



WHEN TRUST MATTERS

# Sesam Time Domain Workflows for FOWT

Structural Assessment for FOWT Substructures. A Case Study with the  
VolturnUS-S and the IEA 15MW Wind Turbine

28 May 2025

# Agenda

## Introduction

## Sesam Workflows for Floating OWT

- Time Domain Direct Load Generation Method
- Time Domain Load Reconstruction Method
- Time Domain Response Reconstruction Method

## VoltturnUS with IEA15MW Case Study

## Summary and Q&A

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# Methods and workflows depend on design phase

- Initial sizing / preliminary design

- Frequency domain (FD) or time domain (TD)
- Uncoupled or 'simplified' coupled analysis (low detail on other model parts, e.g. simplified turbine)
- Fast design iterations
- Limited number of design load cases

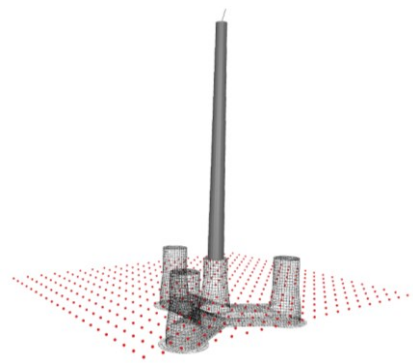
- Detailed design

- 'Detailed' TD coupled analysis (higher detail)
- TD loads and/or stresses on structural mesh
- Higher fidelity, suitable for certification
- Large number of design load cases

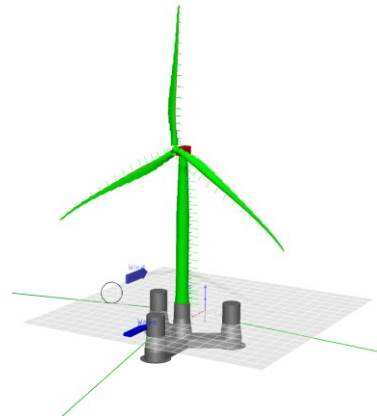
The presented methods are complementary for the whole design cycle



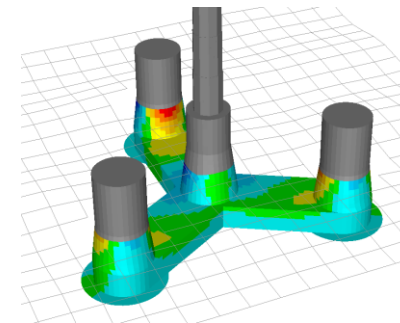
Modelling CAD/FEM  
(GeniE)



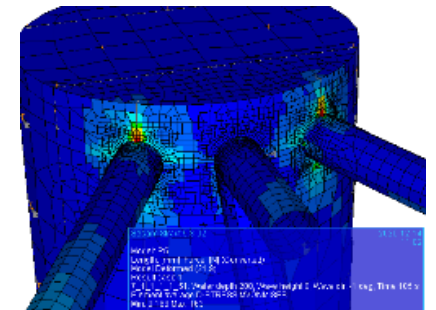
Frequency domain hydrodynamics  
(HydroD)



Coupled analysis  
(Bladed or Sima)











Hydrodynamic load generation & mapping  
(HydroD, Wasim & Sesam Core)



Structural analysis & code checking  
(Sestra & Sesam Core)

# Sesam analysis methods for FOWT structures

## Overview

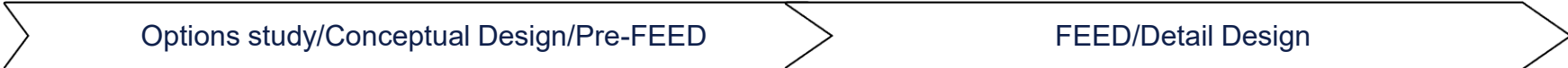
	Frequency Domain Uncoupled	Time Domain Response Reconstruction	Time Domain Load Reconstruction	Time Domain Direct Load Generation
Fidelity	Low	High	High	High
Computational Cost				
Design Phase Applicability	 <ul style="list-style-type: none"> <li>Initial sizing</li> <li>Early design</li> <li>Prototyping</li> </ul>	 <ul style="list-style-type: none"> <li>(pre)FEED</li> <li>Detailed</li> </ul>	 <ul style="list-style-type: none"> <li>(pre)FEED</li> <li>Detailed</li> </ul>	 <ul style="list-style-type: none"> <li>Detailed</li> </ul>

**Fastest** method  
 Wind as extreme load (ULS) or DEL (FLS)  
 Uncorrelated wind & wave  
 Linear hydrodynamics

**TD workflow 20x faster!** FLS/ULS in minutes rather than hours  
 Linear hydrodynamic pressure  
 Quasistatic

Hydrodynamic pressure generation 180x faster  
 Linear hydrodynamic pressure  
 Quasistatic or **dynamic** response

**Most accurate method**  
**Non-linear hydro pressure** possible  
 Quasistatic or dynamic response



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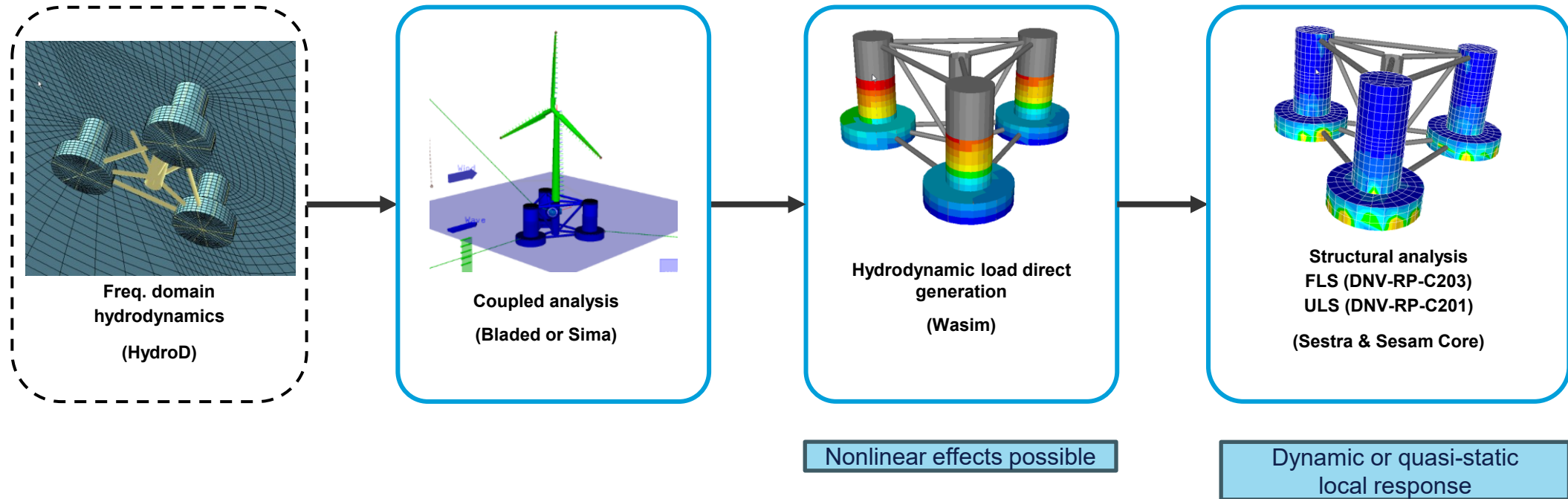
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## VoltturnUS with IEA15MW Case Study

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# Time Domain Direct Load Generation

