Bladed

Presented at DTU Course on Wind Turbine Aeroelasticity

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23 April 2025

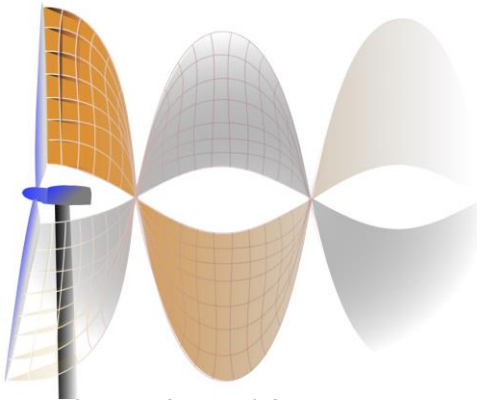
Agenda

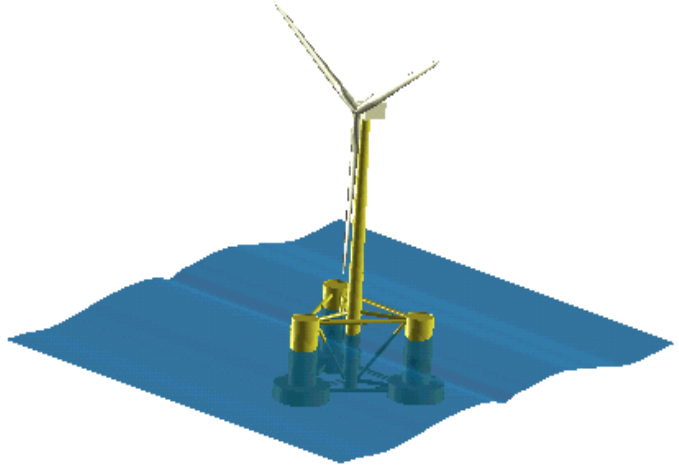
- Introduction to Bladed
- Multibody Structural Dynamics
- Demos
- Q&A

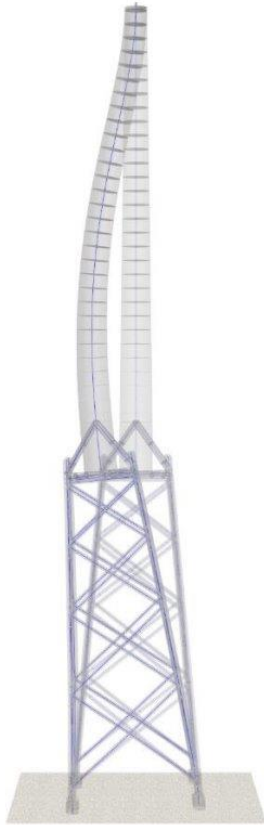
What is Bladed?

A wind turbine design tool capable of:

- Coupled nonlinear aero-hydro-servo-elastic simulation in time domain
  - Aerodynamic models
  - Hydrodynamic models
  - Control and electrical system (servo) dynamics models
  - Structural (elastic) dynamics models
- Stability analysis







Bladed – 32 years of development

1993
Bladed is started by Dr Andrew Garrad

1996
Bladed commercial launch

2000
Wave module added to support offshore modelling

2006
Offshore support structure modelling

2011
Floating turbines.
Catenary and tension leg moorings using lookup tables.

2010
Electrical dynamics

Multibody dynamics

2013
New function based External Controller interface

2014
New batch run tool
Import radiation diffraction hydrodynamics
LIDAR functionality

2016
Non-linear "multi-part" blade model (and new integrator methods)
New BEM aerodynamics implementation
3D results animation
Bladed Cloud
Multibody mooring line model
Blade stability tool

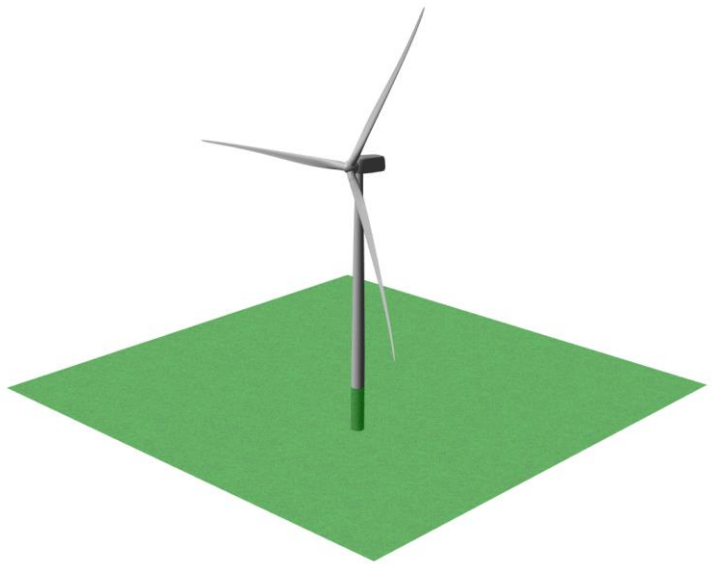
2018
Bladed API
External Loads DLL
NOK 30 million sales for 2018
Moved to Digital Solutions

2020
Bladed on Linux
Calculation engine speed up project
Integrated Jacket structure analysis enhancements…
Floating structure analysis workflow integration…

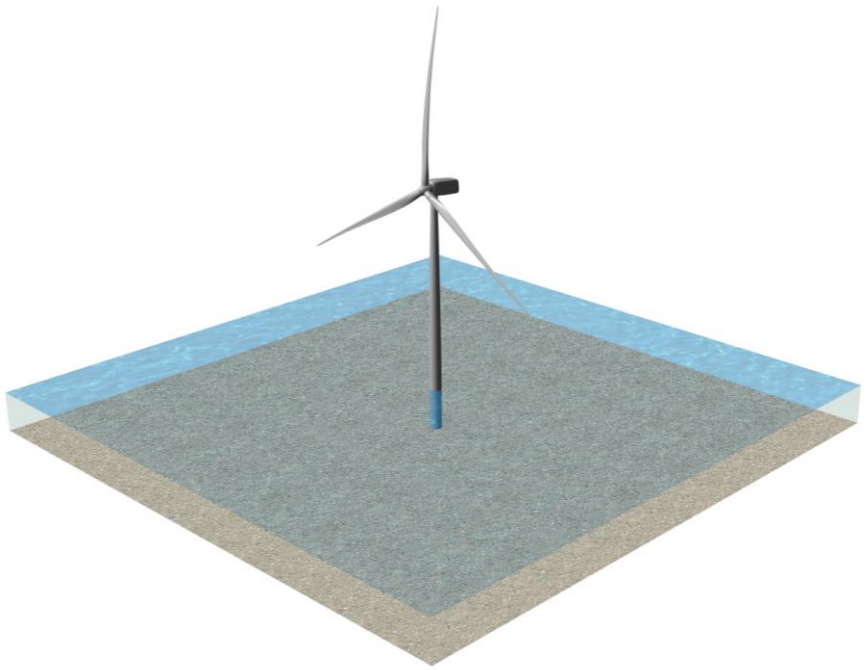
2025+
Bladed 5
First commercial release

What can Bladed model?

