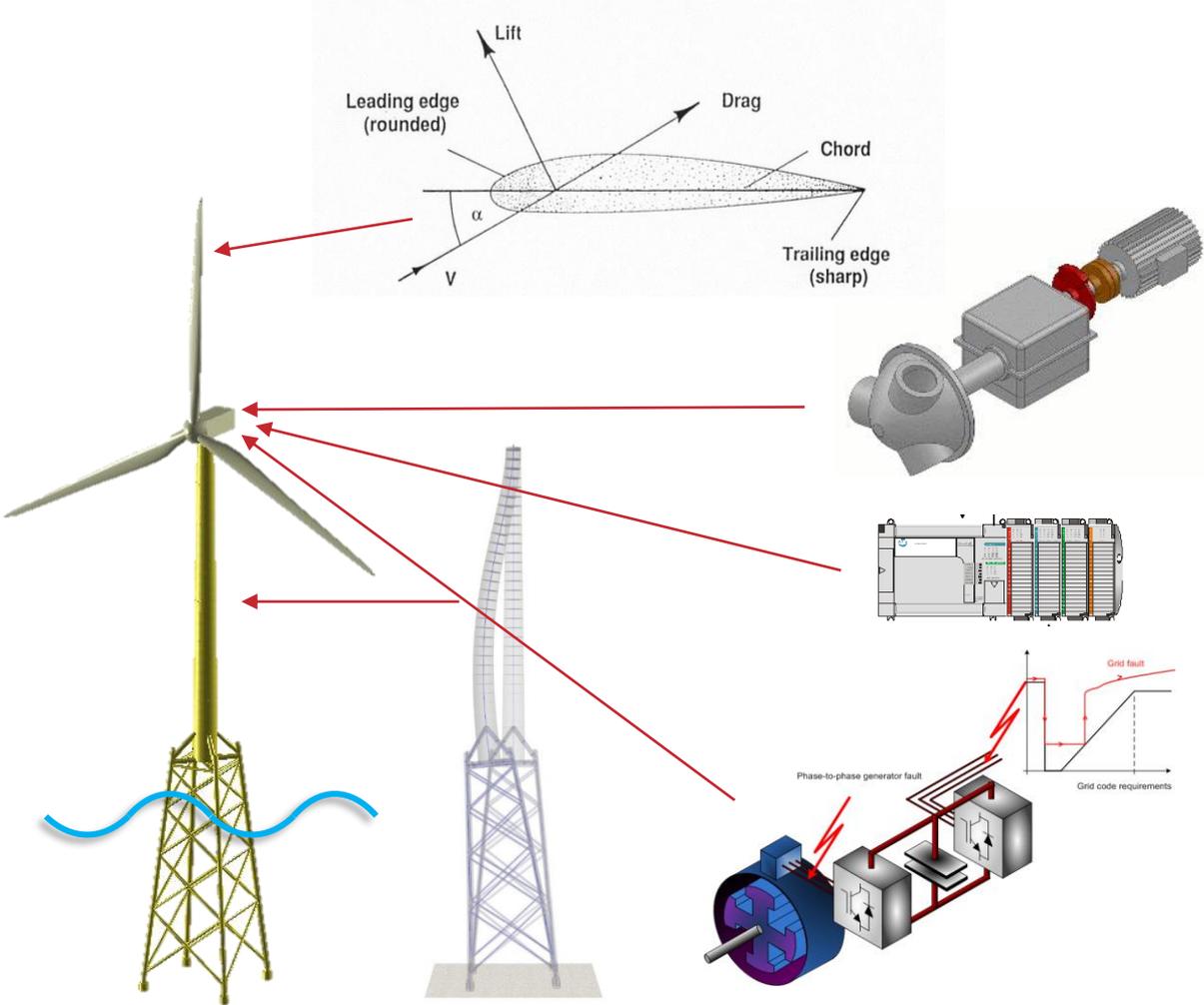
DNV GL has 25+ years of hands-on experience with wind turbines.

DNV GL Software provides 45+ years of offshore oil & gas experience.

Global leader in risk management of offshore wind projects

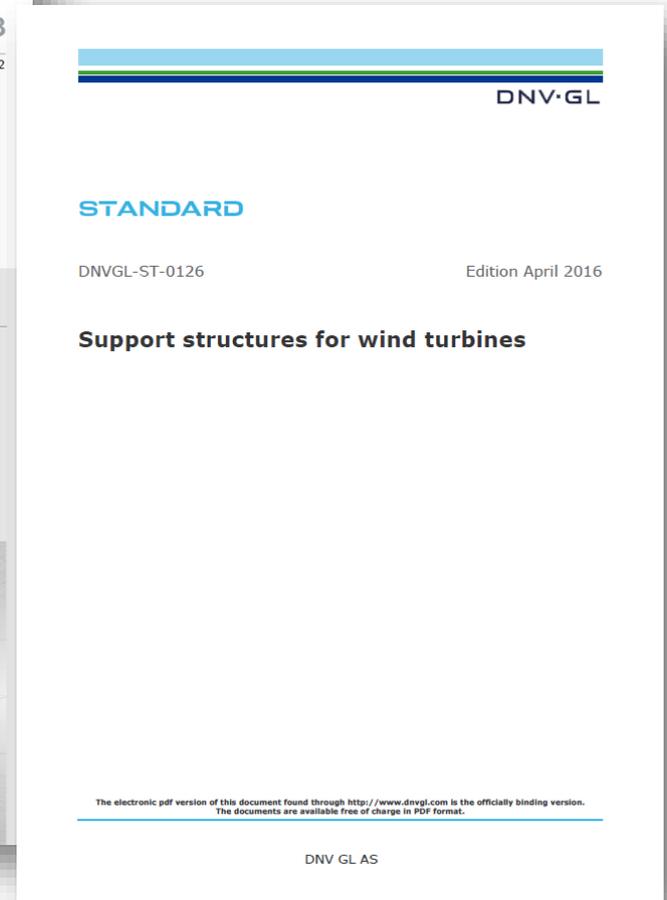
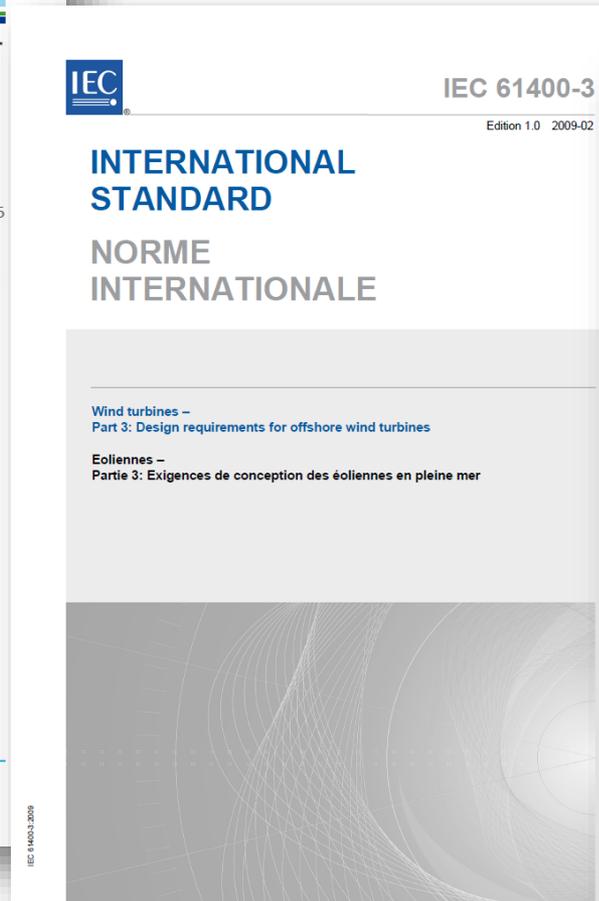