The baseline time domain workflow in Sesam



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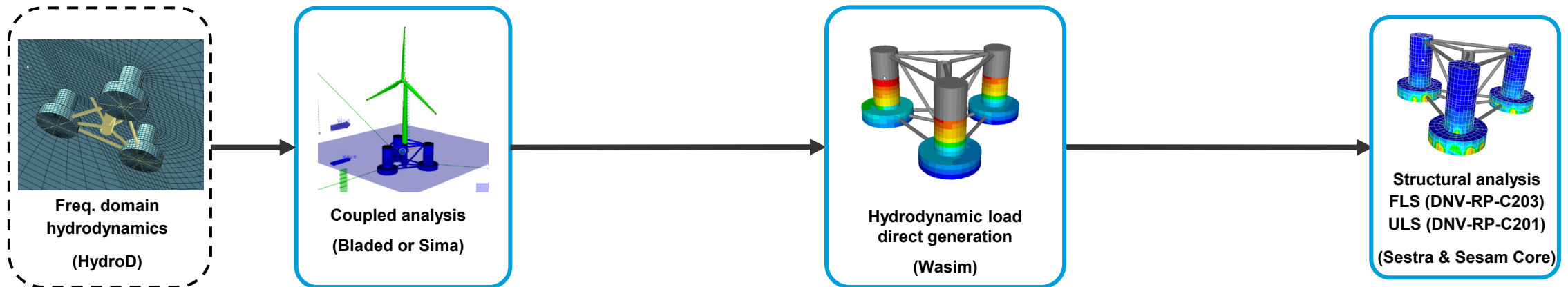
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## Summary and Q&A

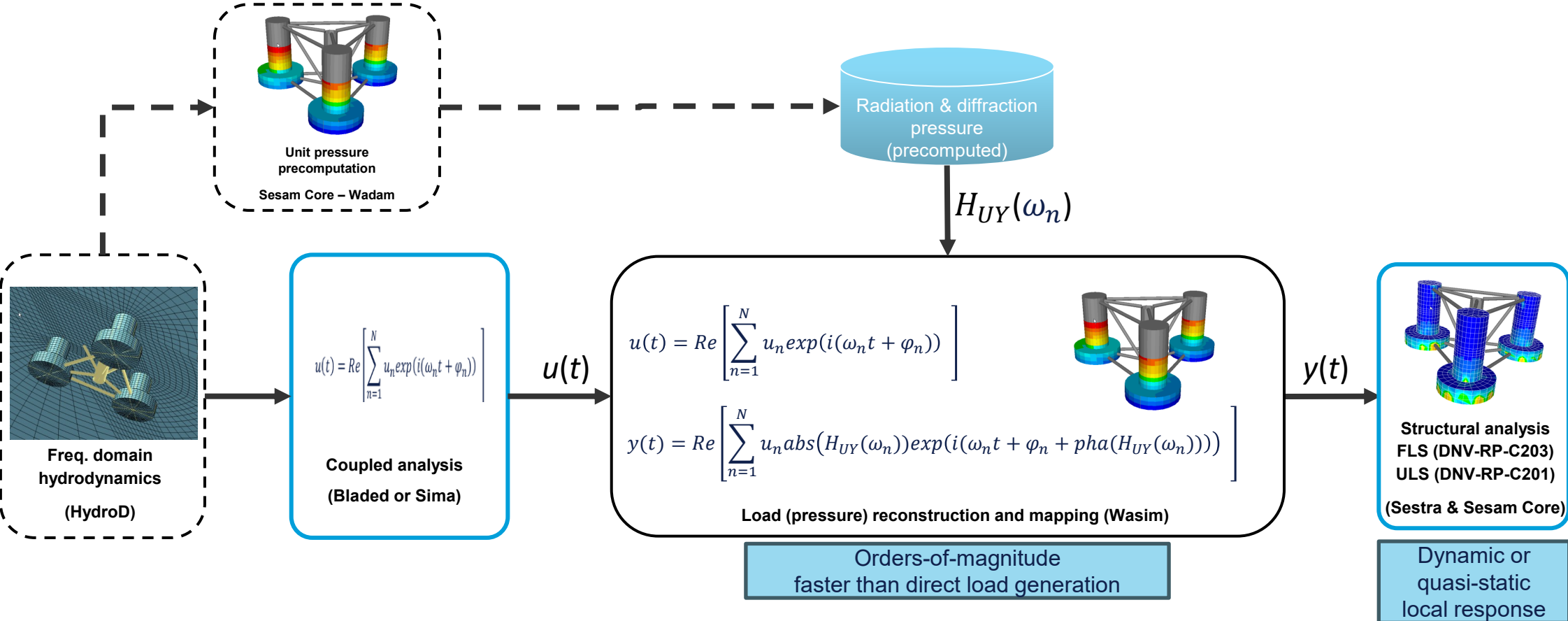
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The baseline time domain workflow in Sesam

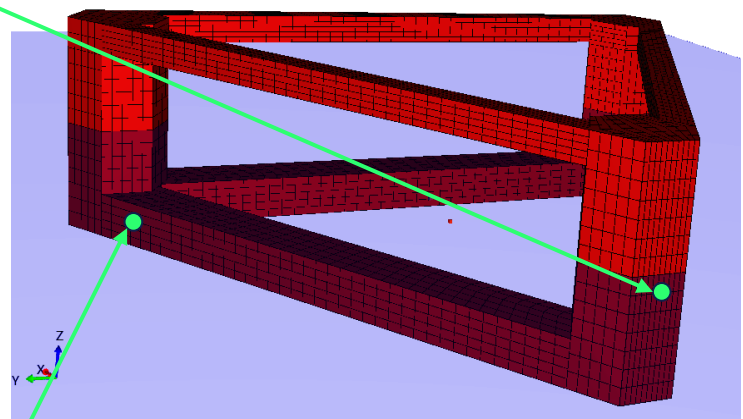
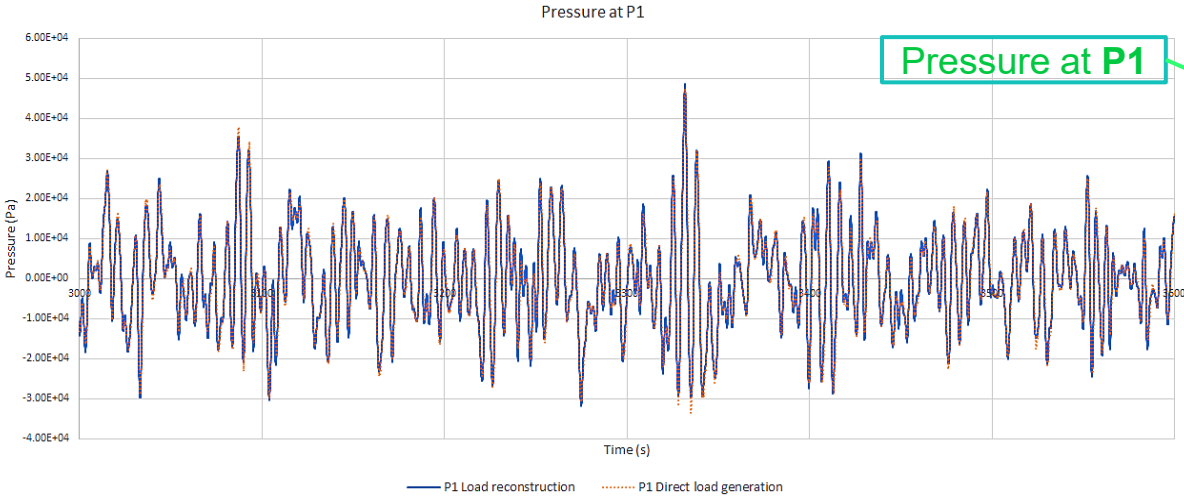


