Maynooth Wave Energy Workshop, 23 / 1 2026

On the choice of Technology Simulation Level

and its importance in wave energy design calculations

Johannes Palm and Claes Eskilsson,
Agaton Hydrodynamics AB

Introducing latest developments in MoodyMarine in collaboration with RISE
Project examples courtesy of Sigma Energy and Marine and Ocean Harvesting Technologies

AHAB Sigma Energy & Marine RI. SE COER Centre for Ocean Energy Research Maynooth University National University of Ireland Maynooth

Agaton Hydrodynamics AB

J. Palm and C. Eskilsson

Consulting services in marine technology

- Design code calculations
- Scientific computing and numerical model development.
- Mooring design, Potential flow, CFD, Machine learning
- Close collaboration with Sigma Energy and Marine

→ *Choose the right method for the job*

Innovations starting up in 2026

- Component development for marine energy

Consultancy

Research
Design
Bespoke software

Innovation

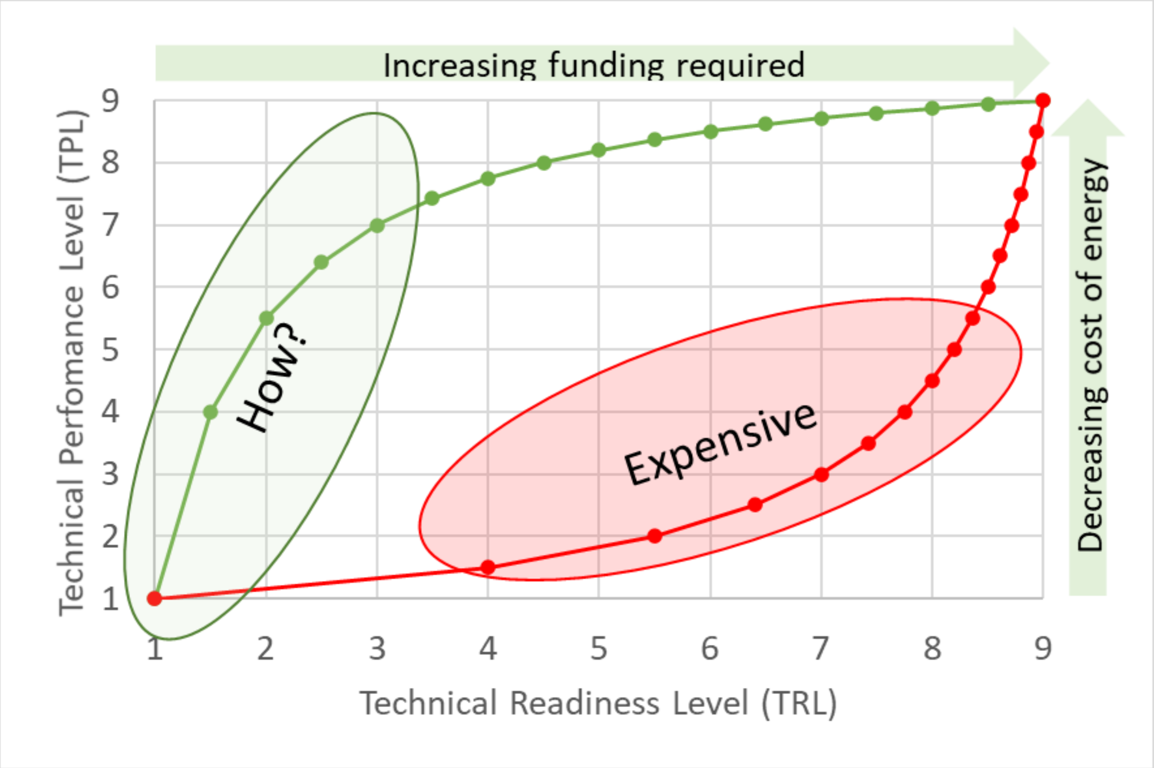
Mooring
Anchoring
Buoyancy

“It is easy to make a device that will respond vigorously to the action of sea waves.
Indeed, it is quite hard to make one that will not.”

S. H. Salter, J. R. M. Taylor, and N.J. Caldwell. Power conversion mechanisms for wave energy. Proc. Instn Mech Engrs Part M, 216, 2002.