# Bladed





# Standards referred



# Offshore load analysis methodologies

- a) Integrated analysis
- b) Superelement analysis

# a) Integrated Analysis

# Integrated Analysis

**Sesam  
GeniE**  
Modelling



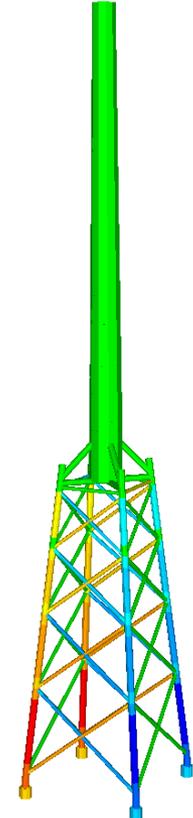
Model

**Bladed**  
Wind load computation  
Wave load computation  
Structural analysis

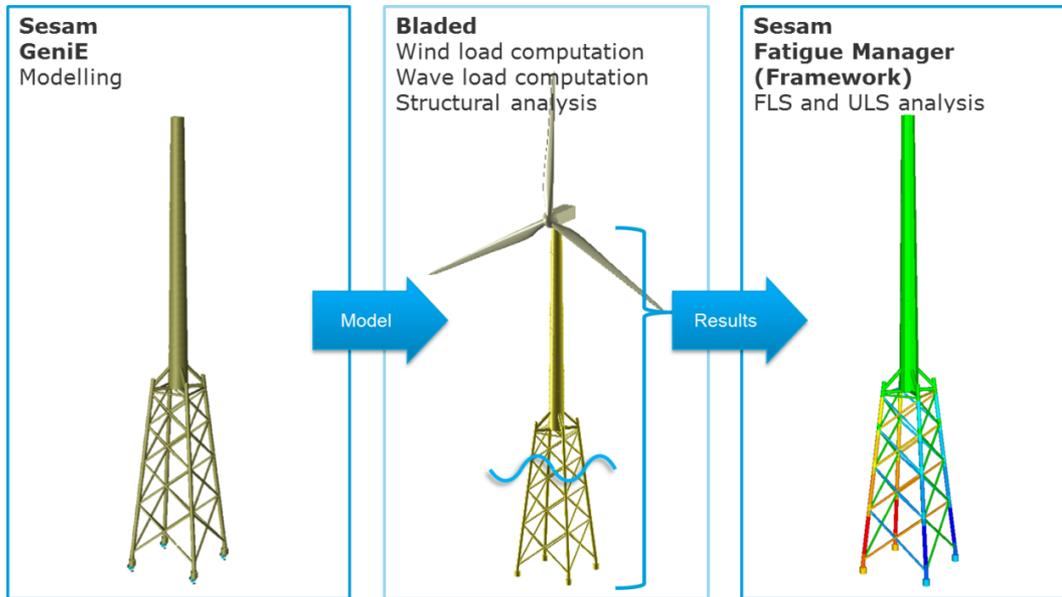


Loads

**Sesam  
Fatigue Manager  
(Framework)**  
FLS and ULS analysis



# Integrated Analysis



- ✓ Captures all dynamic feedback from combined wind and wave loading
- ✓ Easy for FD and WTG designer to optimise design of whole structure
- ✓ Wind/wave load calculation only done once
- ✓ Bladed encryption feature prevents need to share foundation design
- ✗ Limit on structural complexity of jacket (e.g. no shell elements)
- ✗ WTG designer takes responsibility for wave loading and jacket definition

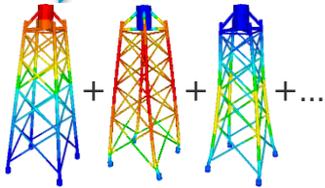
## b) Superelement Approach

# Creating a Superelement

**Sesam  
GeniE**  
Jacket design  
**Fatigue Manager  
(Wajac)**  
Wave loads

**Sesam  
Fatigue Manager**  
Reduction into  
superelement and  
load files

Full model and  
wave loads

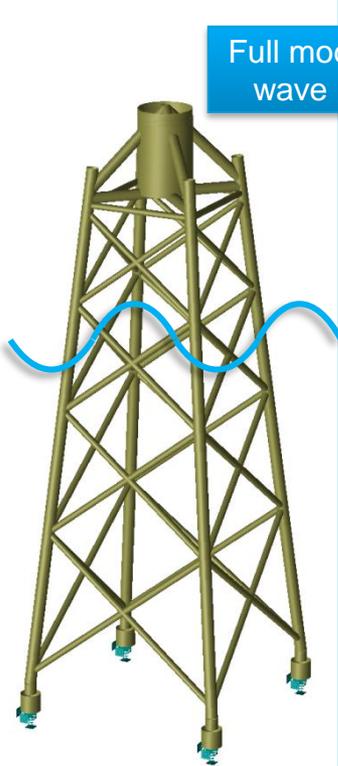


$[K], [M], [F]$

- Superelement created using Craig-Bampton reduction
  - **Interface:** six degrees of freedom on top of jacket
  - **Mode shapes:** Eigen modes of original jacket, adding additional degrees of freedom
  - Modes give reduced  $[K], [M], [F]$  for use directly in Bladed