# Time Domain Load Reconstruction

180x faster hydrodynamic pressure generation



# Time Domain Load Reconstruction



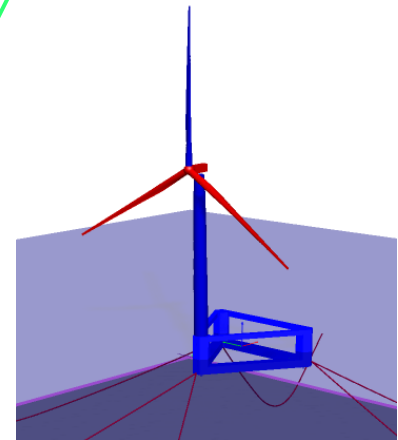
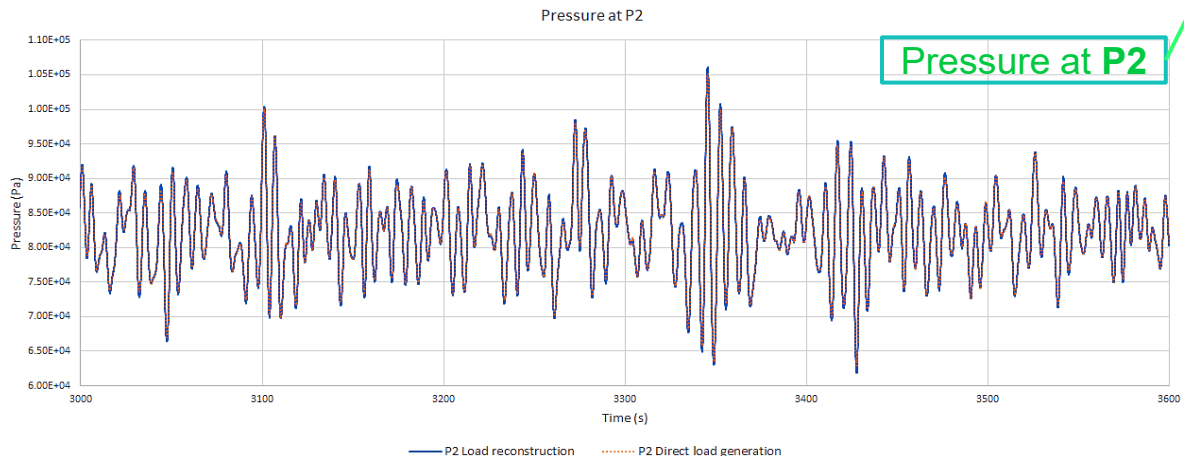
**EMULF I&II**

- "Efficient numerical methods for ultra large floating wind turbines"
- Joint industry project
- Funding from COWI/fonden
- Balancing accuracy and time

Accuracy

Time

COWI
COWIfonden
DTU
DNV



Simulation Stage	Variable	Value	Units
Model Information	Model	EMULF-Delta	-
	Wet Panels	1621	-
	Finite Elements	43073	-
Precomputation	Wave direction	0	deg
	Wave Frequencies	0,1:0,02:5	rad/s
Time Domain Coupled Analysis	Wave Spectrum	JONSWAP	-
	Hs	3,0	m
	Tp	6,9	s
	Wind speed	15,0	m/s

Time history of total pressure at P1 & P2

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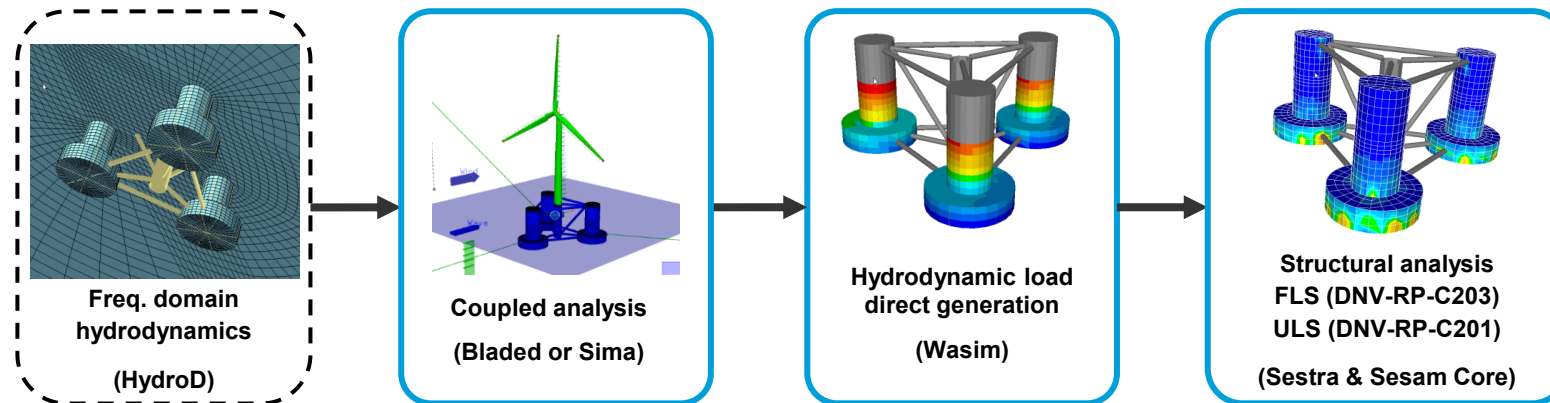
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## VoltturnUS with IEA15MW Case Study