TRL – TPL roadmap

14 years in the making



Level		1	2	3	4	5	6	7	8	9
TRL	*Test*	None		TANK			PILOT	DEMO		ARRAY
TPL	*Cost of Energy*	High			Medium			Competitive		

Adopted from Weber, J. WEC Technology Readiness and Performance Matrix – finding the best research technology development trajectory. In: *Proc.of the 4th International Conference on Ocean Energy*, 17 October 2012, Dublin, Ireland

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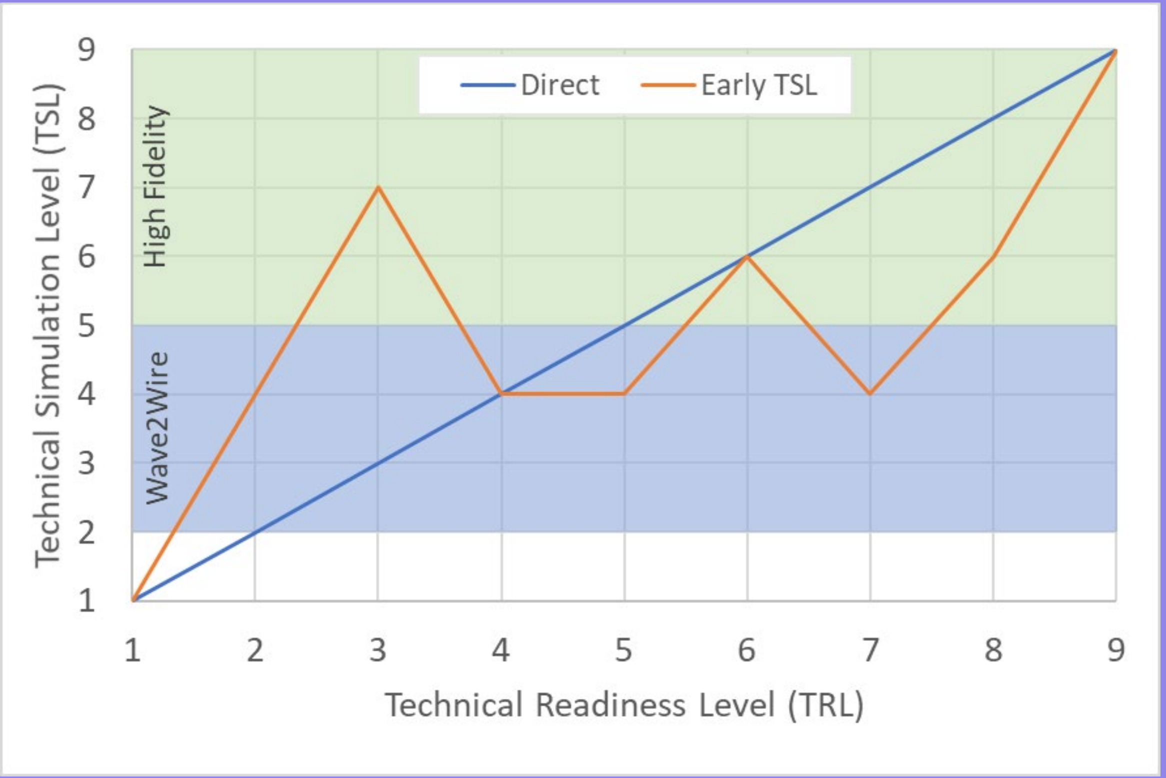
TRL – TSL roadmap

4 years in the making



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J.Palm, C.Eskilsson, On the choice of simulation methods for ocean energy technology at different stages of development ICOE-OEE 2022 poster. San Sebastian

Technology Simulation Level

- Achieving a high TPL is the ultimate goal.
- Experimental tests (increasing TRL) tell you how things work, not why.
- Numerical modelling plays an essential part to increase the understanding and test design iterations
- TSL is a complement to experimental tests
- We promote early TSL development