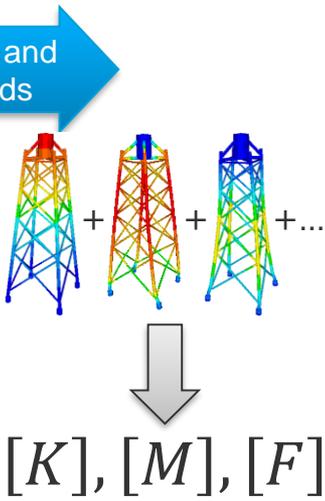
# Superelement Analysis

**Sesam GeniE**  
Jacket design  
**Fatigue Manager (Wajac)**  
Wave loads



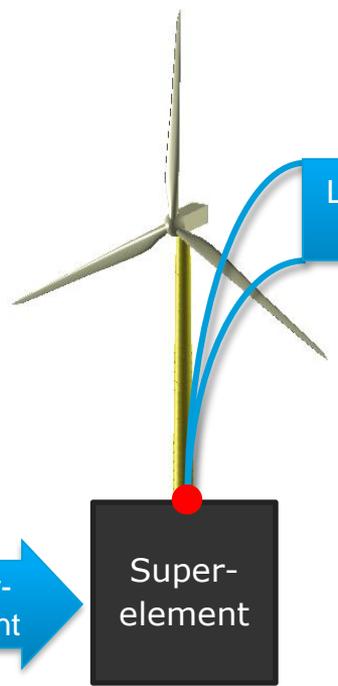
Full model and wave loads

**Sesam Fatigue Manager**  
Reduction into superelement and load files

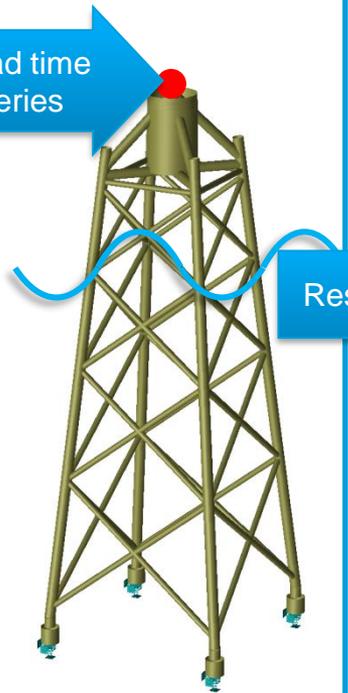


Super-element

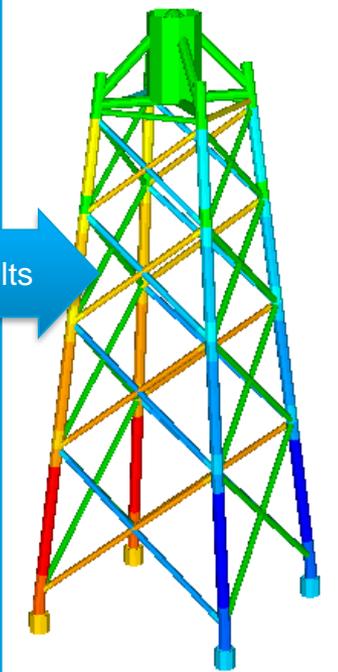
**Bladed**  
Wind loads computation  
Structural analysis



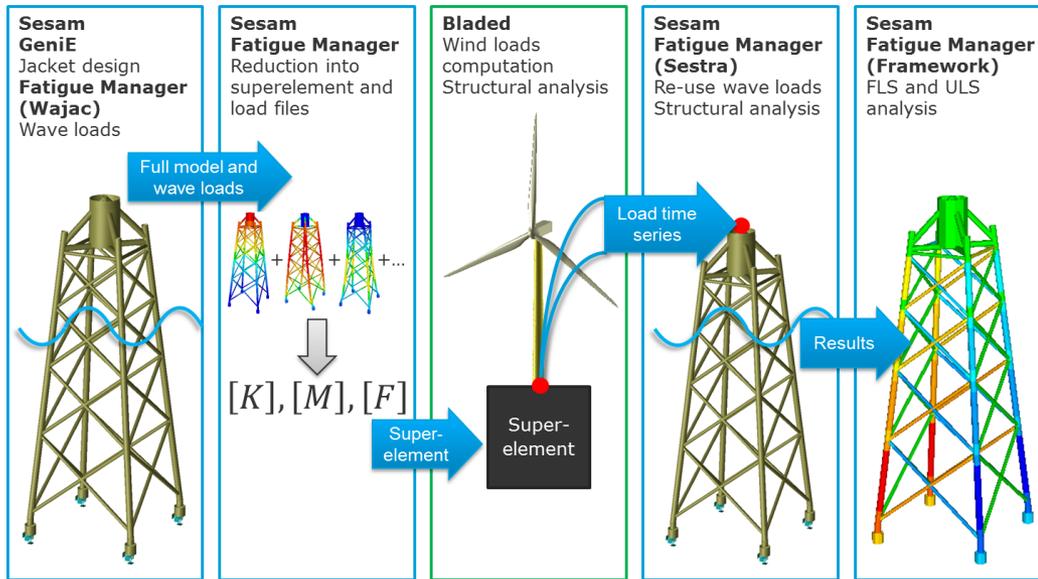
**Sesam Fatigue Manager (Sestra)**  
Re-use wave loads  
Structural analysis



**Sesam Fatigue Manager (Framework)**  
FLS and ULS analysis



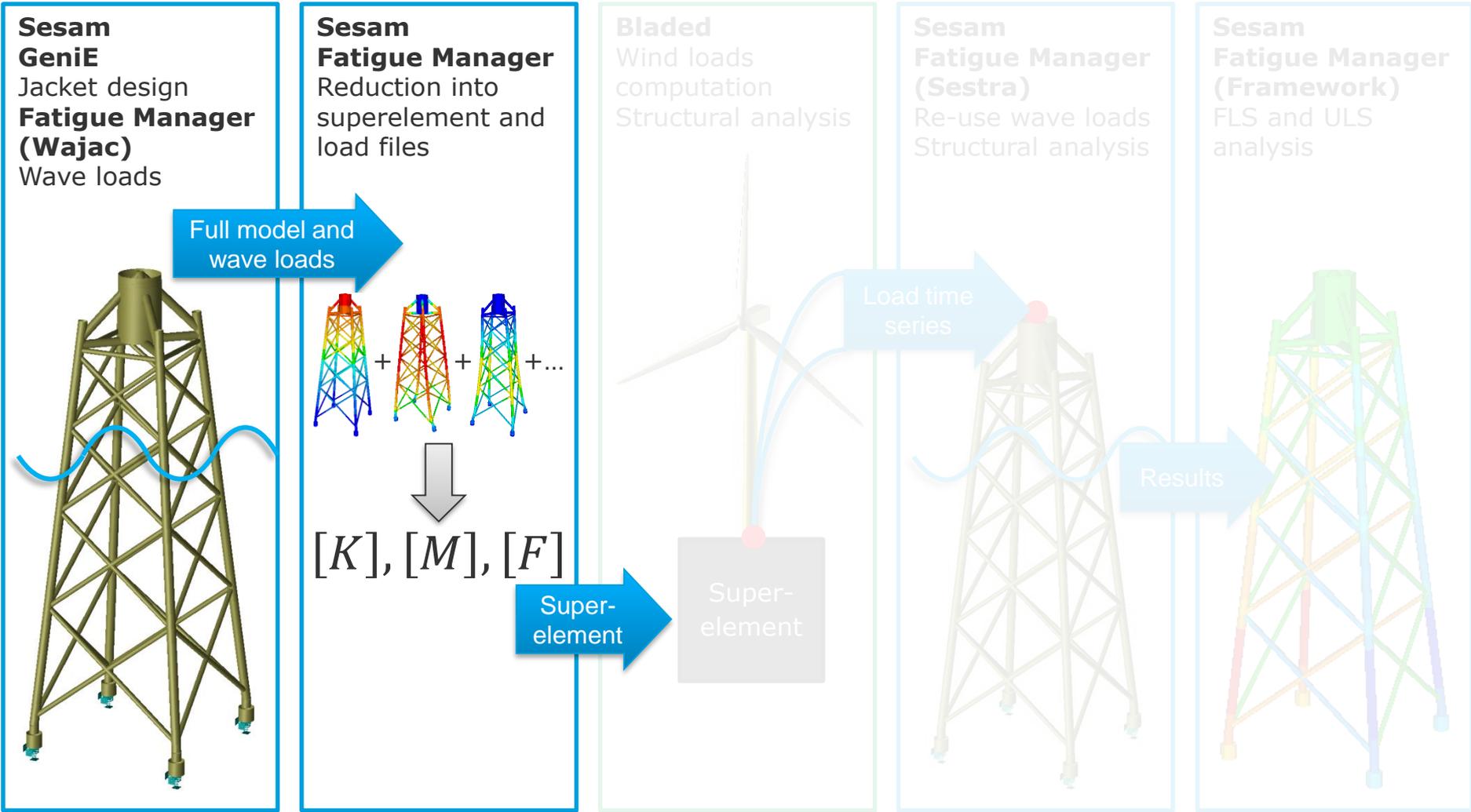
# Superelement Analysis



- ✓ Wave load calculation responsibility remains with FD
- ✓ FD does not need to share design details with WTG designer
- ✓ Allows complex jacket features to be modelled (e.g. shell elements)
- ✗ Design load cases simulated twice
- ✗ More difficult for FD and WTG designer to optimise design of whole structure
- ✗ Hydro-elastic feedback not accounted for (wave loads known at start)