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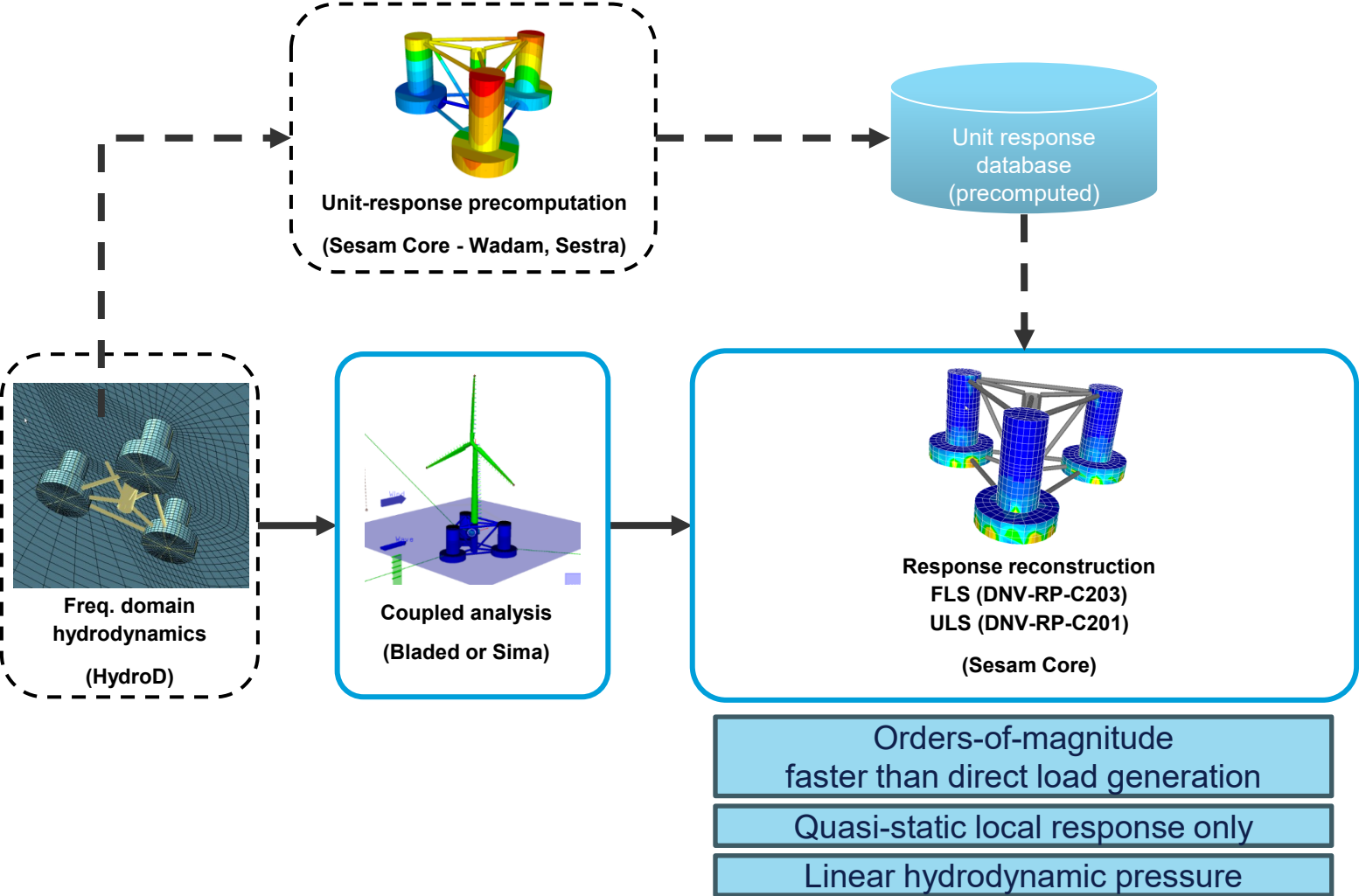
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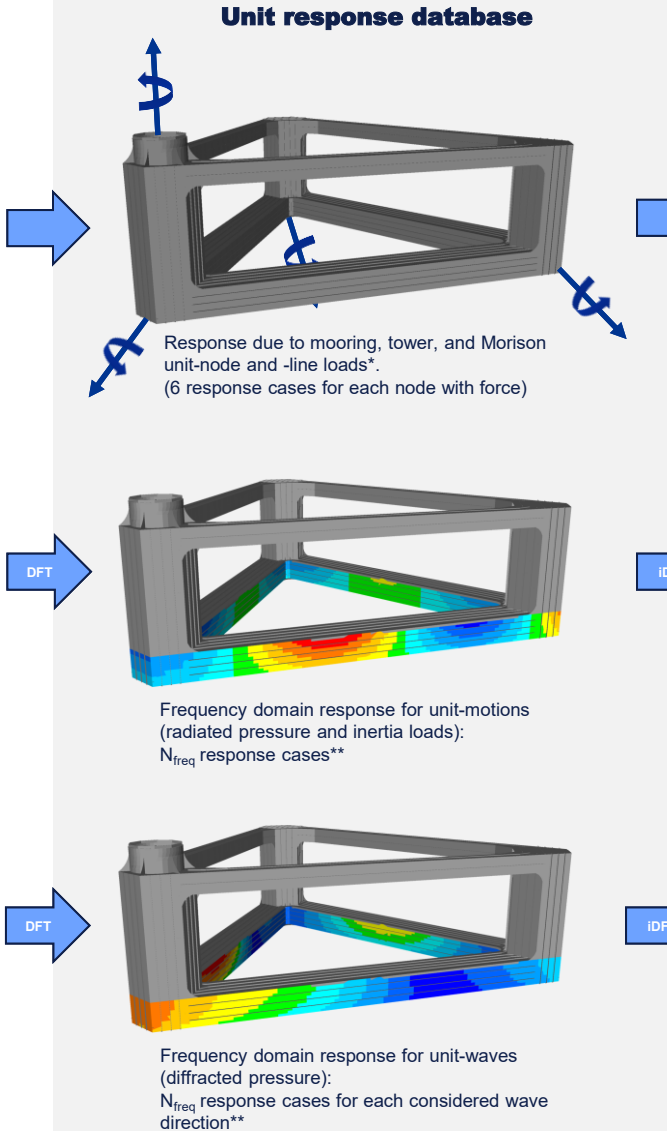
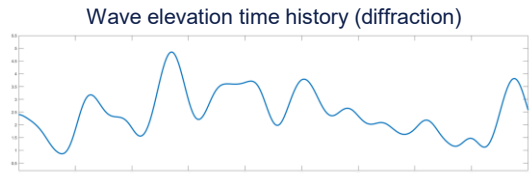
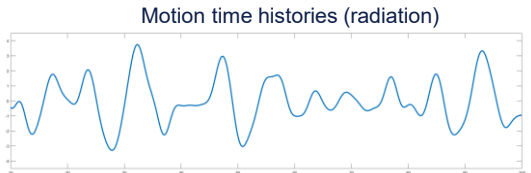
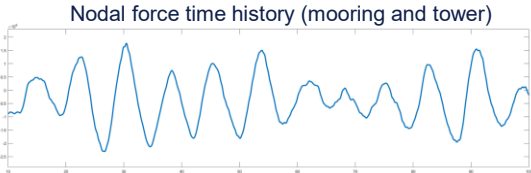
# Time-Domain Response Reconstruction

20x faster workflow. FLS/ULS in minutes rather than hours

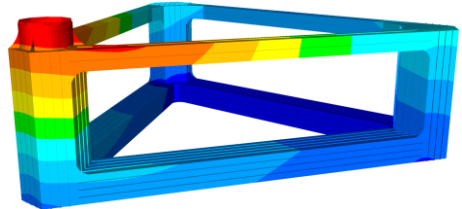


# Time-Domain Response Reconstruction

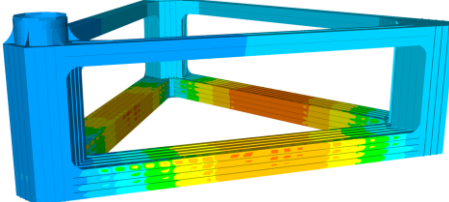
**Coupled analysis results**



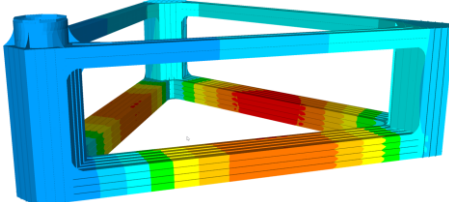
**Physical responses (time domain)**



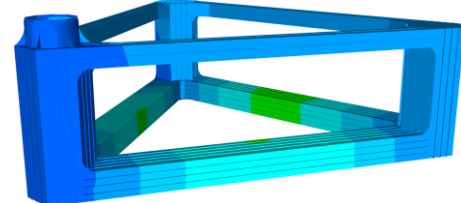
+



+



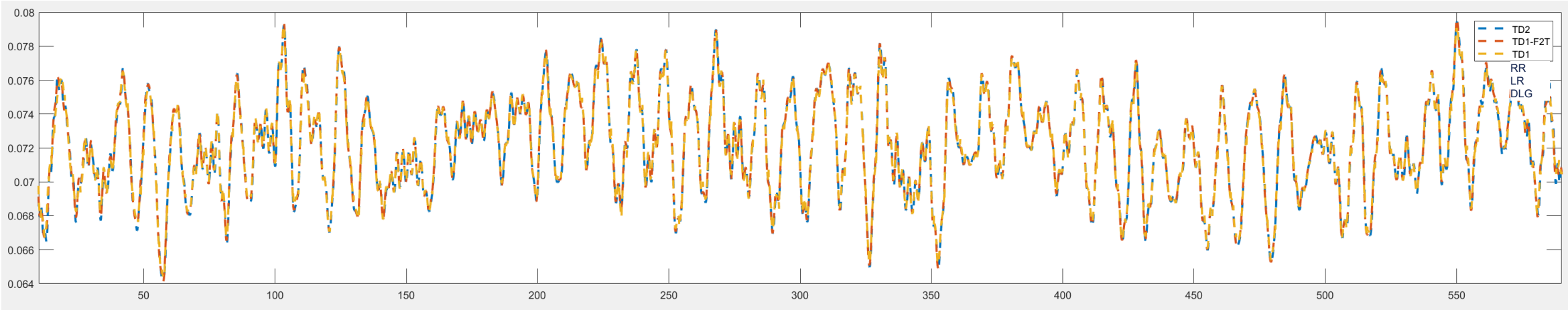
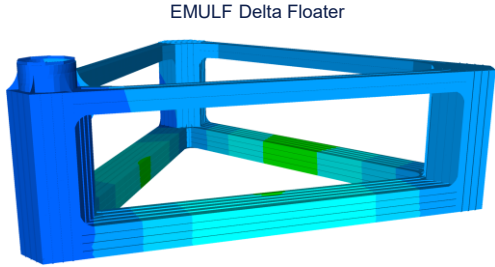
**Linearly combined response (time domain)**