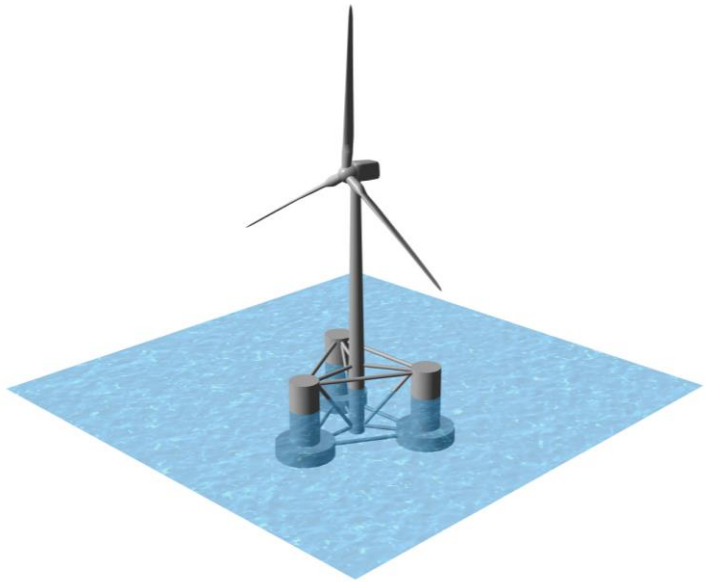
Onshore



Offshore Fixed

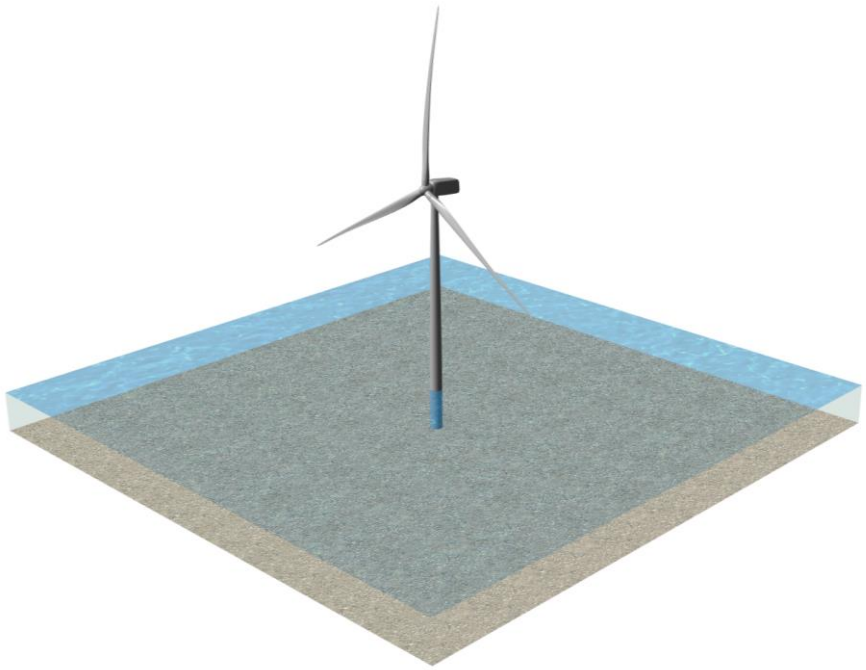


Floating

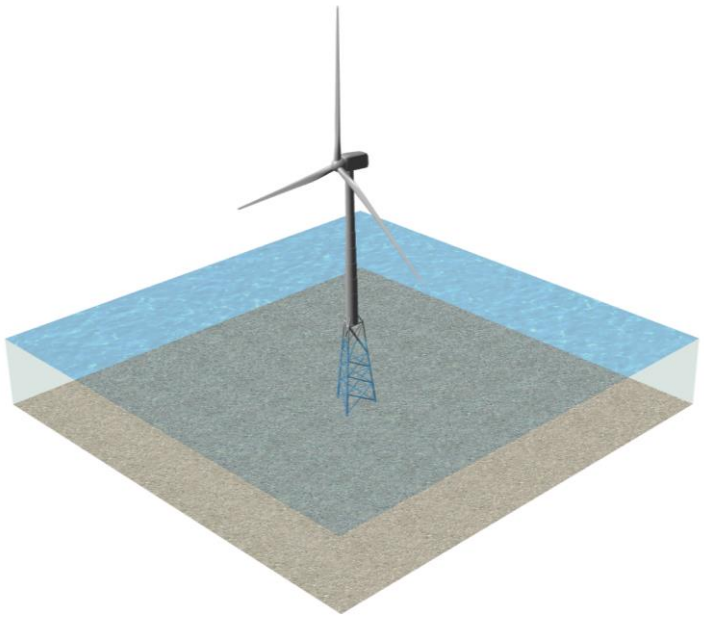


What can Bladed model: Offshore Fixed

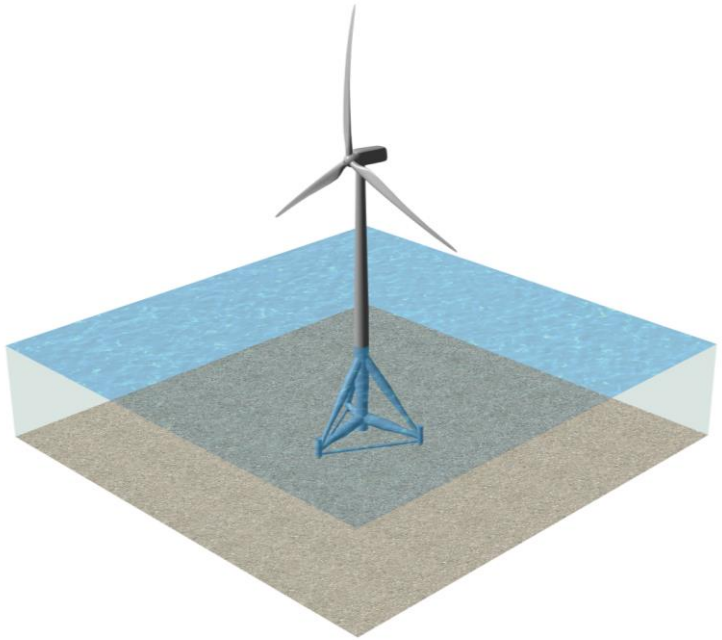
Monopile



Jacket

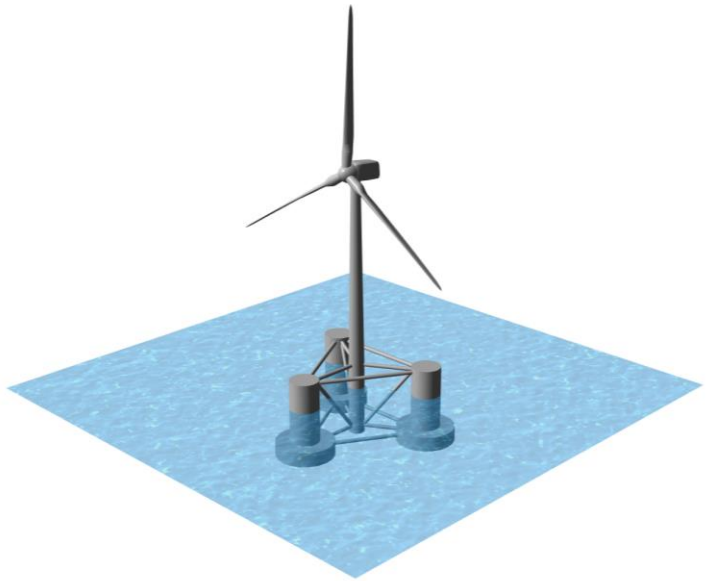


Tripod

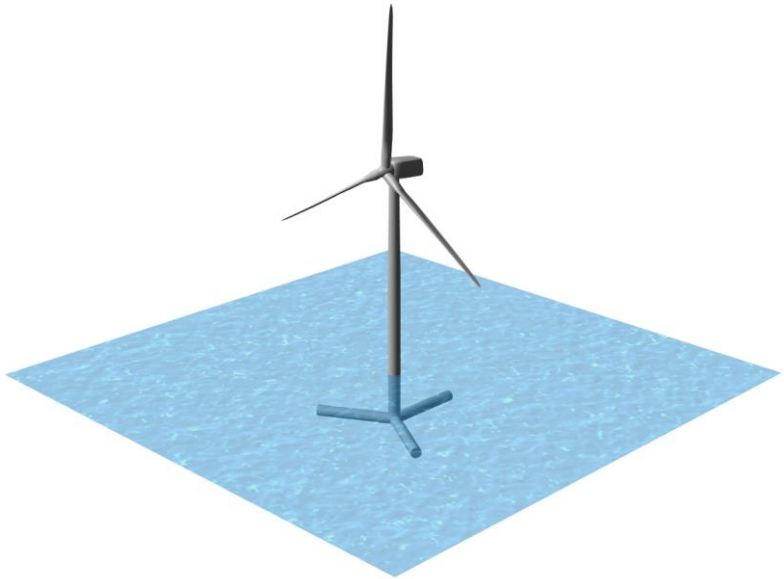


What can Bladed model: Floating

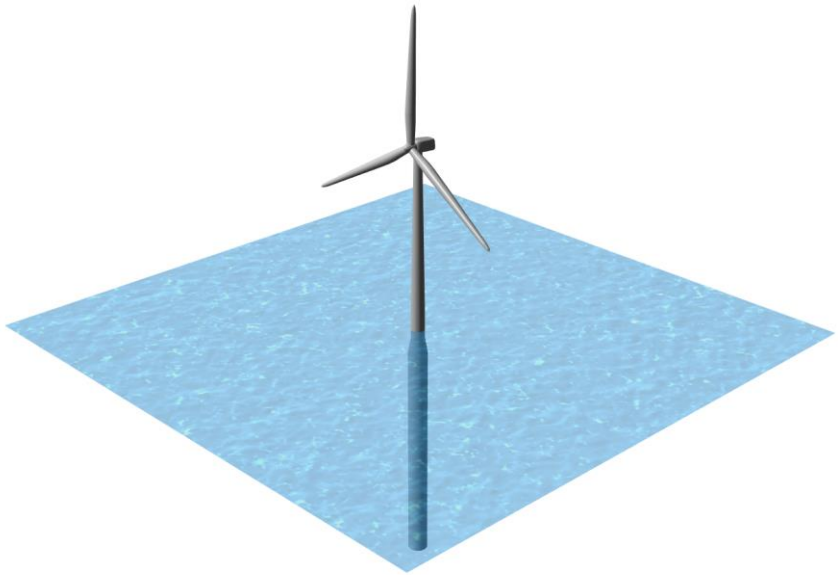
Semi-Submersible



Tension Leg Platform

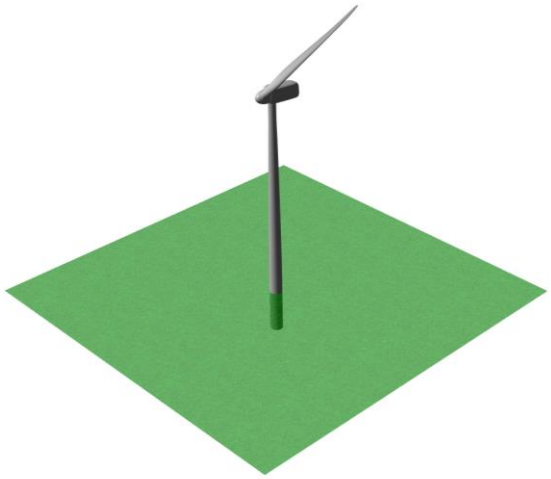


Spar

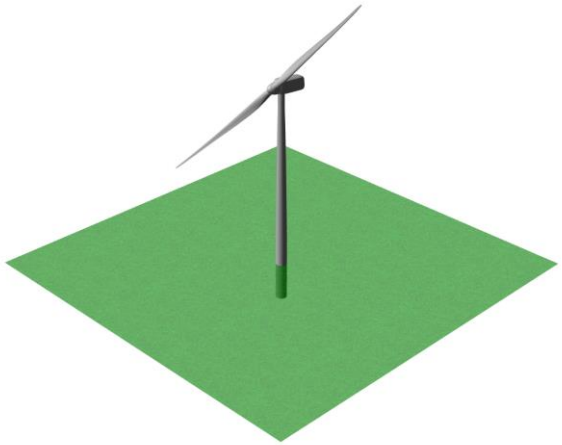