TSL	Hydrodynamic	Mooring	Power Take Off
1	Linear wave theory, (dof limit)	Quasistatic	Parametric
2	Linear wave theory (dof limit)	Dynamic	Parametric
3	Linear wave theory, full motion.	Dynamic	Parametric
4	Weakly nonlinear models	Dynamic	Control, parametric
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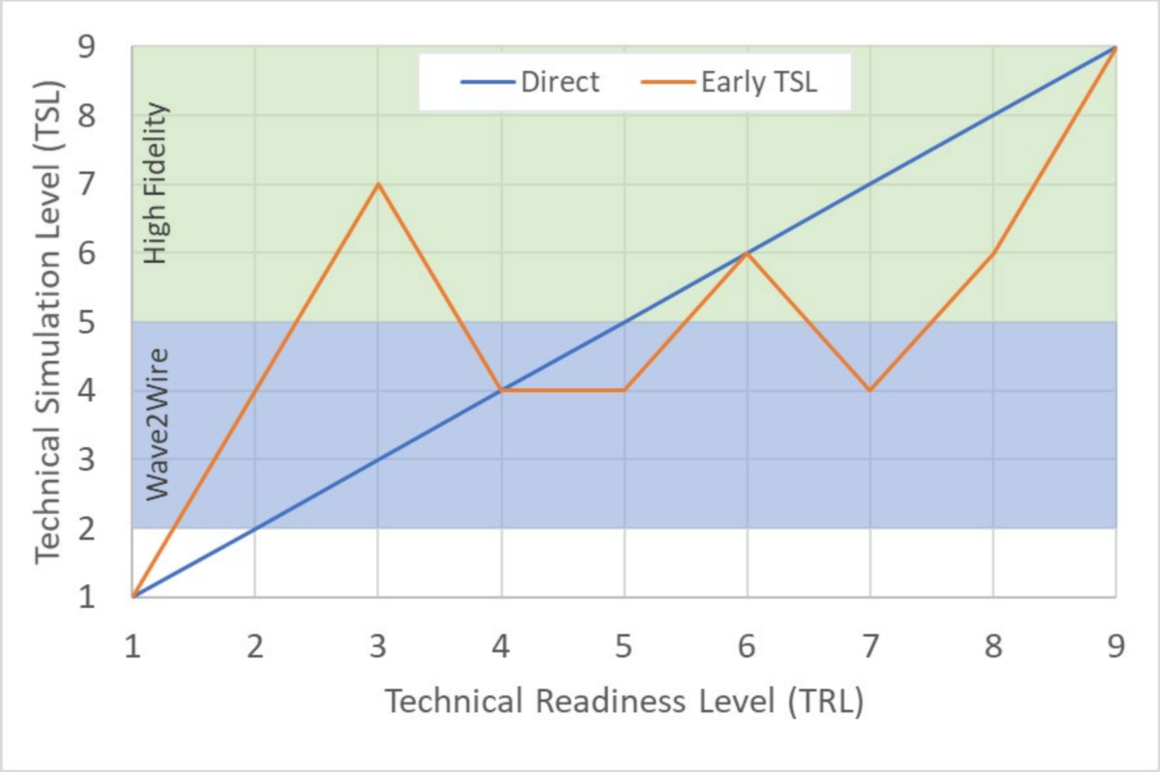

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The varying role of TSL

- TRL 1-3: Concept validation
  - Recuce uncertainties by high-fidelity simulations
  - High TPL impossible without relevant loads -> cost estimate.
  - Get ready for successful tank test
- TRL 4-5: Model refinement and validation
  - Wave2wire model improvement
  - High TSL & experiments for calibration
- TRL 6-7: Detailed output
  - Sizing and sourcing of components in pilot
  - Scale-effects validation with high-fidelity model
- TRL 8-9: Digital twin
  - Conditional monitoring
  - Maintenance schedule
  - Data available for high-fidelity validation and minor design iterations. Commercial conditions apply.