\* If the model contains submerged beams, Morison loads are included in a similar fashion using line loads.  
 \*\*N<sub>freq</sub> is selected by the user. For short-crested sea, multiple wave directions are considered for diffraction due to wave spreading.



# Results comparison of all three methods

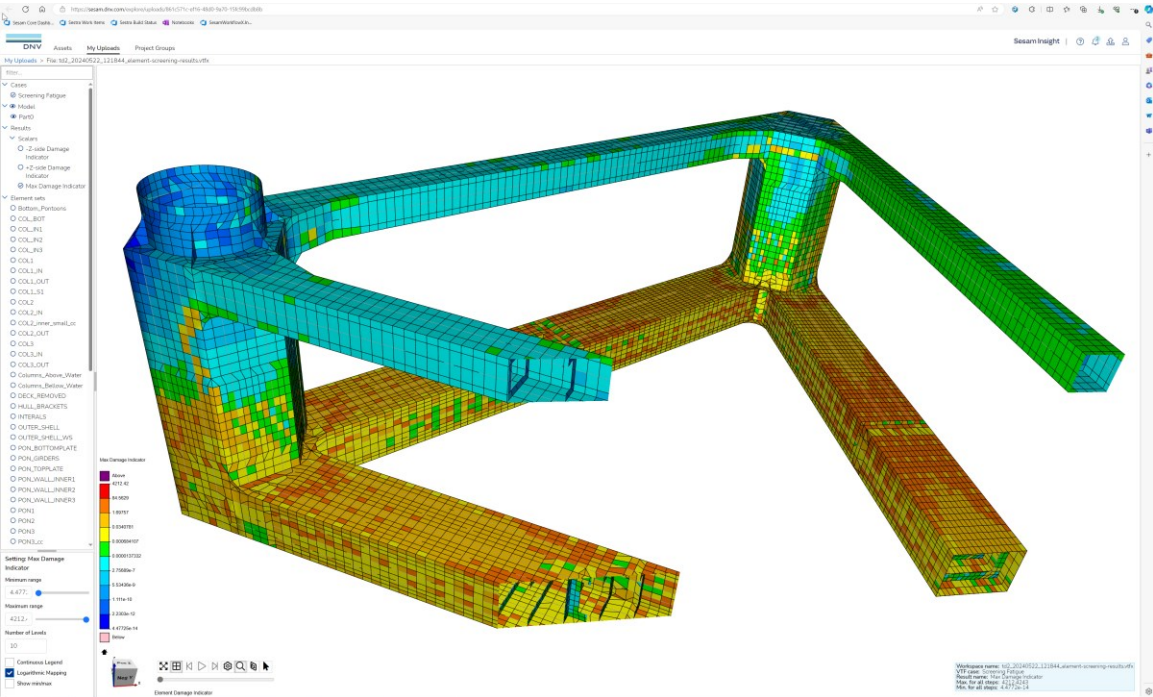


z-displacement at an arbitrary node as function of time

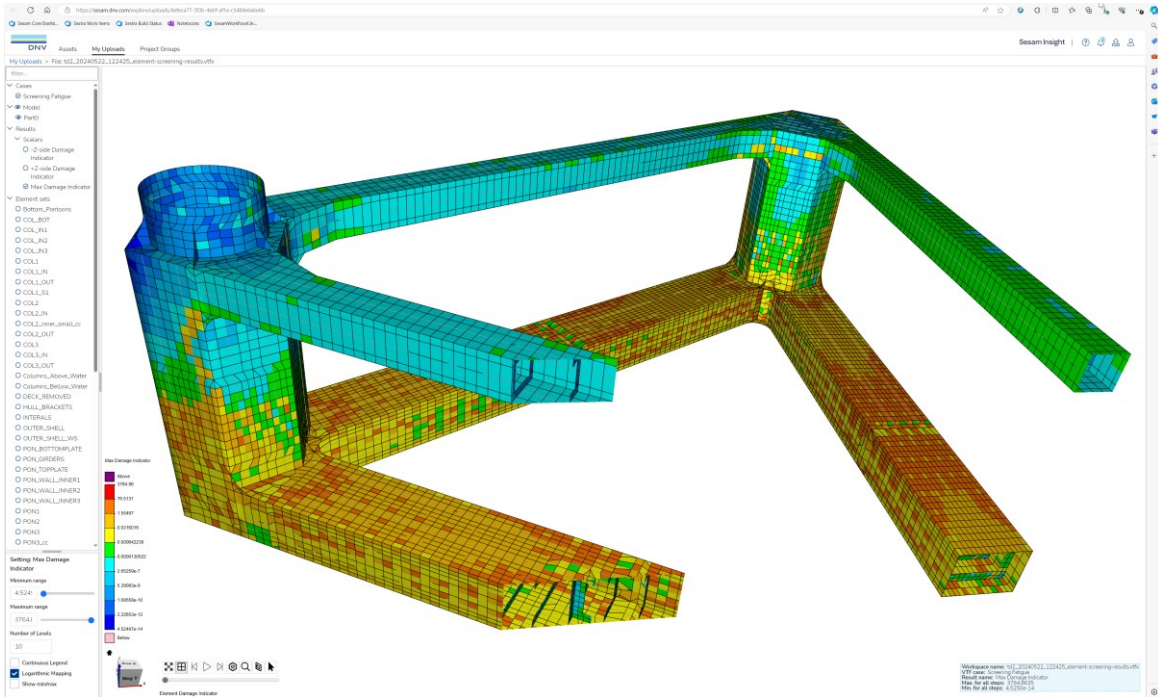
Time Domain **Response Reconstruction** (RR) vs Time Domain **Load Reconstruction** (LR) vs Time Domain **Direct Load Generation** (DLG)  
All results are with linear hydrodynamics and quasistatic structure response