What can Bladed model: Number of blades

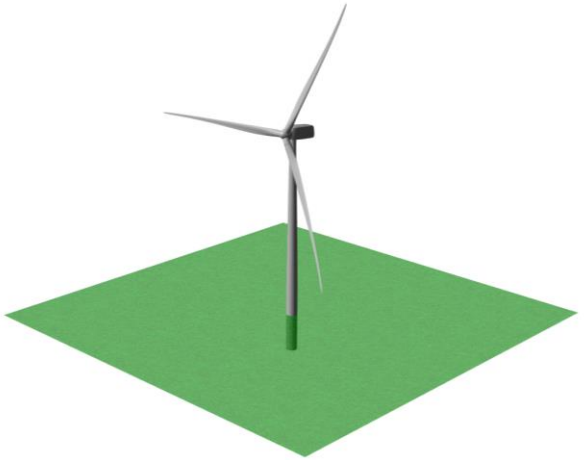
Single



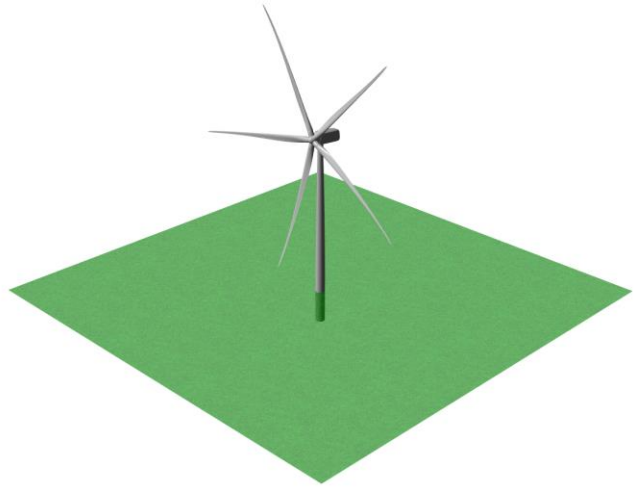
Two



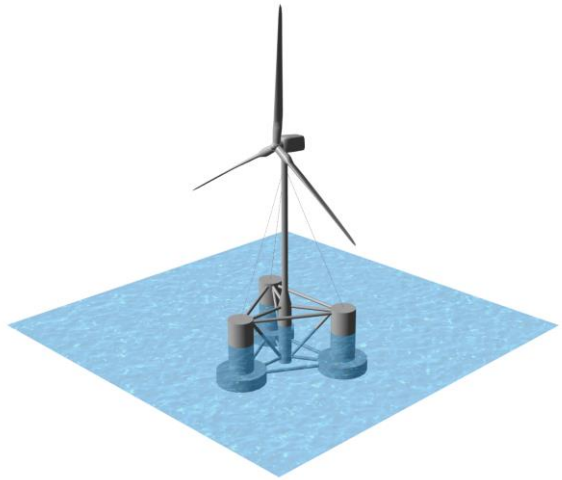
Three

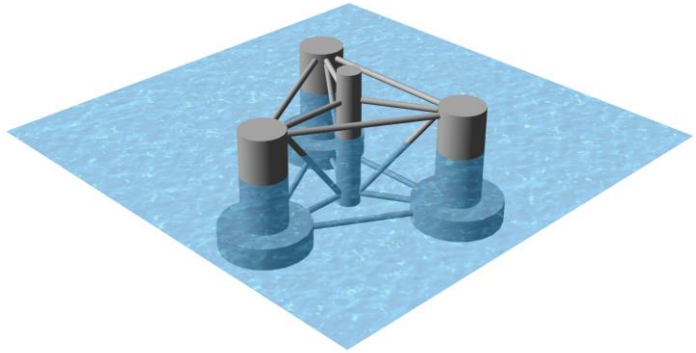


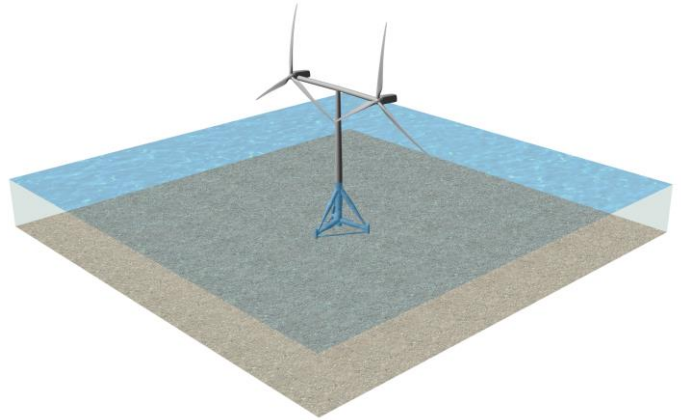
Multiple

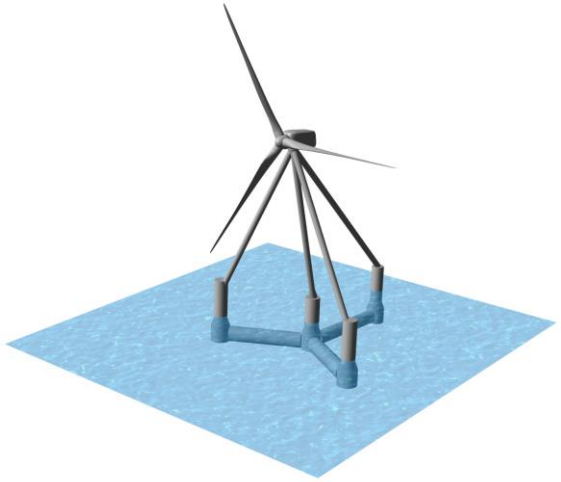


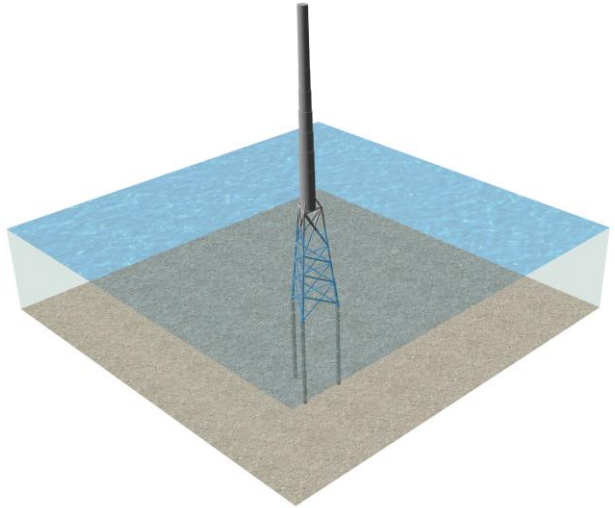
What can Bladed model: Concepts

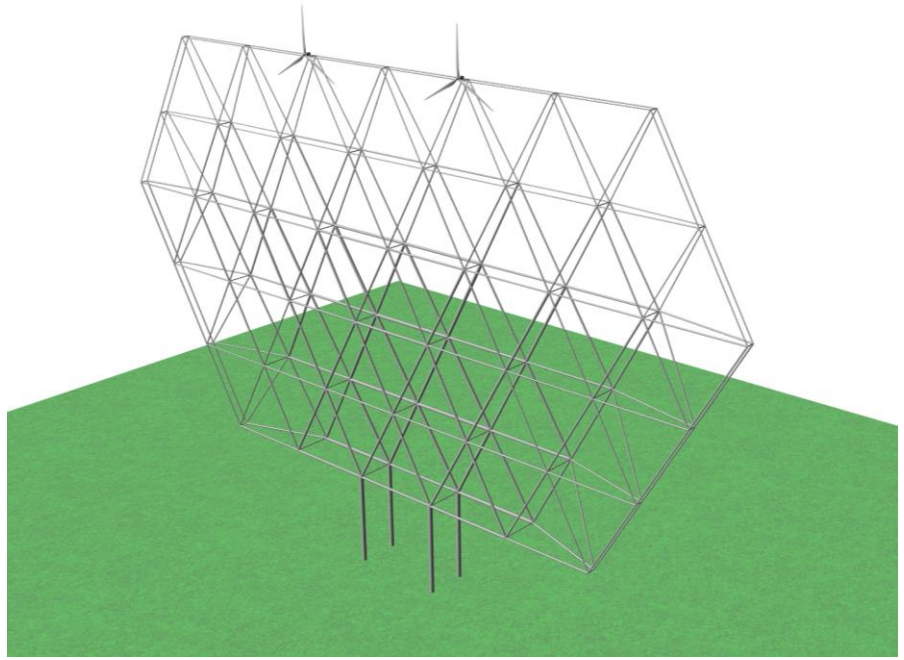












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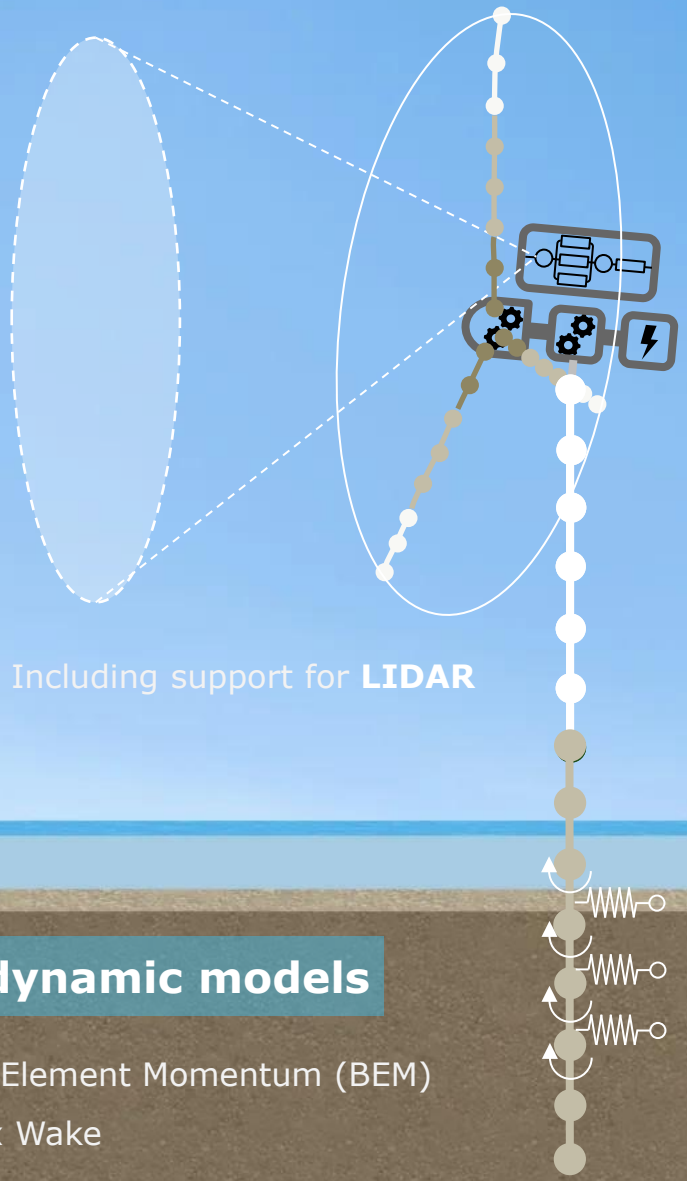