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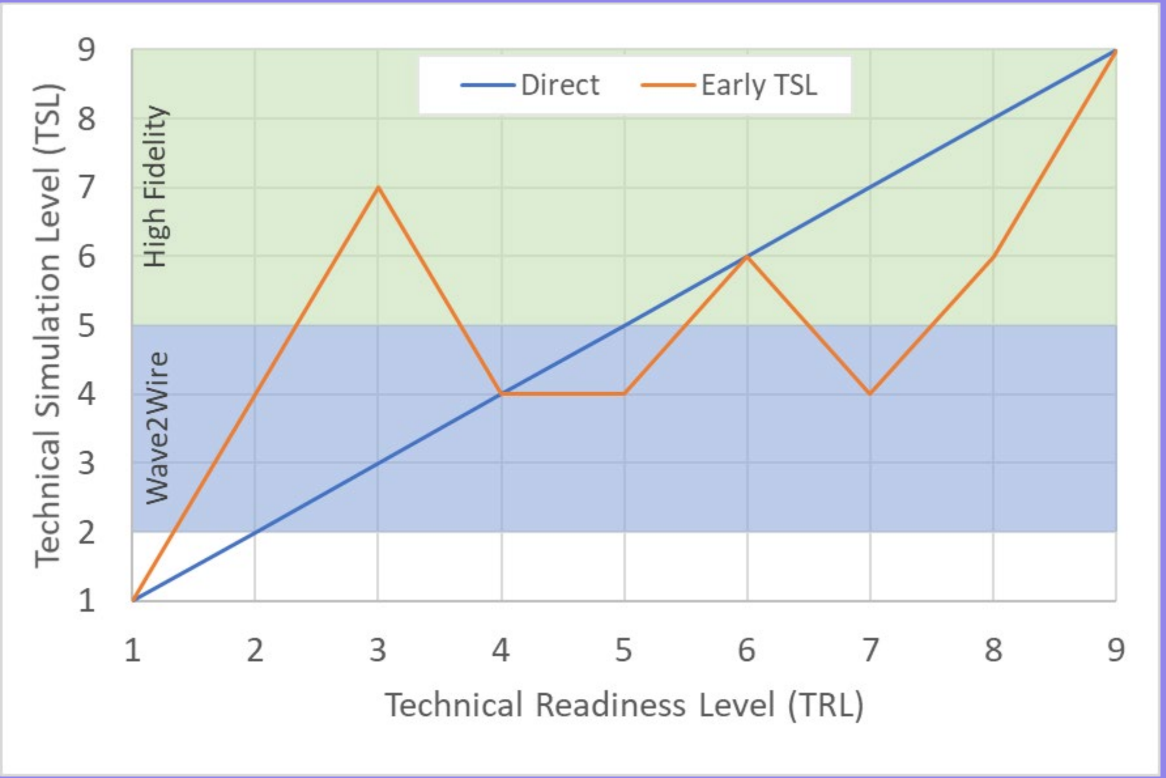

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  - Data available for high-fidelity validation and minor design iterations. Commercial conditions apply.
- Data driven models
  - The glue between TSL and TRL.
  - High-fidelity training data needed

Tools of the trade

- TSL sets methodological limits
- Tools sets practical limits
  - May cover several TSLs

- Tools and frameworks
  - Orcaflex
  - ProteusDS
  - Ansys
  - WaveDyn
  - DeepLines
  - WEC-Sim
  - MoorDyn (mooring)
  - MoodyMarine
  - CFD-tools (Ansys, StarCCM+,OpenFOAM…)
  - …
- Choice of framework
  - Output required
  - License costs
  - APIs to specialised software
  - → Room to grow