# Response Reconstruction vs Direct Load Generation

## FLS Screening Indicator, Sesam Insight

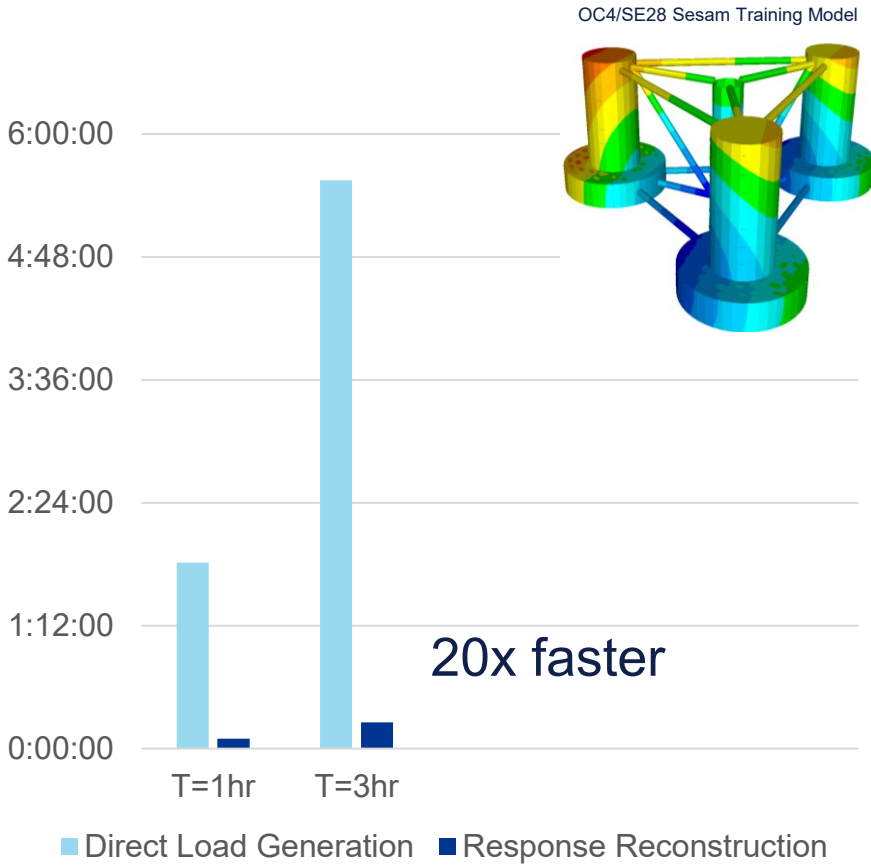
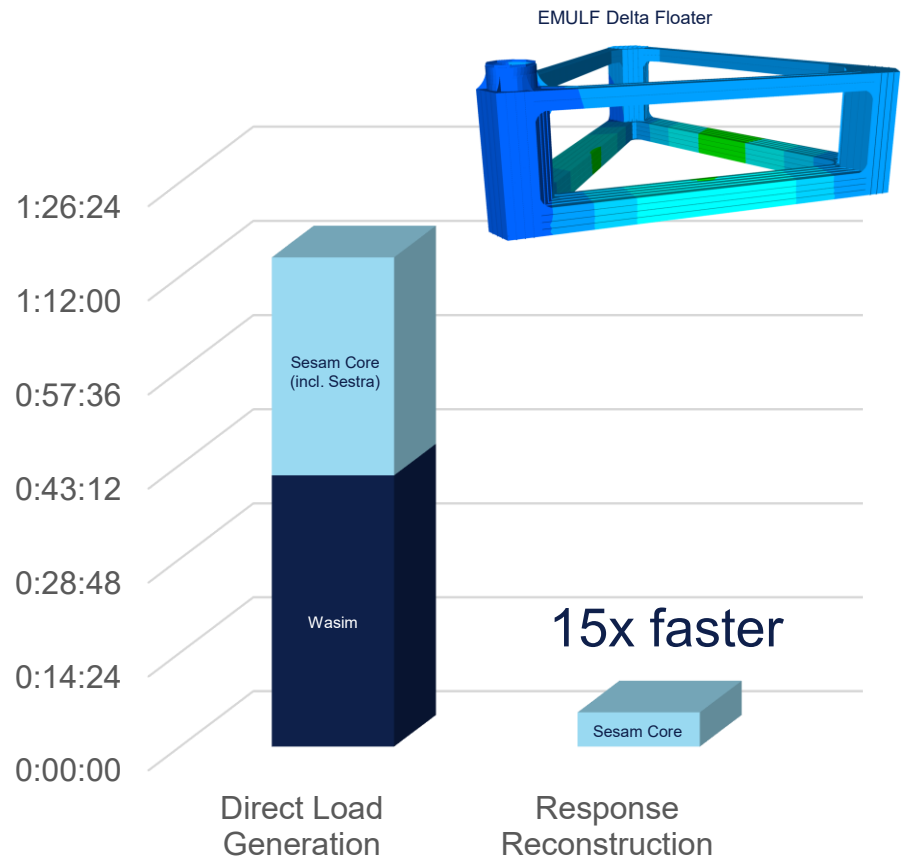


Direct Load Generation

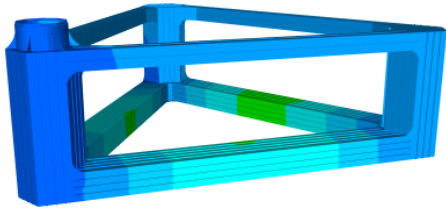


Response Reconstruction

# Response Reconstruction vs Direct Load Generation



# Response Reconstruction vs Direct Load Generation



EMULF Delta Floater  
 $N_{\text{elements}} = 43\,073$   
99 frequencies  
Long-crested sea  
(single wave heading)

## Unit-response database

<input checked="" type="checkbox"/> Dir1.SIN	254 508 KB	Unit-wave-generated response
<input checked="" type="checkbox"/> RaFxR1.sin	252 747 KB	Unit-motion-generated response
<input checked="" type="checkbox"/> RaFyR1.sin	252 747 KB	
<input checked="" type="checkbox"/> RaFzR1.sin	252 747 KB	
<input checked="" type="checkbox"/> RaMxR1.sin	252 747 KB	
<input checked="" type="checkbox"/> RaMyR1.sin	252 747 KB	
<input checked="" type="checkbox"/> RaMzR1.sin	252 747 KB	
<input checked="" type="checkbox"/> UnitNodalR1.sin	50 335 KB	Unit-load-generated response
< 2GB		

## Storage

### Direct Load Generation:

- For **each DLC**: **80 GB** Loads Interface File (assuming 1hr simulation)
- Total for 100 DLCs: **8 000 GB**

### Response Reconstruction

- For each DLC: 0.03GB for ULS (negligible for FLS)  
Unit-response database: **2 GB**
- Total for 100DLCs: **5 GB**

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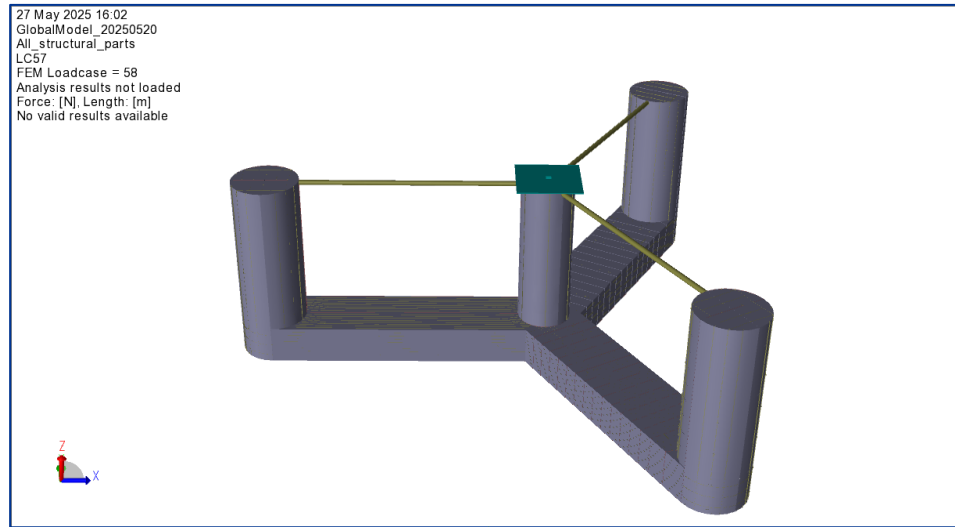
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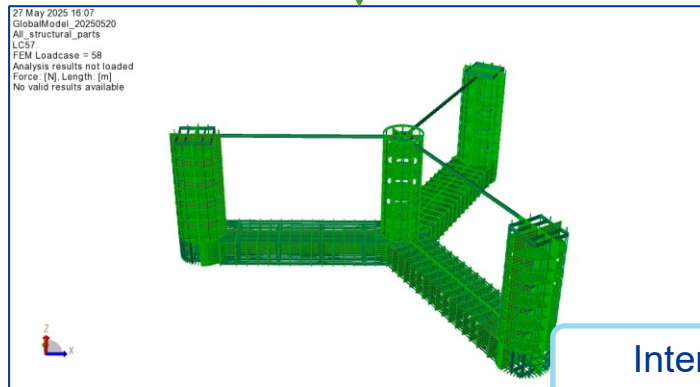
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## Summary and Q&A