Including support for **LIDAR**

Nacelle system sub-models

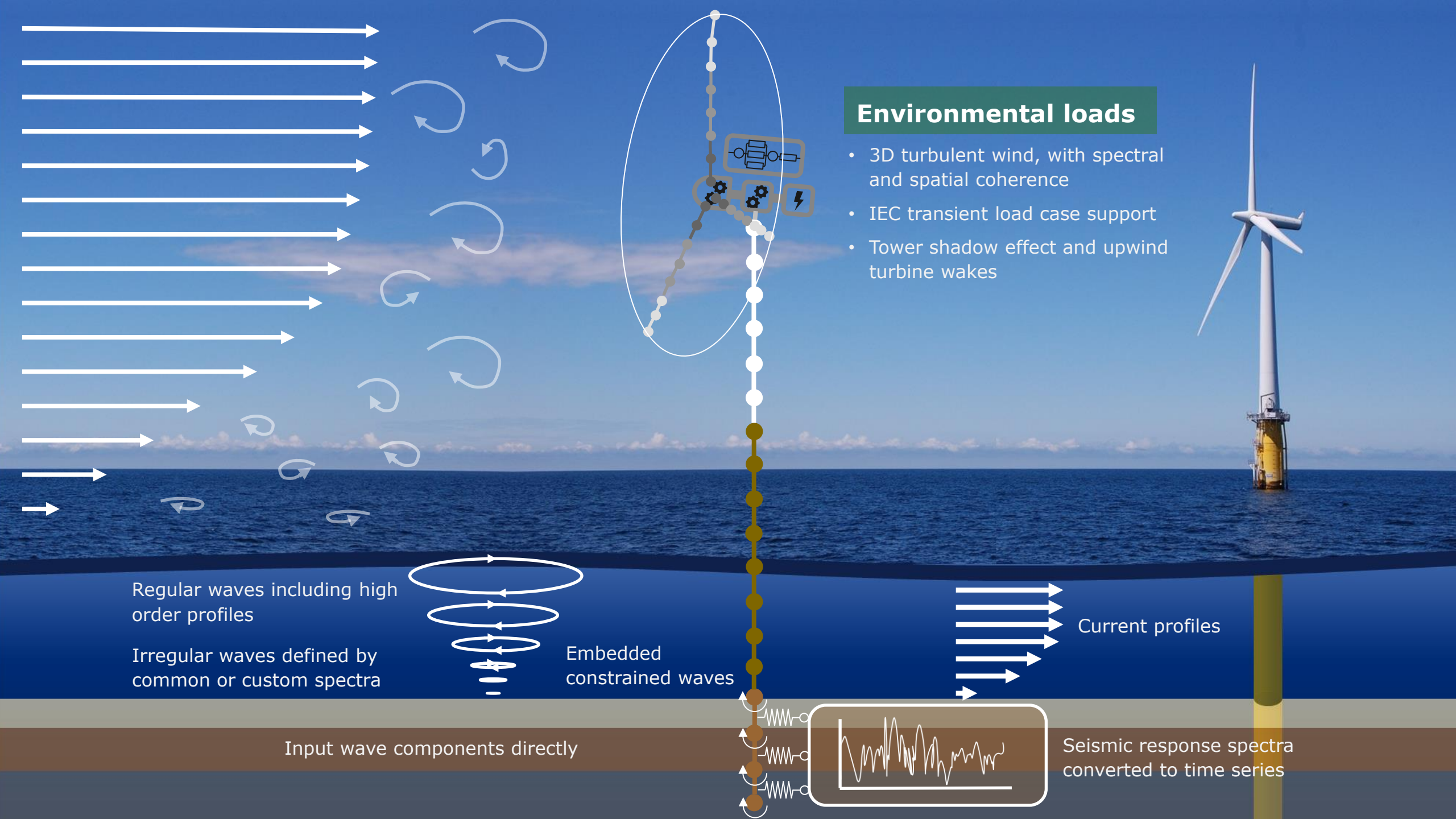
- Rotor, hub and actuators
- Gearbox, shafts and bearings
- Generator and grid connection
- DLL interfaces for custom models
- In-built or custom controllers
- Linearization for controller design

Aerodynamic models

- Blade Element Momentum (BEM)
- Vortex Wake

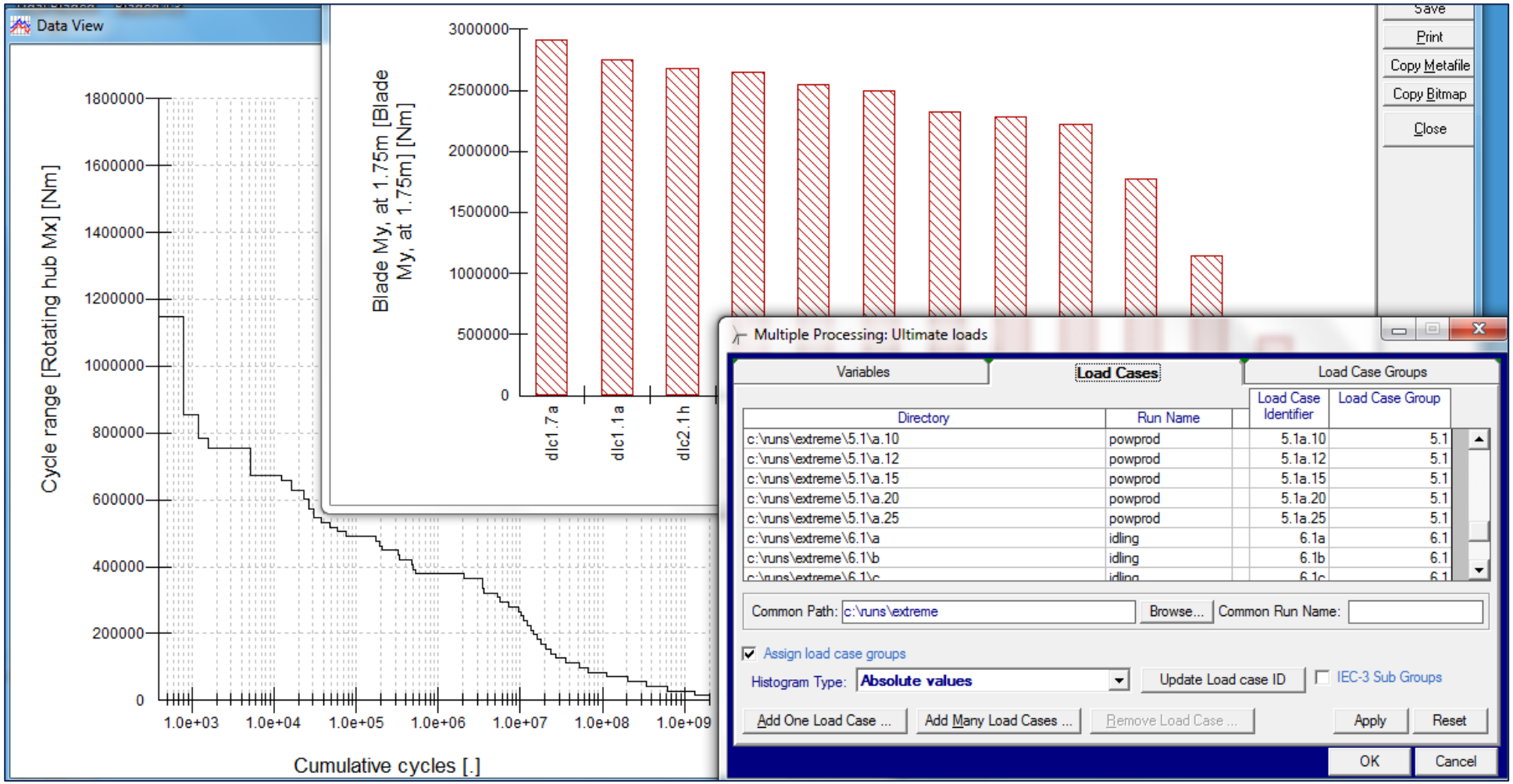
Structural dynamic models

- Multi-body structural dynamics based on Timoshenko FE
- Modal reduction for solver speed
- Non-linear blade deflection model