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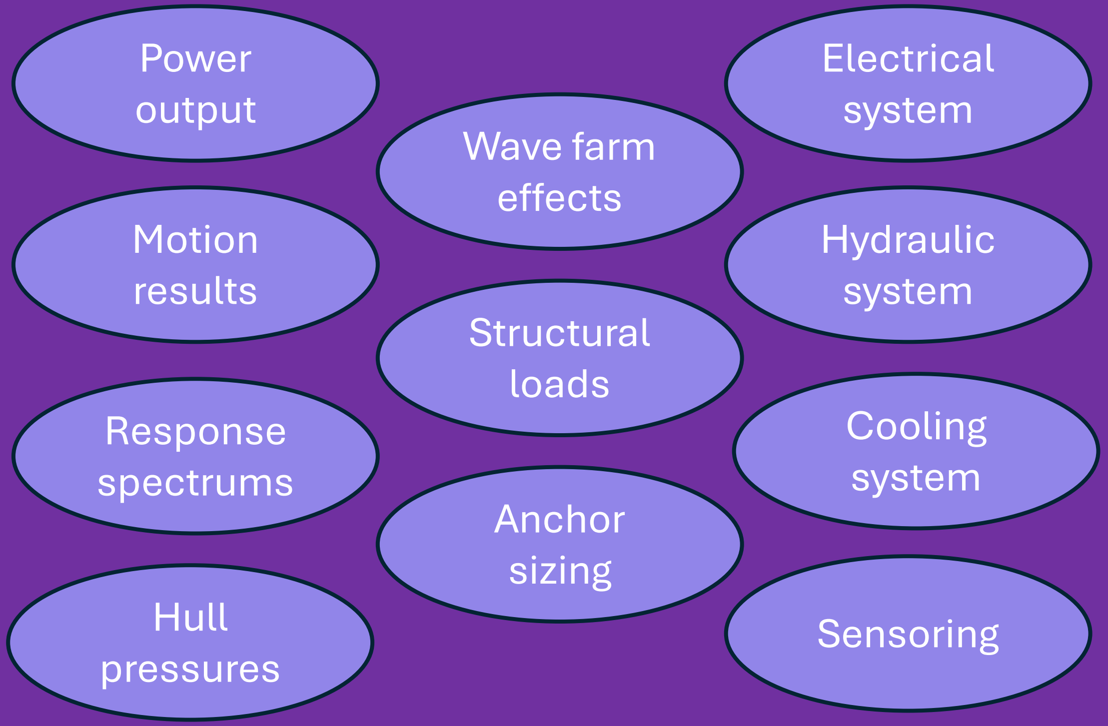
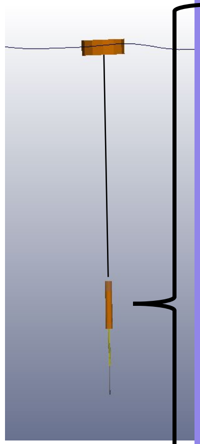


Example: Ocean Harvesting

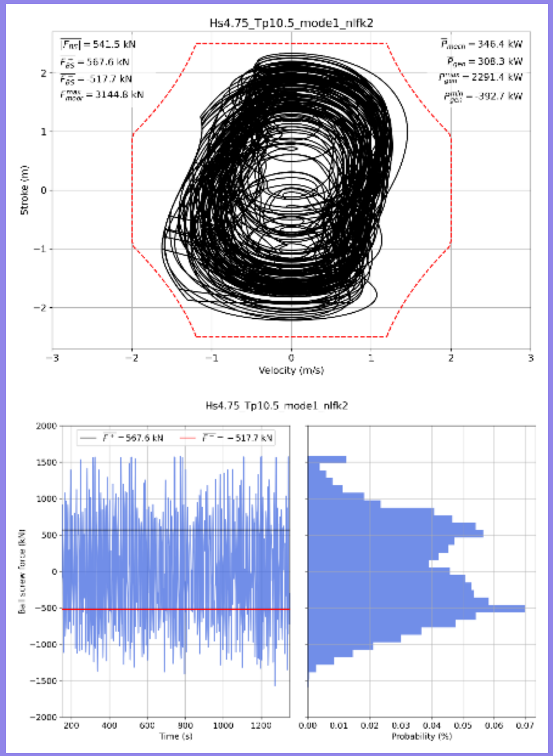
- Infinity WEC concept
  - Concrete buoy floater
  - Pretensioned single point mooring
  - Submerged PTO with ball-screws for instant control.
  - TRL 4-5