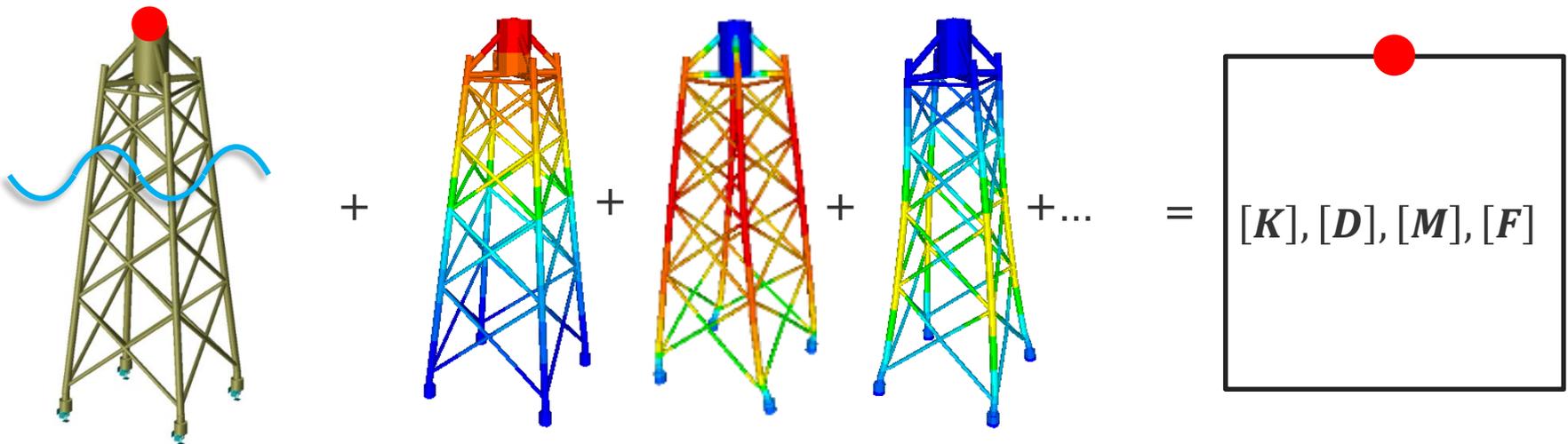
# Superelement method demo in Sesam and Bladed

# Superelement Analysis – part 1 (superelement creation)



# Superelement creation: what is a superelement?

- Boundary node is at the interface, and therefore only contains 6 DOFs
- Additional DOFs are added into superelement to improve dynamic response of superelement
  - Additional DOFs are based on original model's internal mode shapes (i.e. with fixed interface)
  - How many modes to include? → Run spectral and spatial convergence