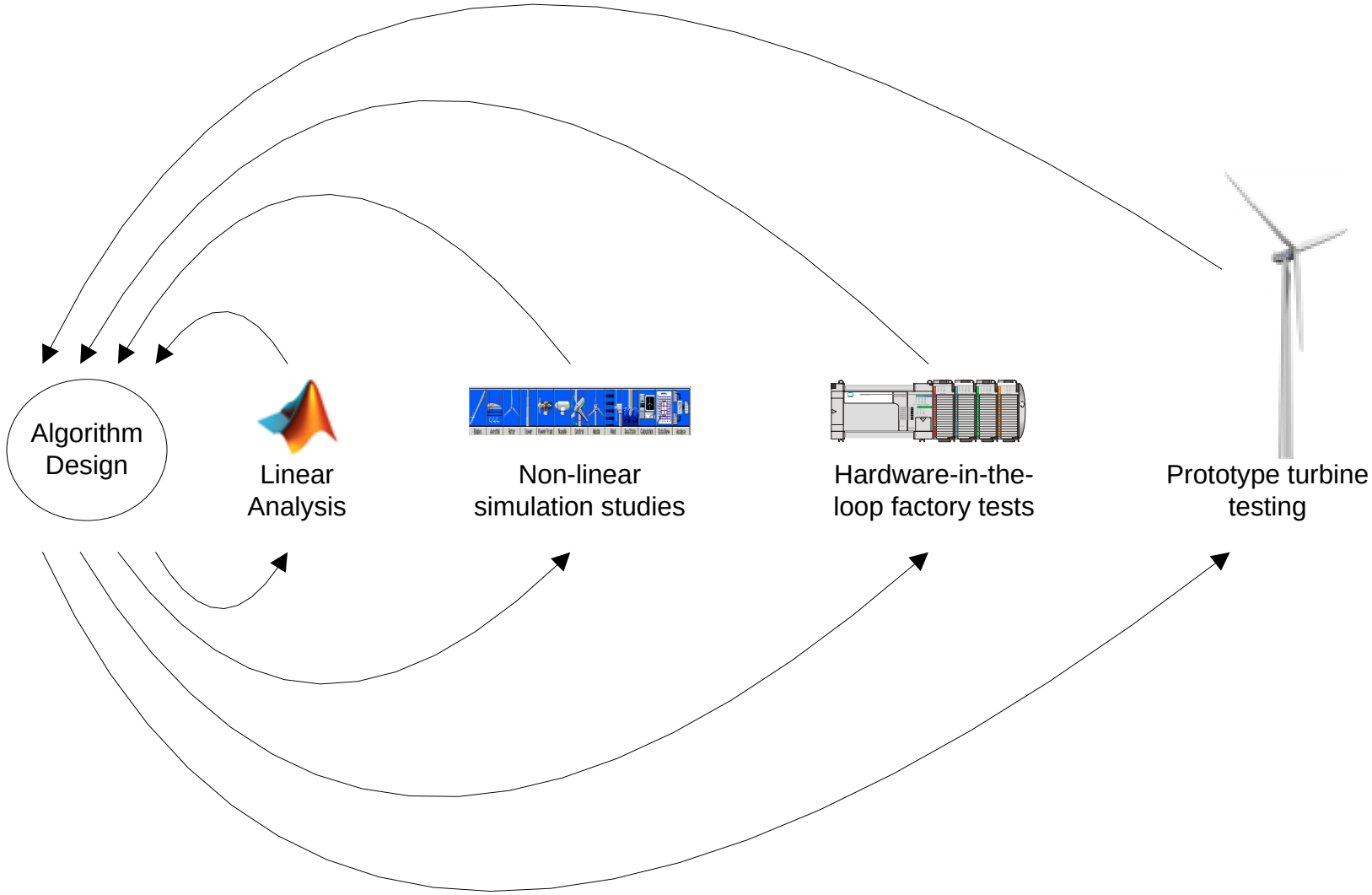

Environmental loads
• 3D turbulent wind, with spectral and spatial coherence
• IEC transient load case support
• Tower shadow effect and upwind turbine wakes
Regular waves including high order profiles
Irregular waves defined by common or custom spectra
Embedded constrained waves
Current profiles
Input wave components directly
Seismic response spectra converted to time series

Example applications

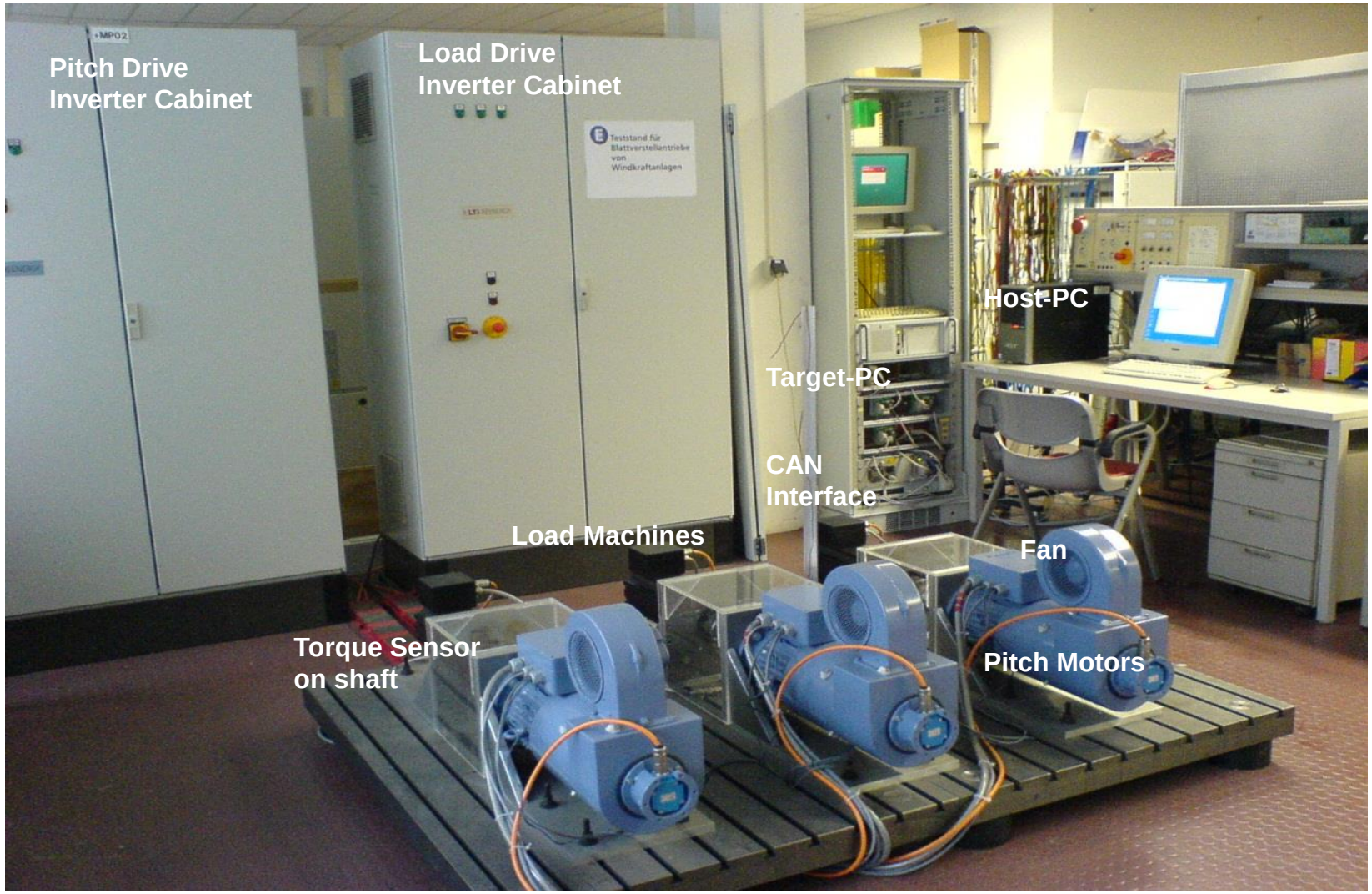
Who uses Bladed? – Load Certification Calculations