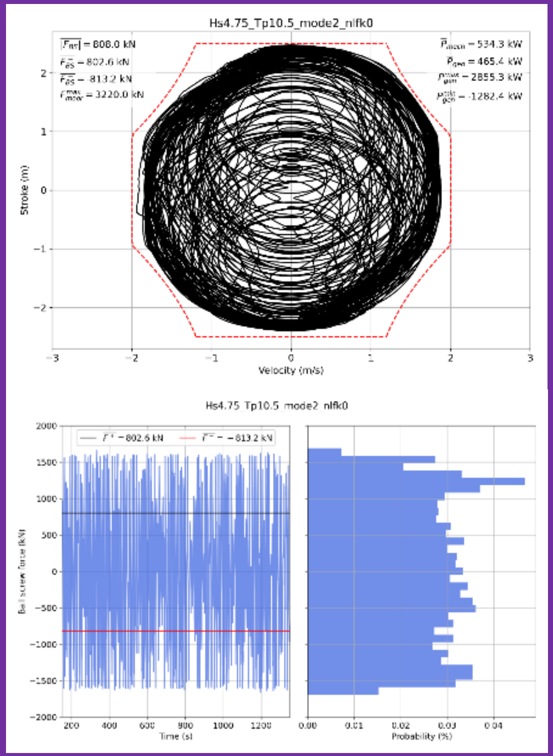
- TSL 3 to 4: WEC-Sim and SM²C toolbox
  - Polynomial Reactive Control (PRC)
  - Model Predictive Control (MPC)
  - 30% yearly average energy output
  - Investigation ongoing of fatigue implications

- Ongoing project for dry testing of MPC algorithm in ¼ scale PTO.

PRC



MPC



The SM2C toolbox was provided in collaboration with Maynooth University, and Dr. N. Faedo at Polytecnico di Torino

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- TSL 6: OpenFOAM and MoodyCore
  - Multibody CFD simulation (intermoored)
  - PTO component in coupled simulation
  - Validated with tank tests
  - Validation of WEC-Sim model

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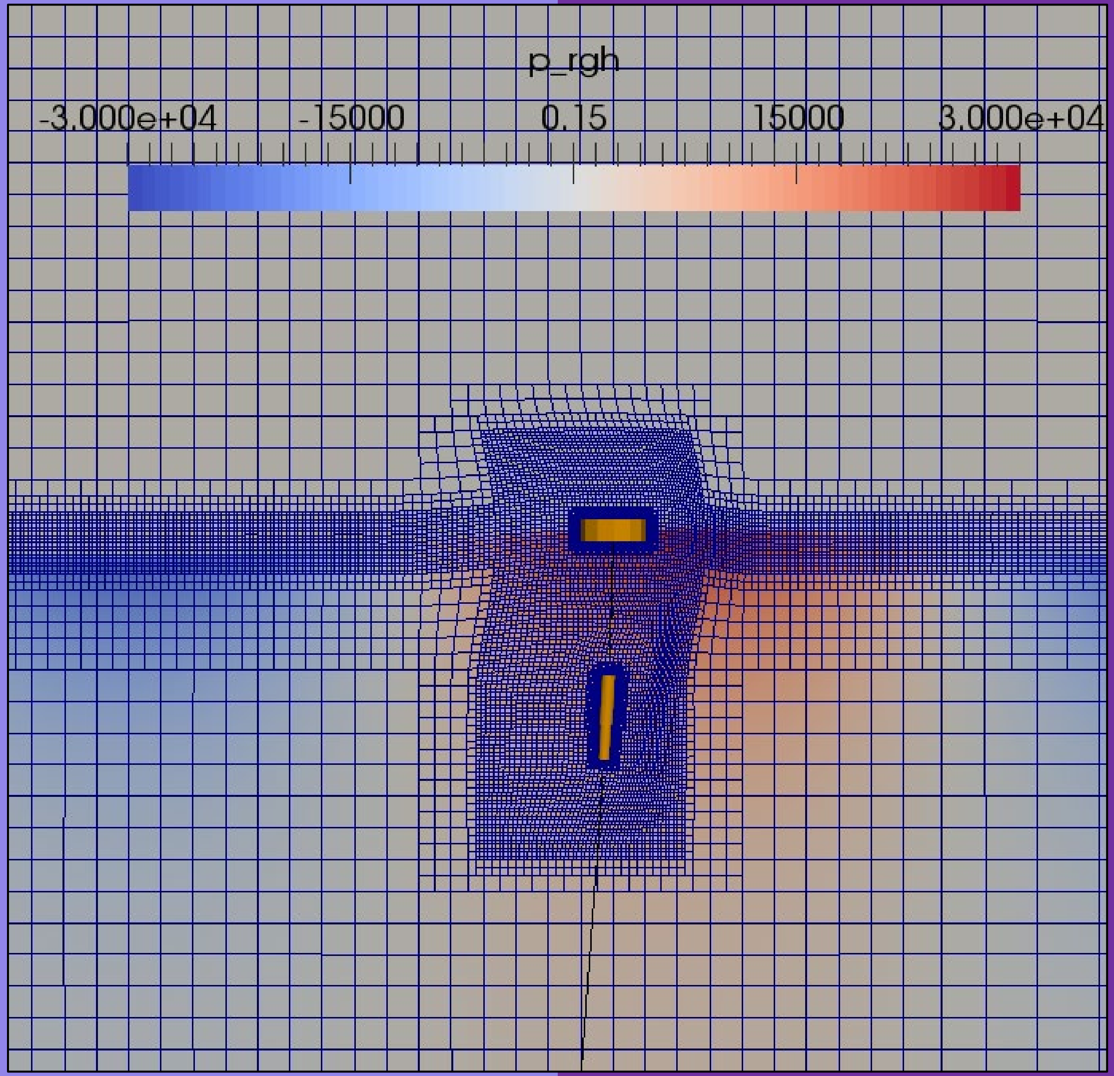