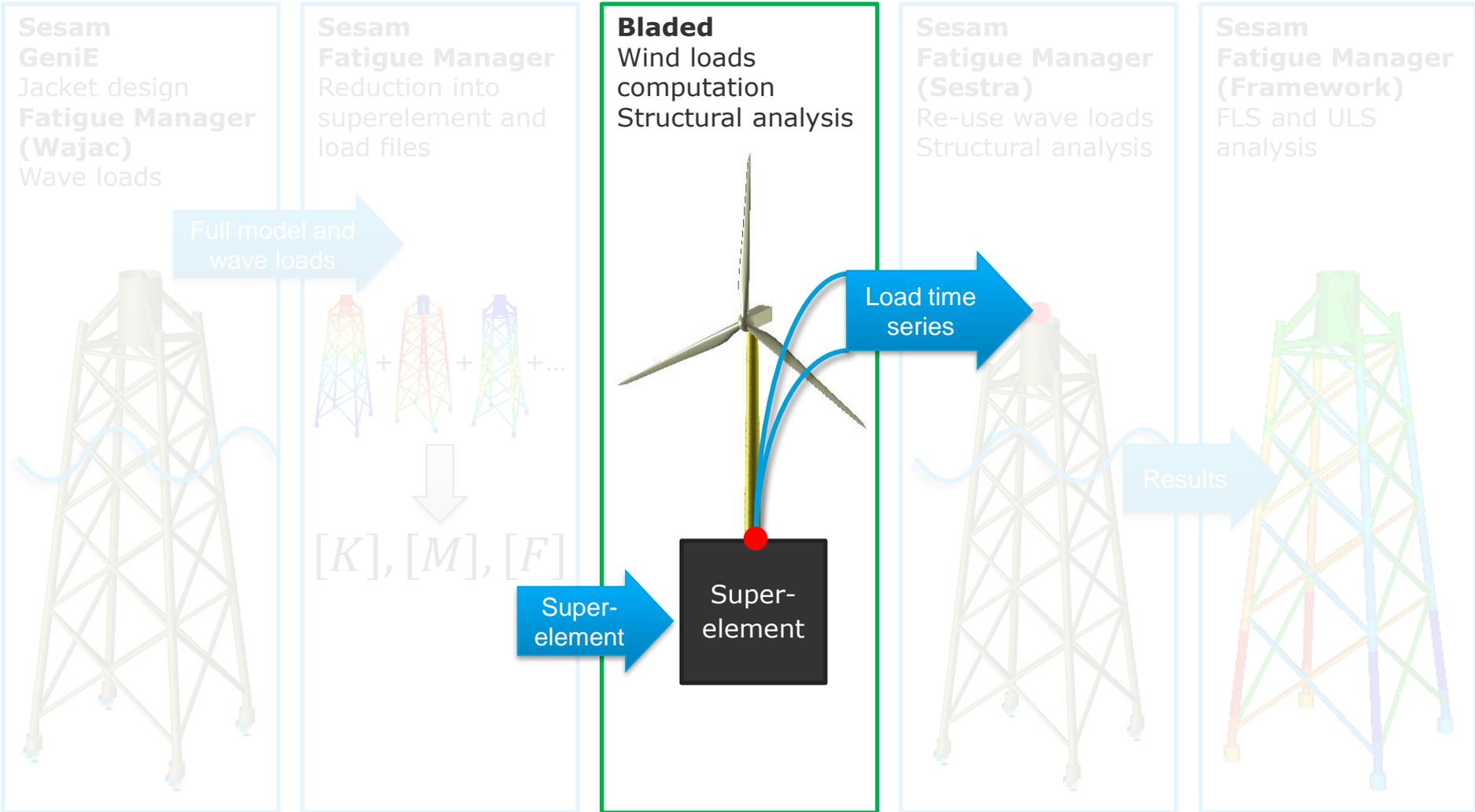


6 DOFs at interface

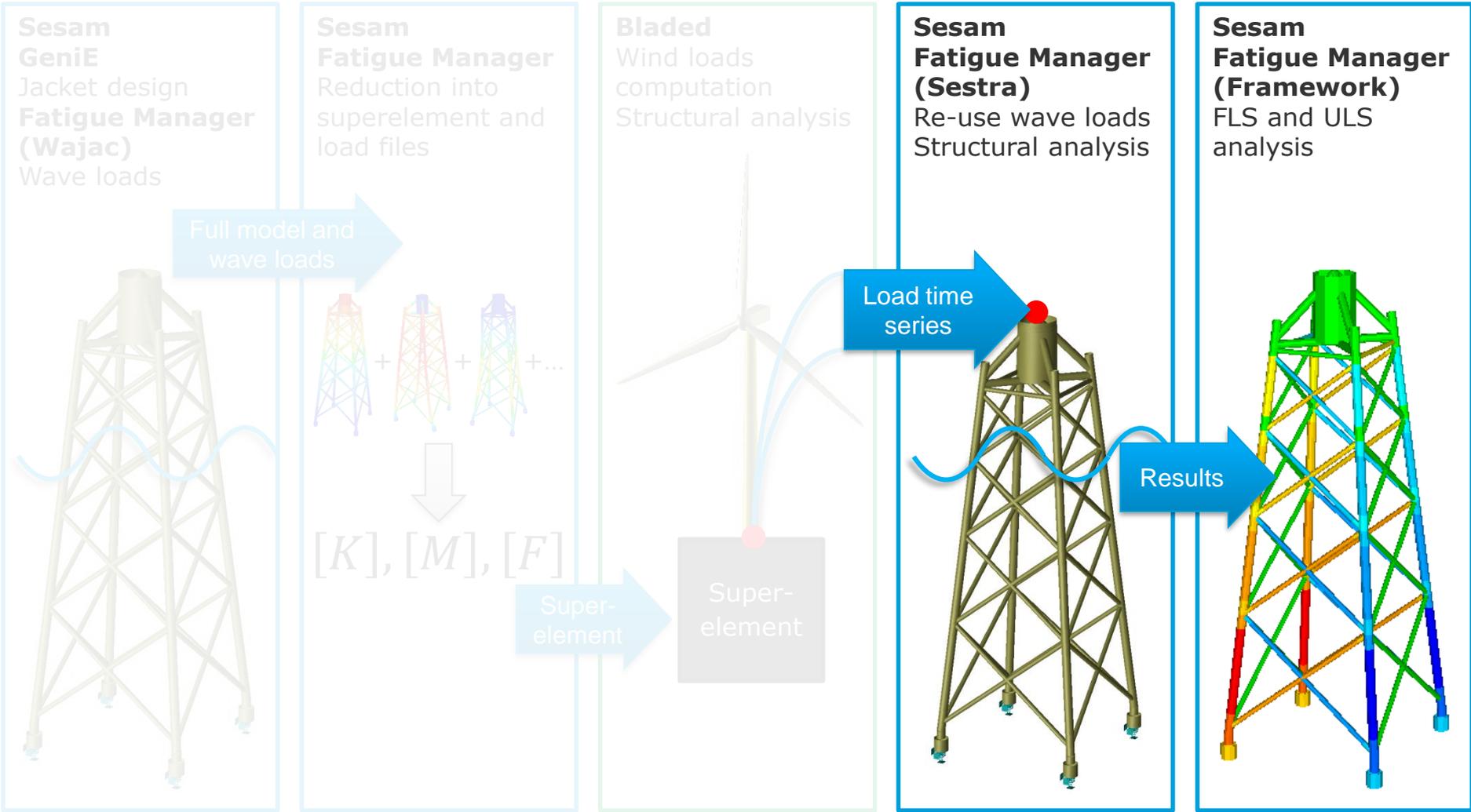
Mode shapes

Superelement

# Superelement Analysis – part 2 (wind turbine dynamic analysis)



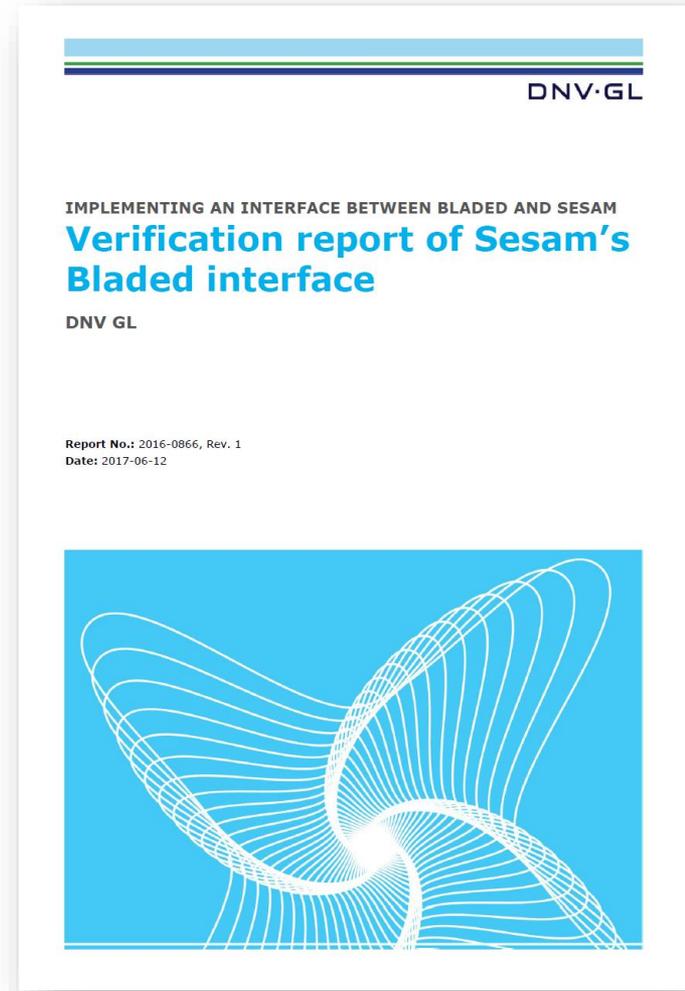
# Superelement Analysis – part 3 (re-simulation and postprocessing)



# Superelement method verification

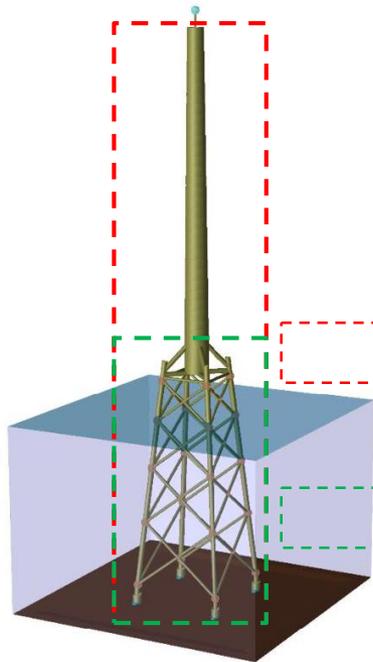
# Verification - aim

- Verify superelement workflow
  - Superelement creation in Sesam
  - Import and simulate with superelement in Bladed
  - Export of Bladed motions and loads to Sesam for post-processing
- Demonstrate alignment integrated and superelement results