Who uses Bladed? – Control Designer



Who uses Bladed? – Hardware-in-the-loop, pitch actuators



Other applications of Bladed

Concept design

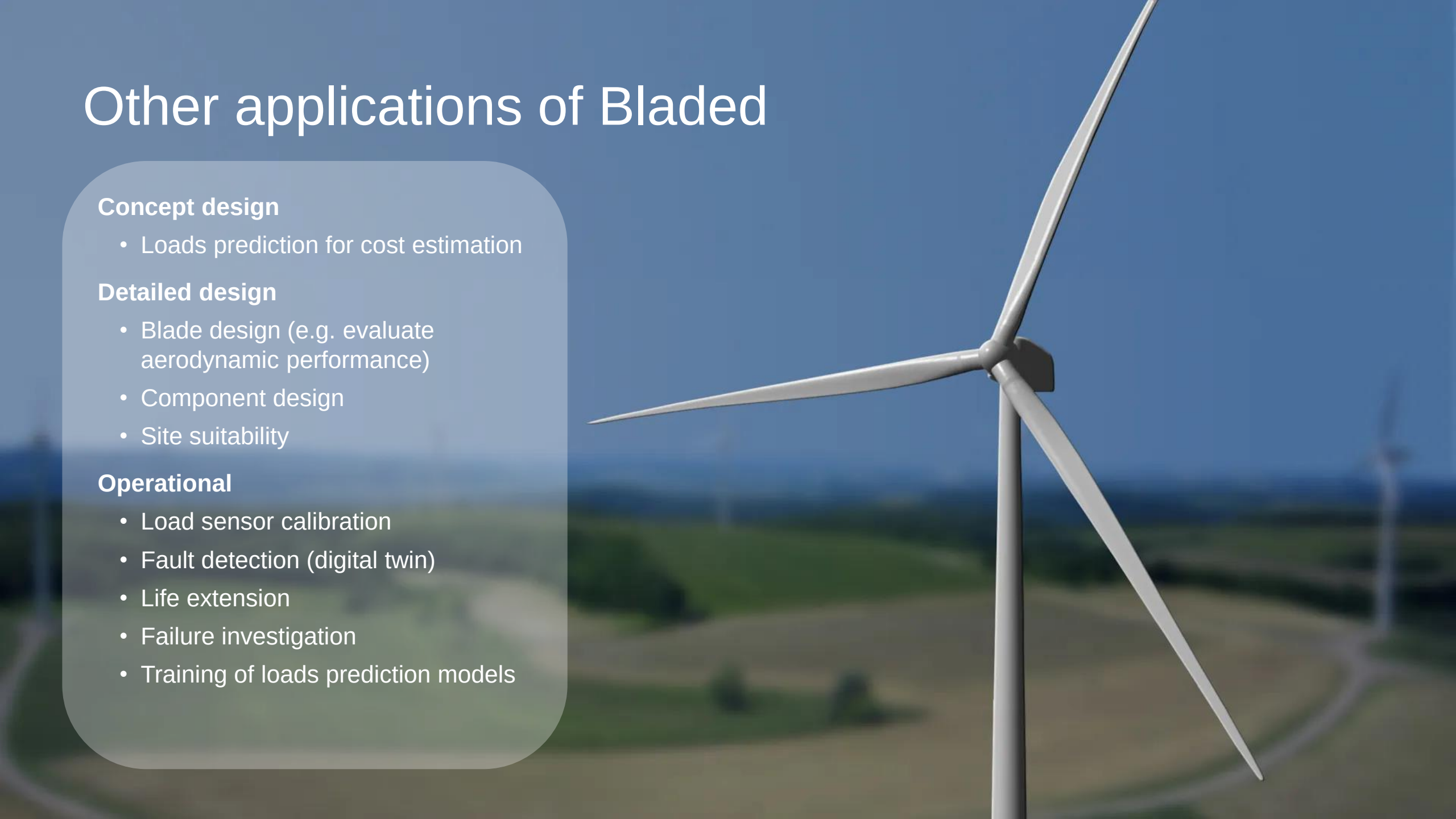
- Loads prediction for cost estimation

Detailed design

- Blade design (e.g. evaluate aerodynamic performance)
- Component design
- Site suitability

Operational

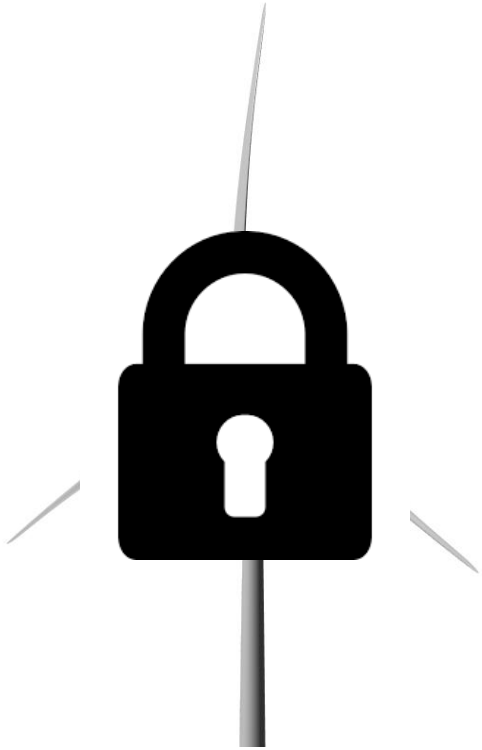
- Load sensor calibration
- Fault detection (digital twin)
- Life extension
- Failure investigation
- Training of loads prediction models