MoodyCore is developed by J.Palm and C.Eskilsson

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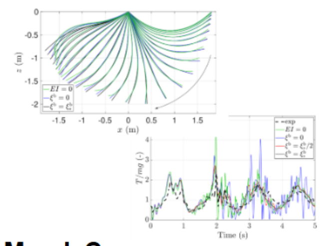
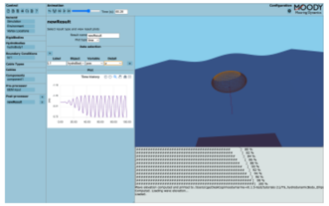
The parts of Moody



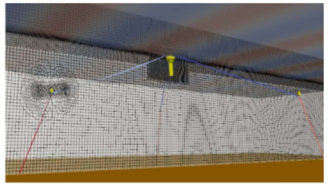
MoodyCore

MoodyCore is the C++ implementation of marine hydrodynamics and high-order finite element solutions for mooring cable dynamics. It has a command-line interface and consists of a group of binary utilities and libraries suitable for parametric investigations.



MoodyMarine

MoodyMarine is the Graphical User Inteface to MoodyCore. It is available cross-platform for Windows, Linux and Mac. 3D visualization in both pre- and post-processing mode can be used to analyse case setup and investigate nonlinear static and dynamic effects on moored installations.



MoodyAPI

MoodyCore can be used as a mooring module to external solvers. Coupling-code for different solvers is provided under the name MoodyAPI. Presently, MoodyAPI contains a coupling to OpenFOAM, enabling coupled dynamic mooring simulations in a high-fidelity numerical wave tank.

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Towards multi-fidelity framework

Introducing Moody
- MoodyCore – freeware c++ software
- MoodyMarine – GUI, Pre-, and post-processor
- MoodyAPI – Interface for coupled analysis

Support
- Linear potential flow bodies, with nonlinear buoyancy.
- Morison spheres and cylinders
- Dynamic mooring lines (high-order FEM)
- Linear and tabulated springs/dampers
- Multibody constraints
- BEM-preprocessor interface (Nemoh v3)

	Old workflow	Streamlined workflow
CFD post-processing	awk and sed	OpenFOAM special functionObject
Cleaning / resampling	Matlab	**MoodyMarine**
Creating training data	batch run with python script	**MoodyMarine**
Training	Matlab deep-learning	**MoodyMarine** (using libTorch)
Real-time prediction	MoodyCore (using Matlab)	**MoodyMarine** (using libTorch)

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- [NEW] Streamlined machine learning integration

Flexibility at early stage TRL
- Use the same submodel, while changing another.
- Augment analysis by training machine learning algorithms (libTorch) to high-fidelity data
- Use API to evaluate subsystems in external software (bespoke PTO-controller e.g.)

On the choice of Technology Simulation Level

and its importance in wave energy design calculations

Summary

- High-fidelity simulations at low TRL can help minimize uncertainty and improve cost estimates
- At higher TRL, experimental data validates calibrated wave-to-wire models
- Machine learning corrections, trained on high-fidelity models can improve both speed and accuracy during development.
- Choice of simulation platform tends to be long-lived. Choose wisely, and allow for multi-fidelity modelling needs.

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