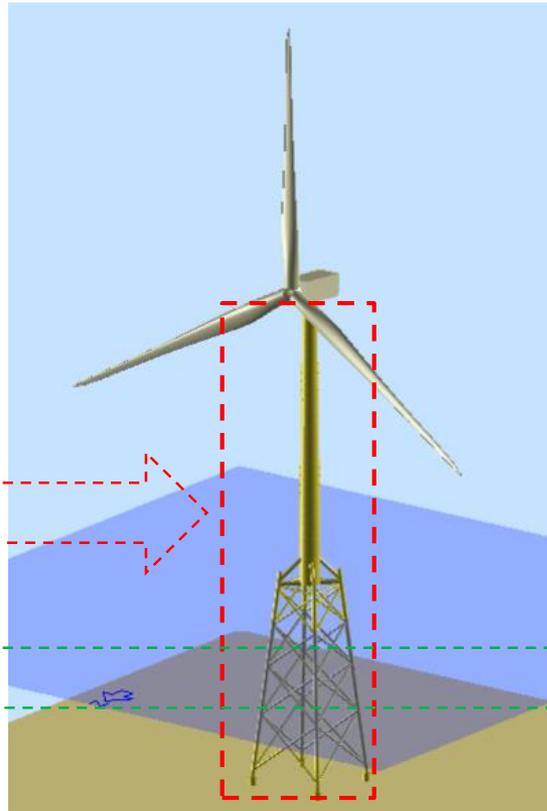


# Verification – 3 models

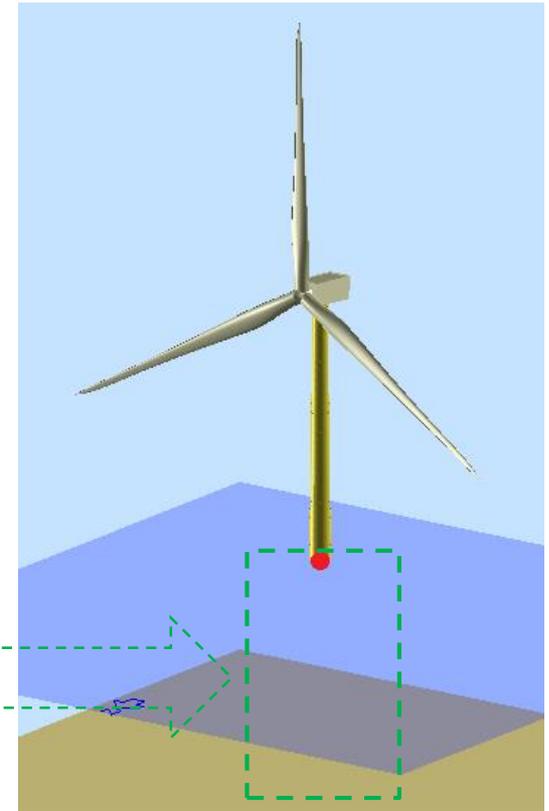
Sesam integrated



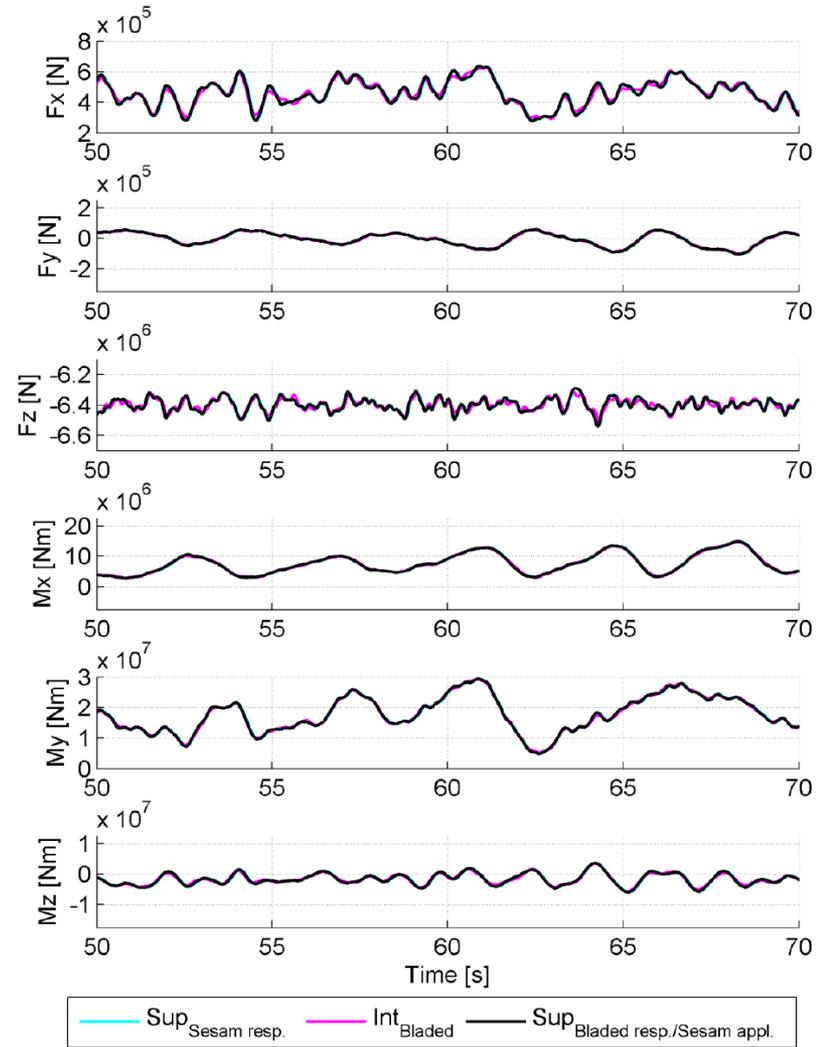
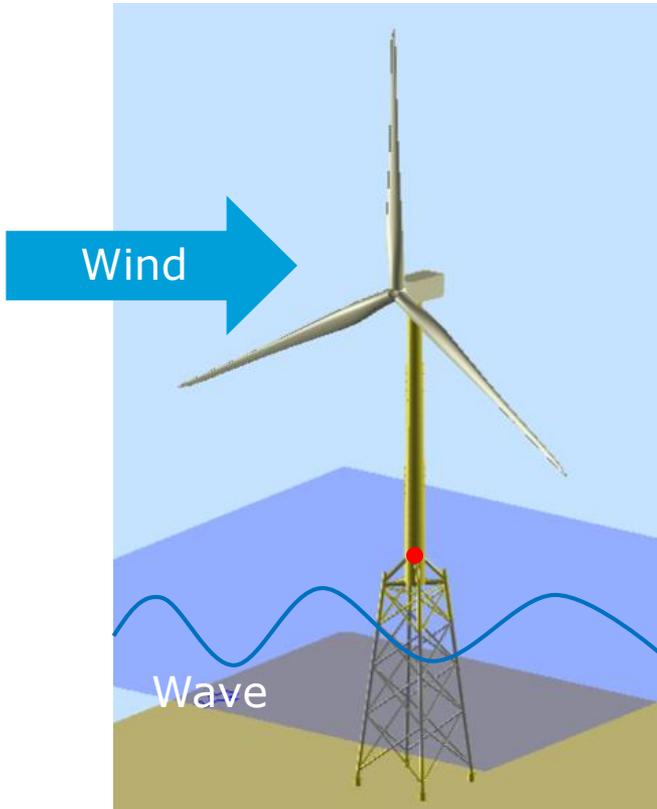
Bladed integrated