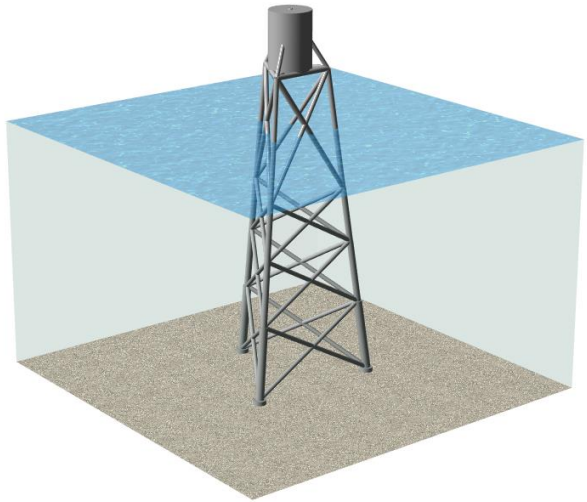
Workflows

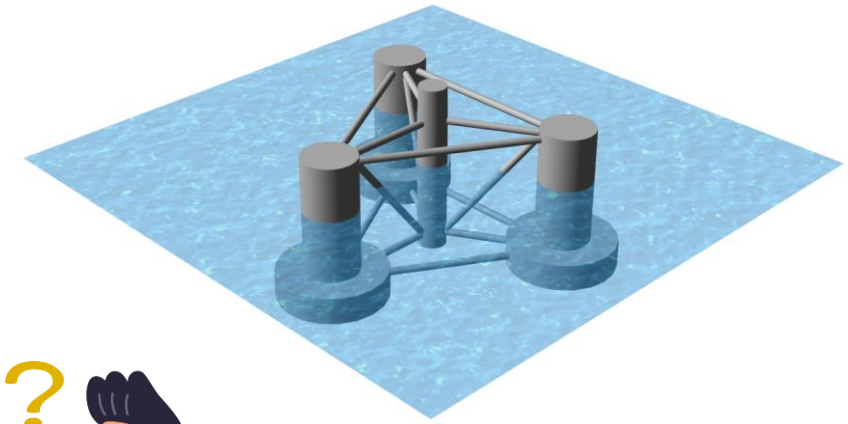
Design workflow

Turbine Manufacturer



Support Structure Designer

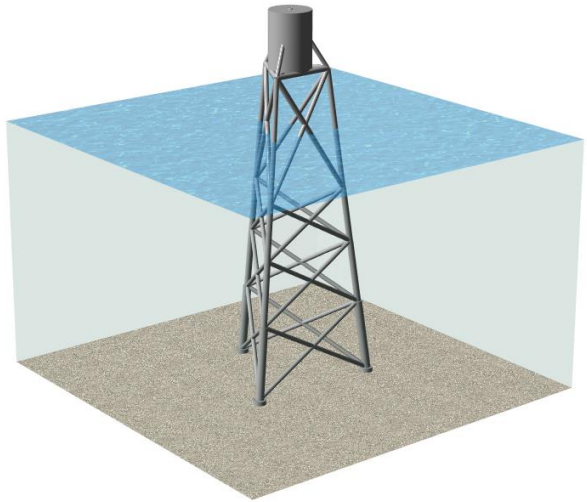


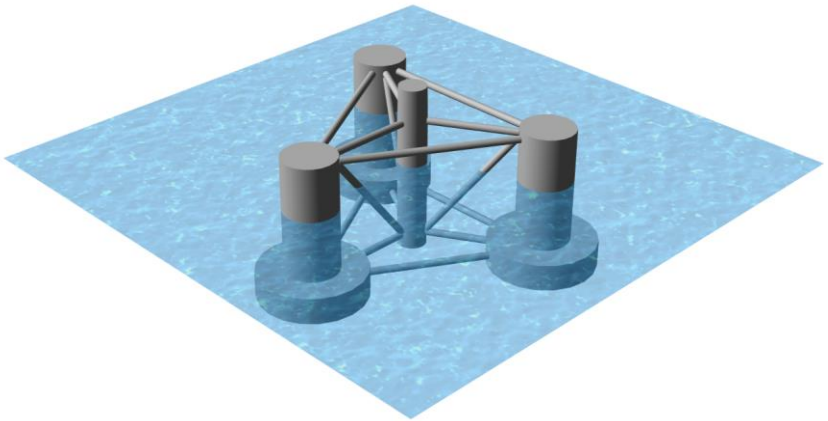


Encryption

Turbine Manufacturer

Support Structure Designer

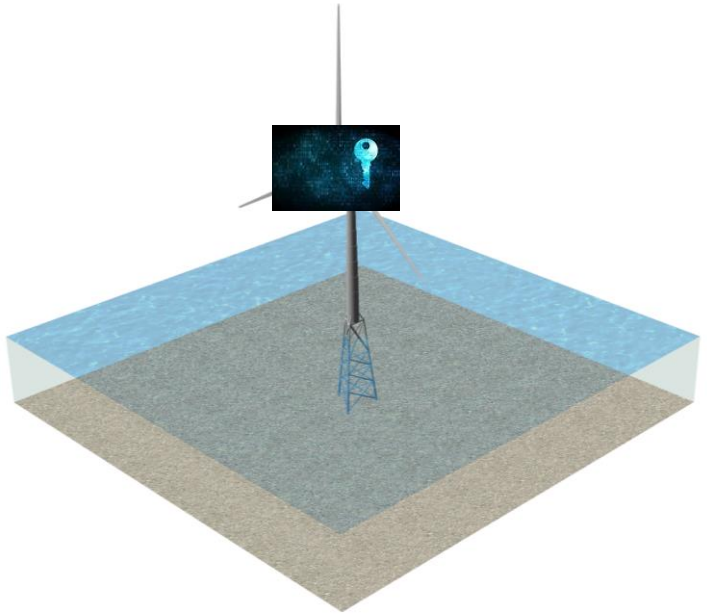


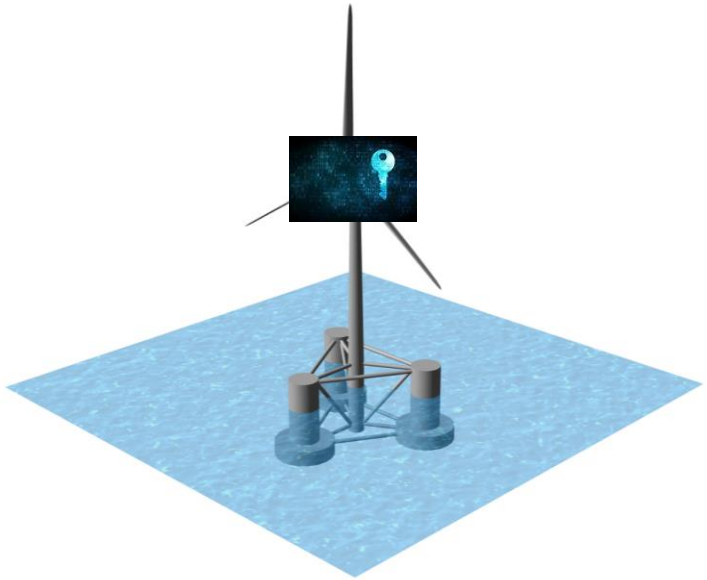


Encryption

Turbine Manufacturer

Support Structure Designer





Run as many times as required

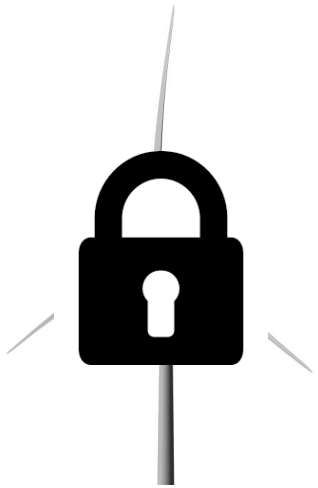
Get the exact model

Very little verification

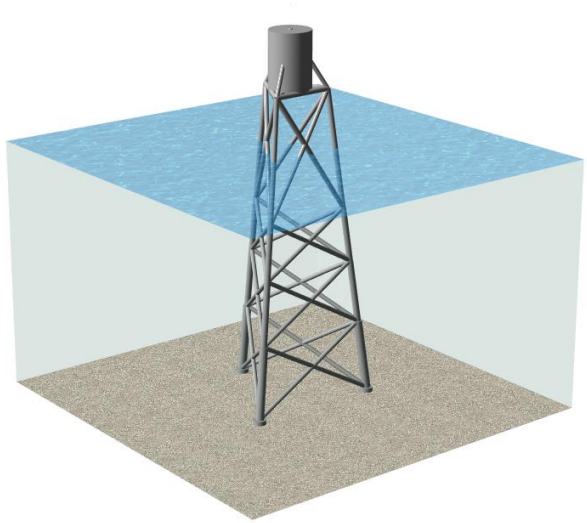
DNV

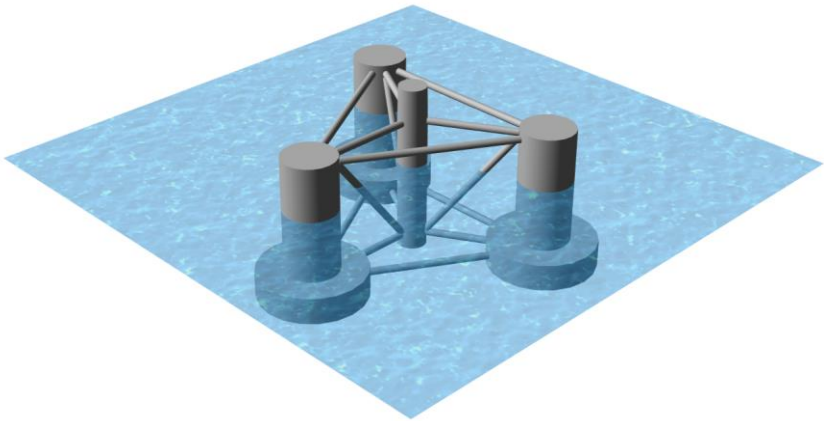
Concept models

Turbine Manufacturer



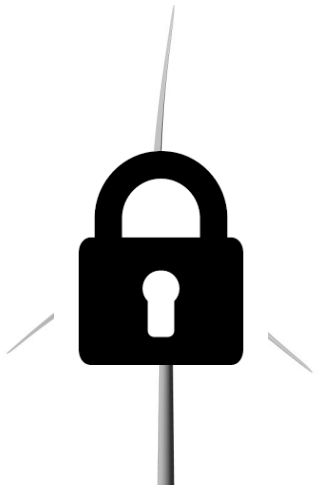
Support Structure Designer





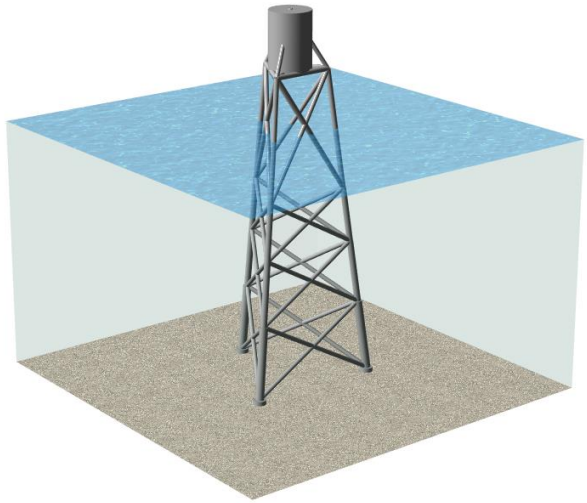
Concept models

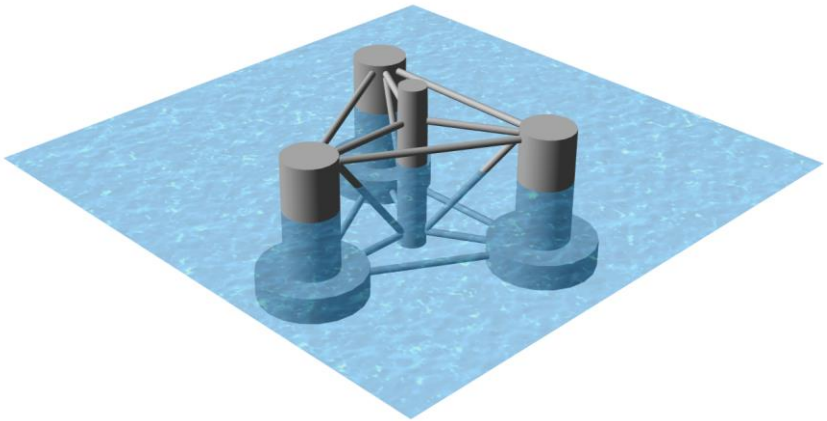
Turbine Manufacturer



Bladed Concept Model

Support Structure Designer





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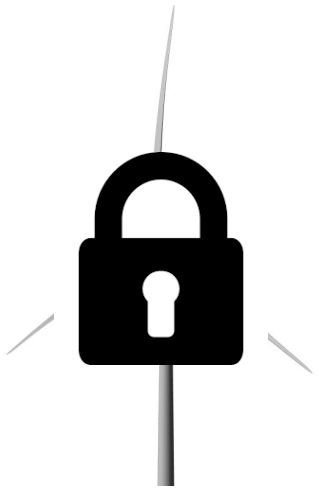
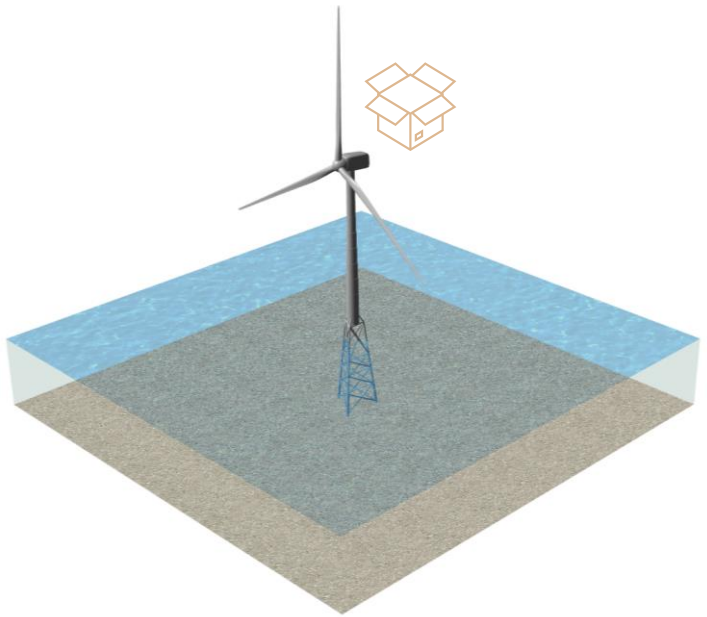
Concept models