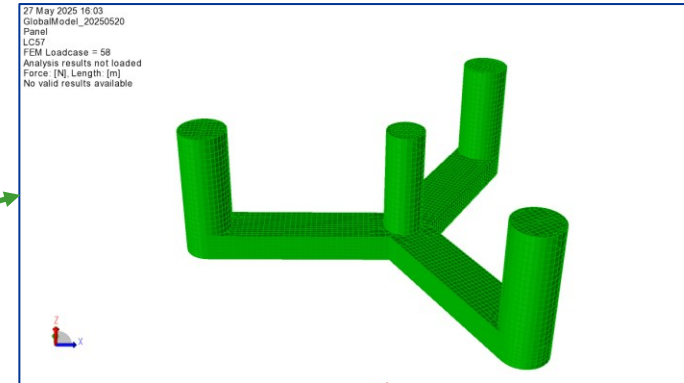
# VolturnUS-IEA15MW: Modelling with Sesam-GeniE



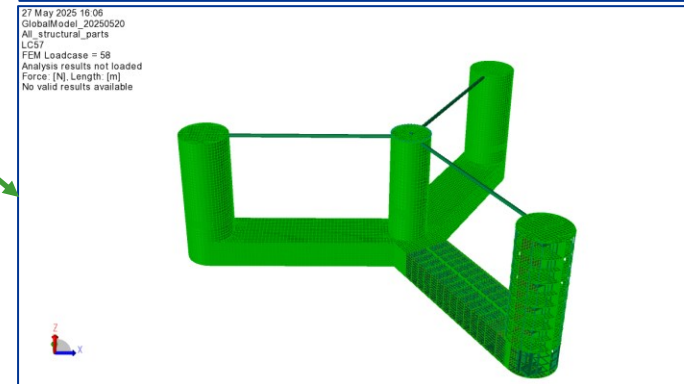
Global Model



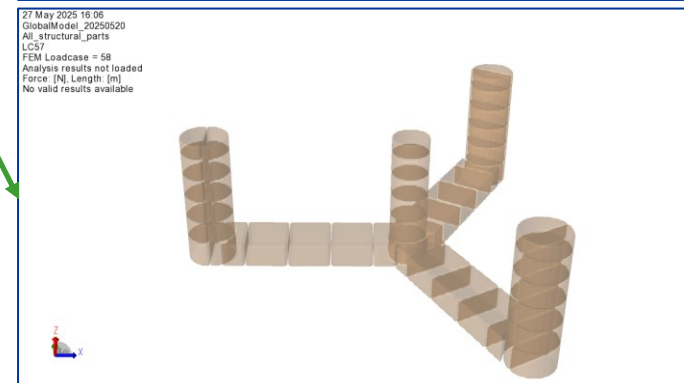
Internal Structure  
Beams+plates/shells



Panel Model

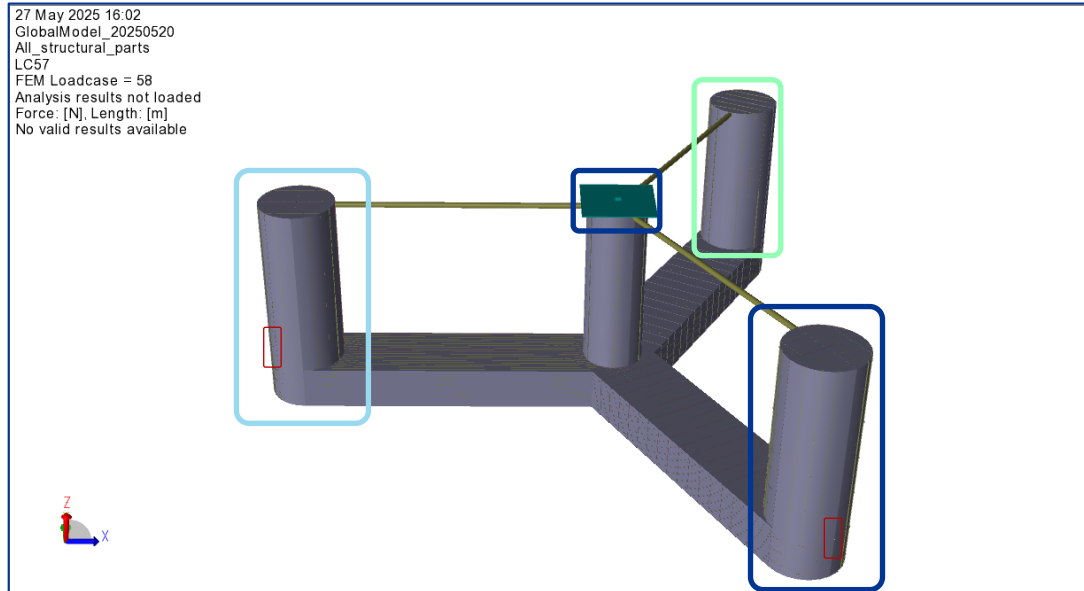


FEA Model  
Includes:  
Mass &  
Morison



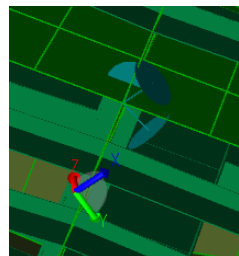
Compartment  
Model

# VolturnUS-IEA15MW: Boundary Conditions

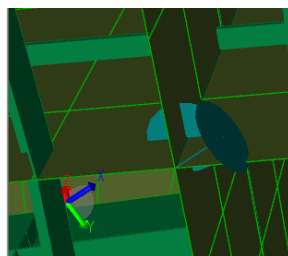


Structure in equilibrium every time step:

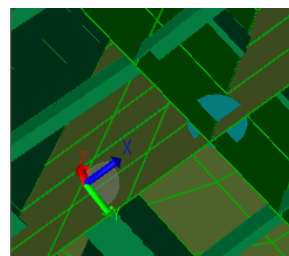
- Structural assessment loads in local coordinates
- Common approach 3-2-1 (6dof restriction)
- Dummy beams for point and line loads:
  - Morison
  - Tower base
  - Mooring fairleads
- Negligible loads/stress at BCs
- Sensitivity analyses required