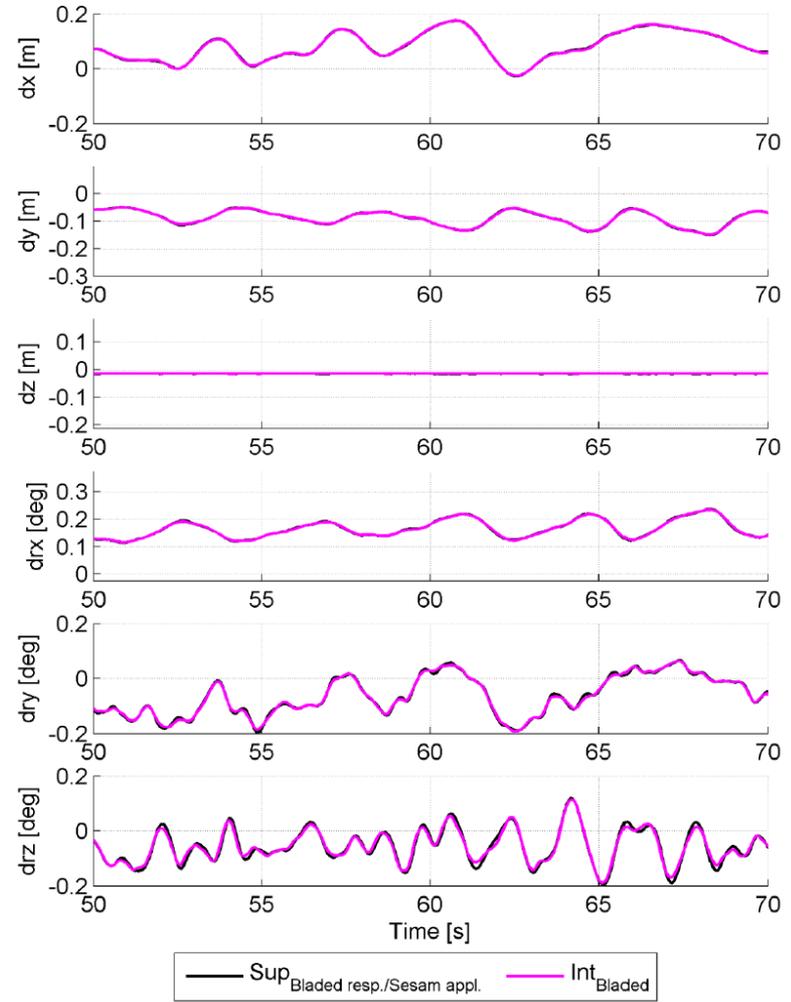
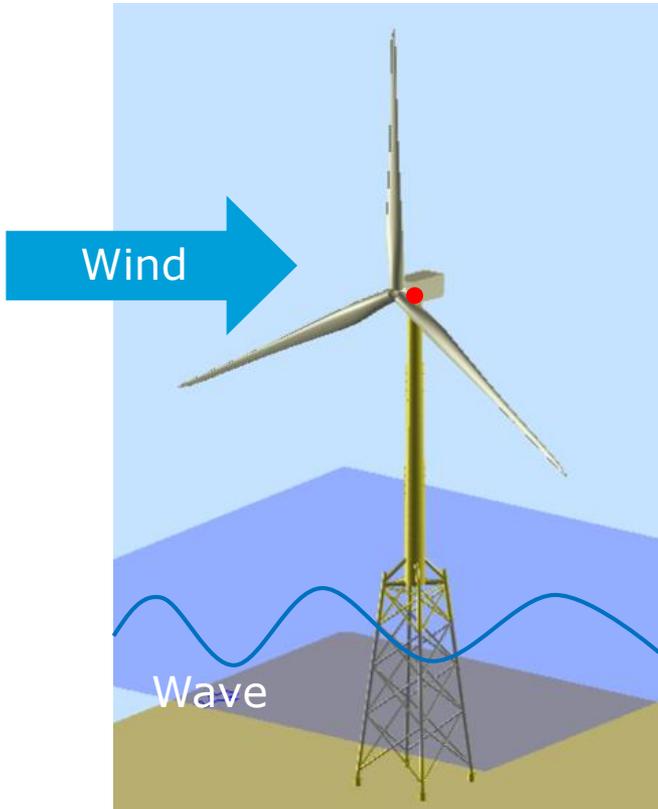
Bladed superelement



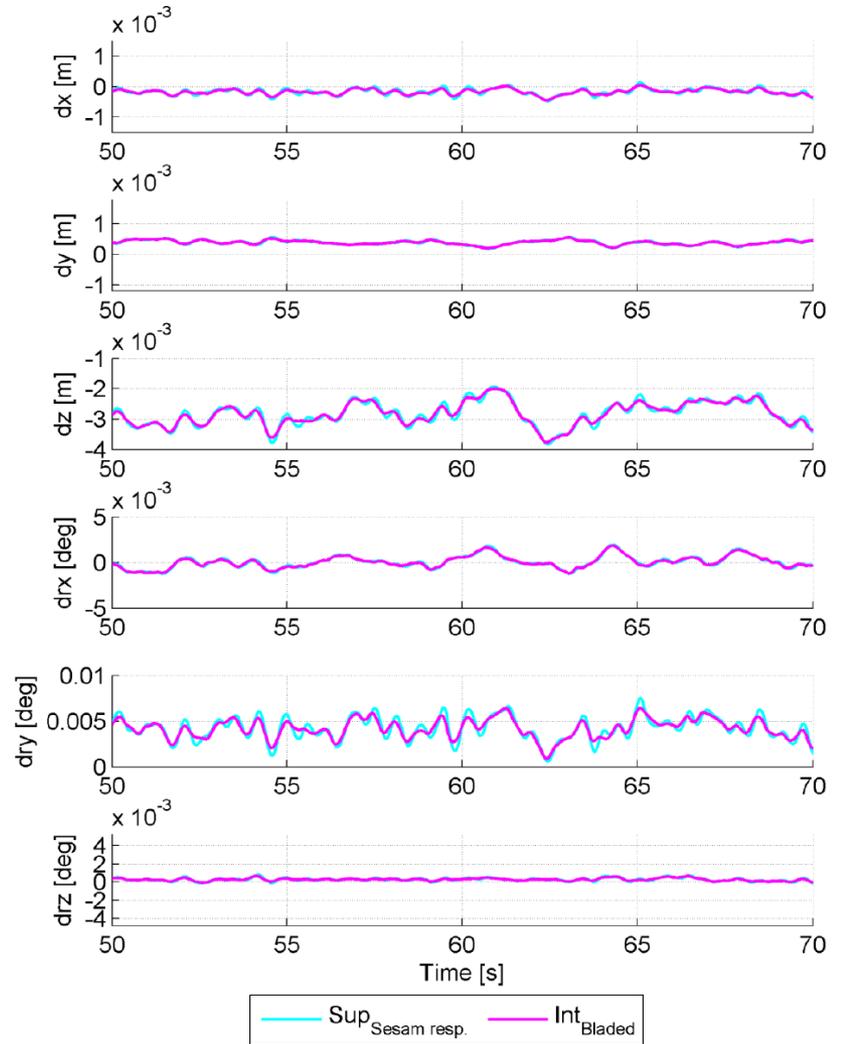
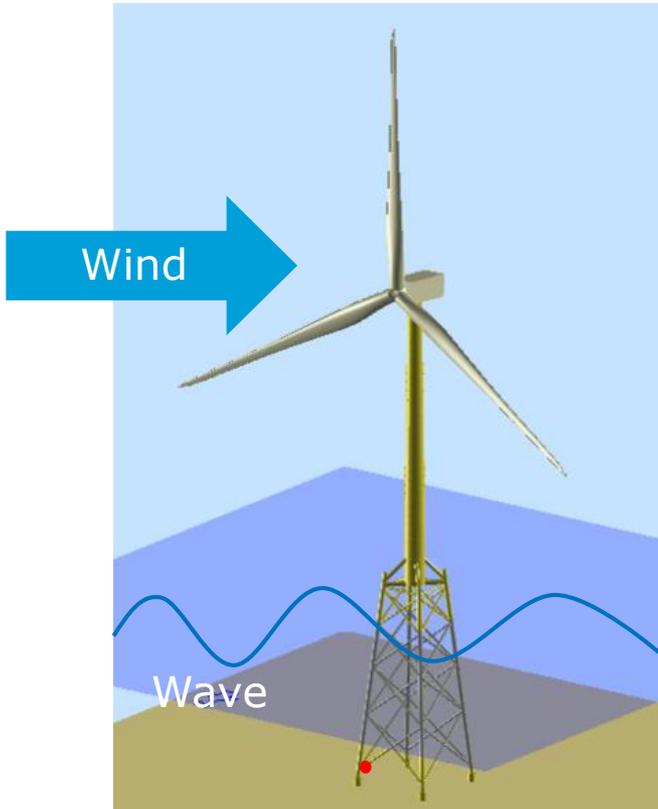
# Verification – interface loads



# Verification – tower top displacements

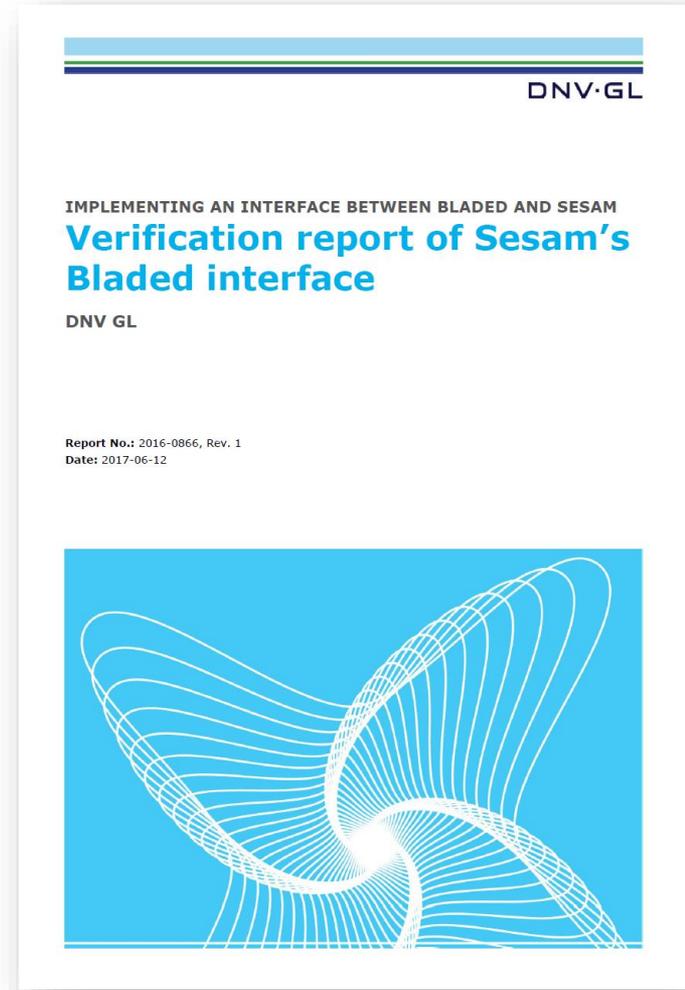


# Verification – node displacements



# Verification - conclusion

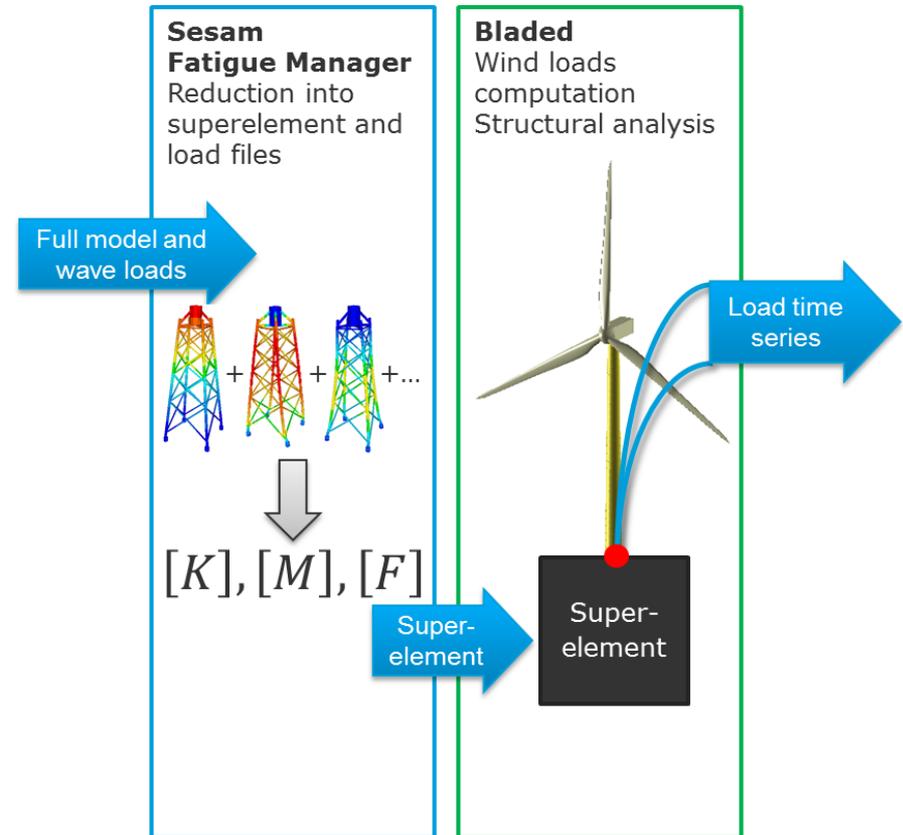
- Verified implementation of
  - integrated design workflow
  - superelement analysis workflow
- Verification of
  - Model and loads transfer
  - Load and deflection predictions
  - Results transfer



# Summary

# Summary

- Sesam and Bladed are well-interfaced:
  - Integrated design approach
  - Superelement analysis approach
- Superelement approach benefits:
  - Wave load calculation responsibility remains with FD
  - FD does not need to share design details with WTG designer
  - Allows complex jacket features to be modelled (e.g. shell elements)
- Well-interfaced tools can save engineering time



# Questions?