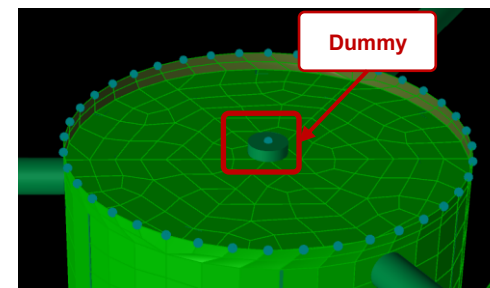
Col. 1:  
x/y/z



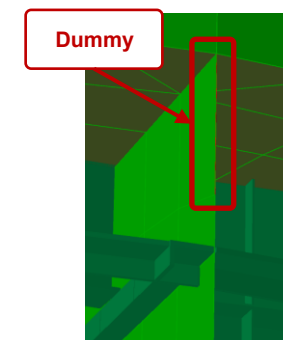
Col. 2:  
x/z



Col. 3:  
z

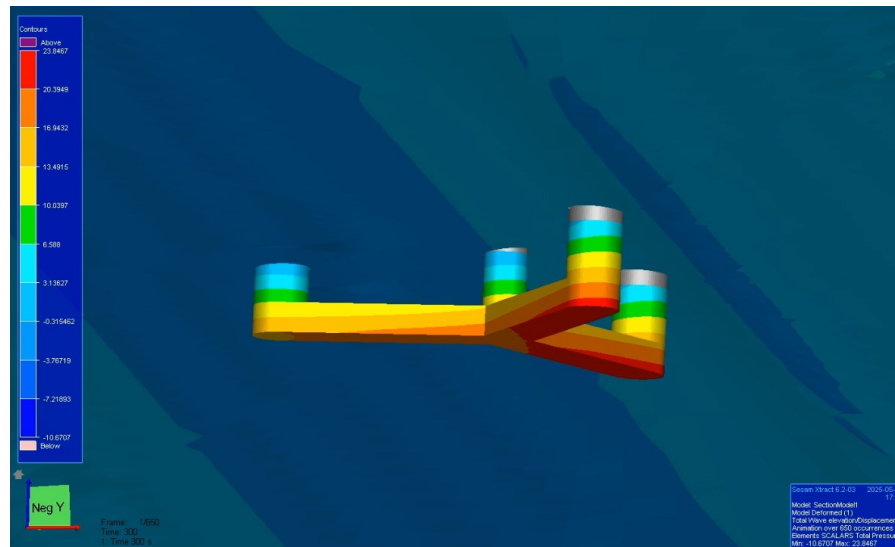
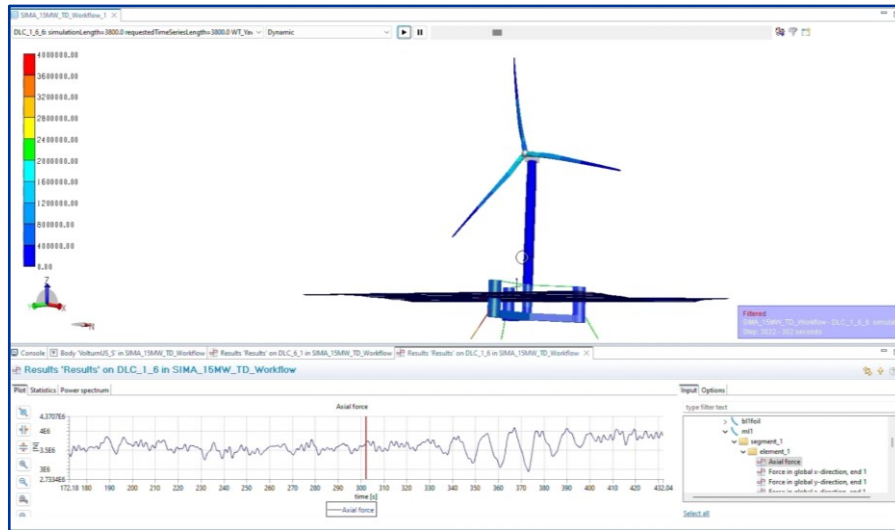


Rigid Link:  
Beam to shell loads transfer



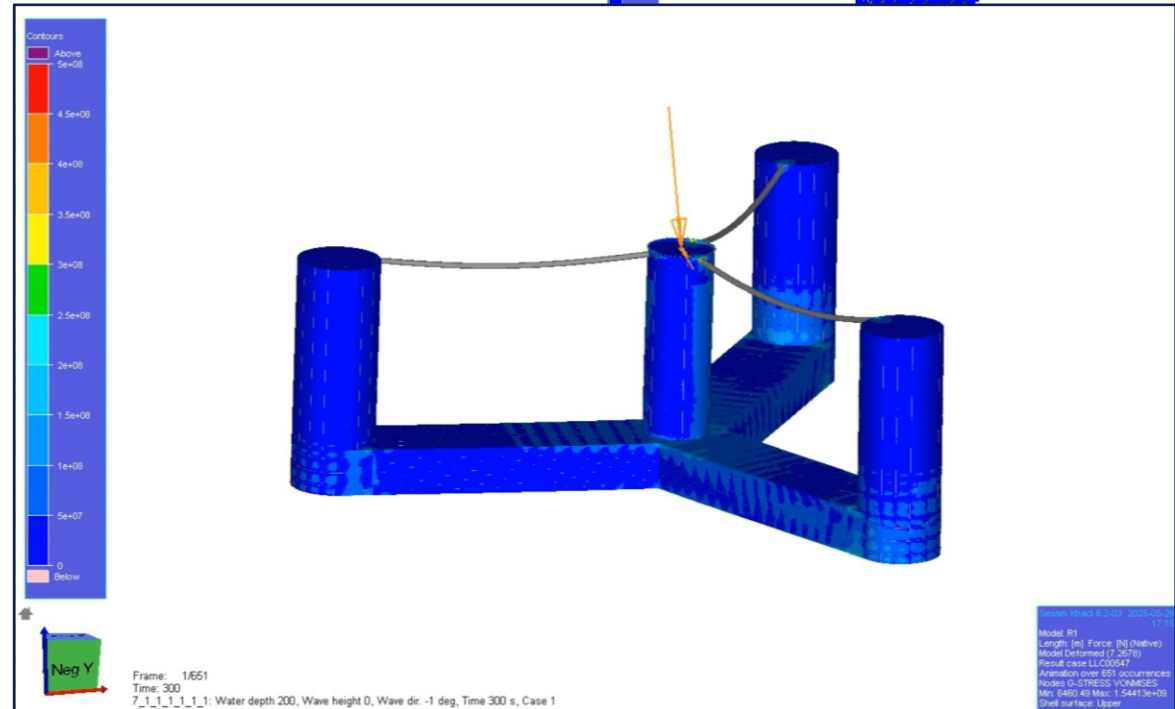
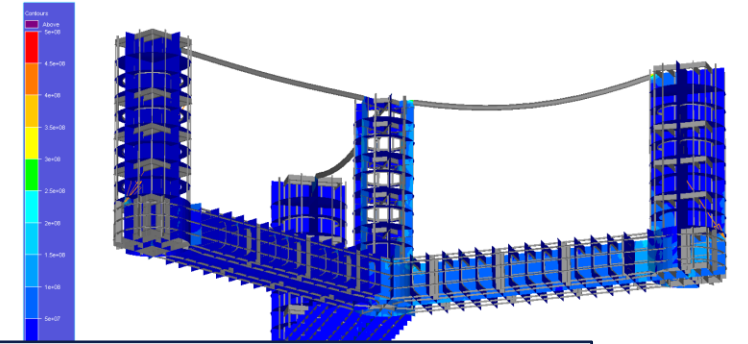
Dummy beam:  
Fairleads

# VolturnUS-IEA15MW: DLC 1.6



## Severe Sea State with Power Production

- $H_s = 8.5\text{m}$
  - $T_p = 13.1$
  - $V_{\text{wind\_mean@HH}} = 14\text{m/s}$
- TD Method: Direct Load\*\*
- \*\*Linear version (submerged geometry)



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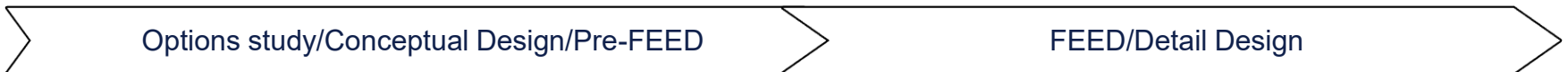
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# Q&A

# Thank you for attending!