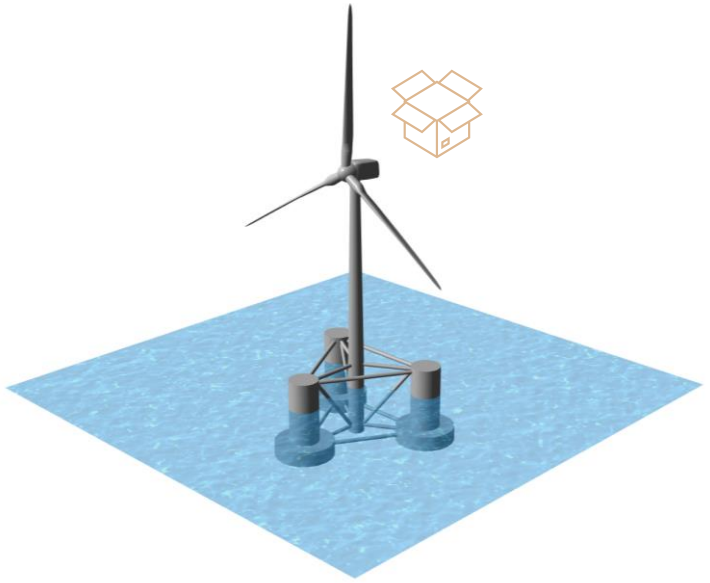
Turbine Manufacturer



Bladed Concept Model

Support Structure Designer





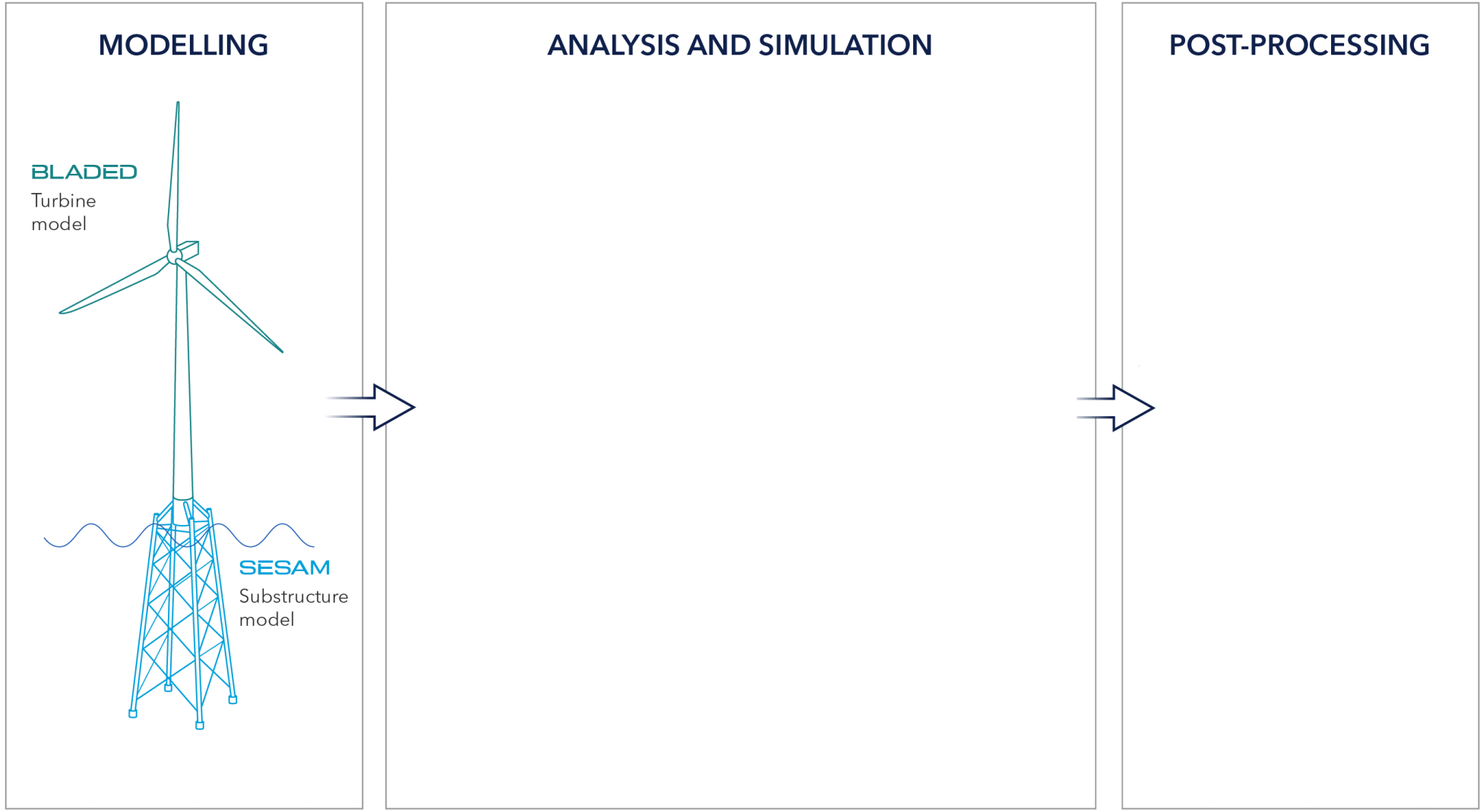
Run as many times as required

Realistic model

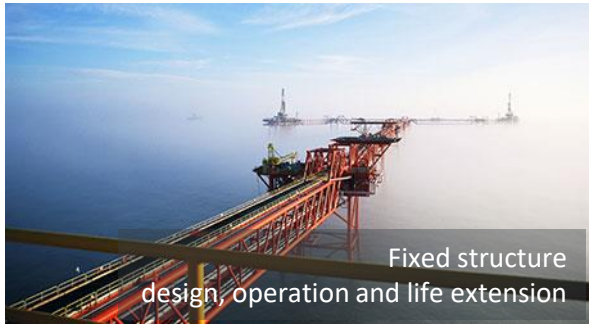
Reduced verification

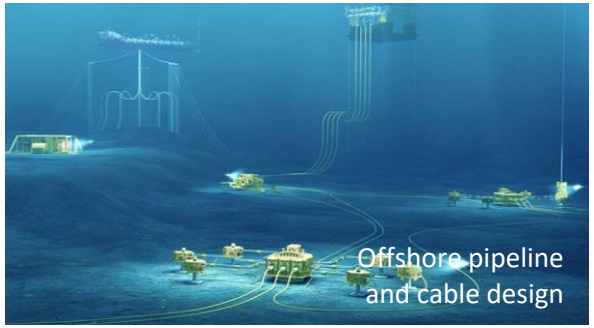
DNV

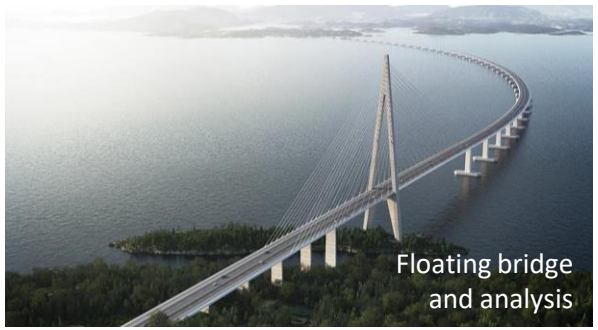
Sesam - Fixed Offshore Wind Workflows



Sesam - Supports a wide range of industries



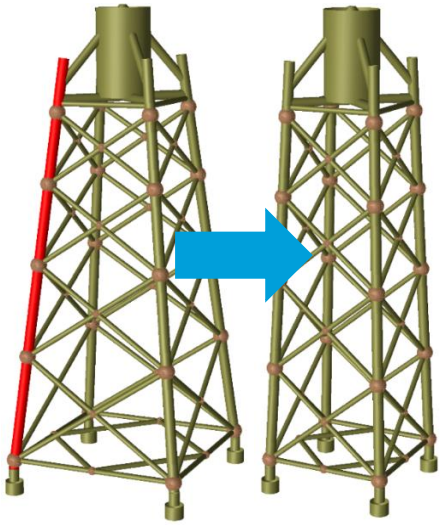




Sesam

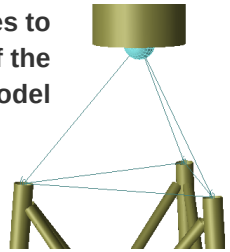
Modelling

- Jackets, monopiles, GBS and floating structures
- Easy and effective 3D modelling
- Frame and shell models
- Complex transition piece and joints
- Parametric scripting

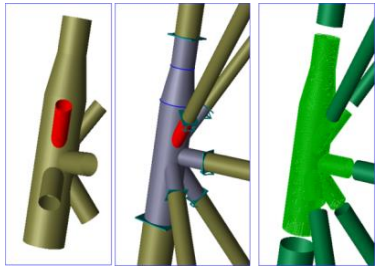


Parametric scripting can be used to quickly redesign the model

External matrices to represent parts of the model

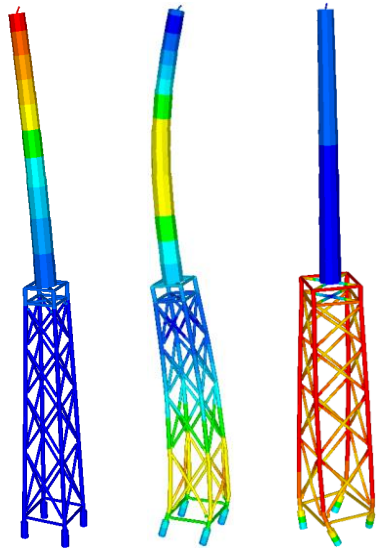


Beam and shell elements in same model

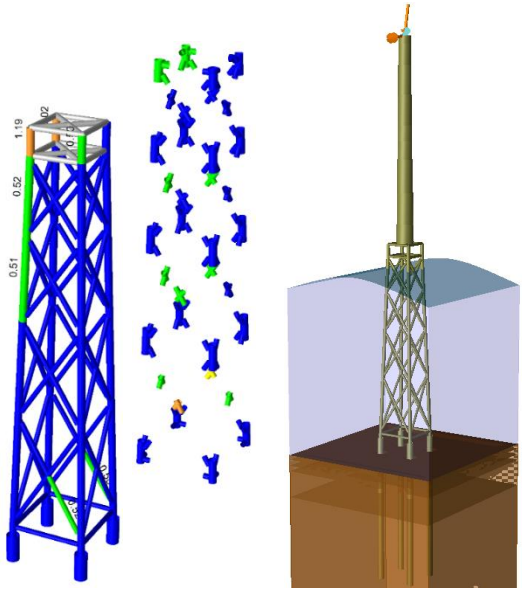


Preliminary design

- Natural frequency analysis
- Fatigue analysis using damage equivalent load cycles and wave loading
- Member check and joint check
- Redesign



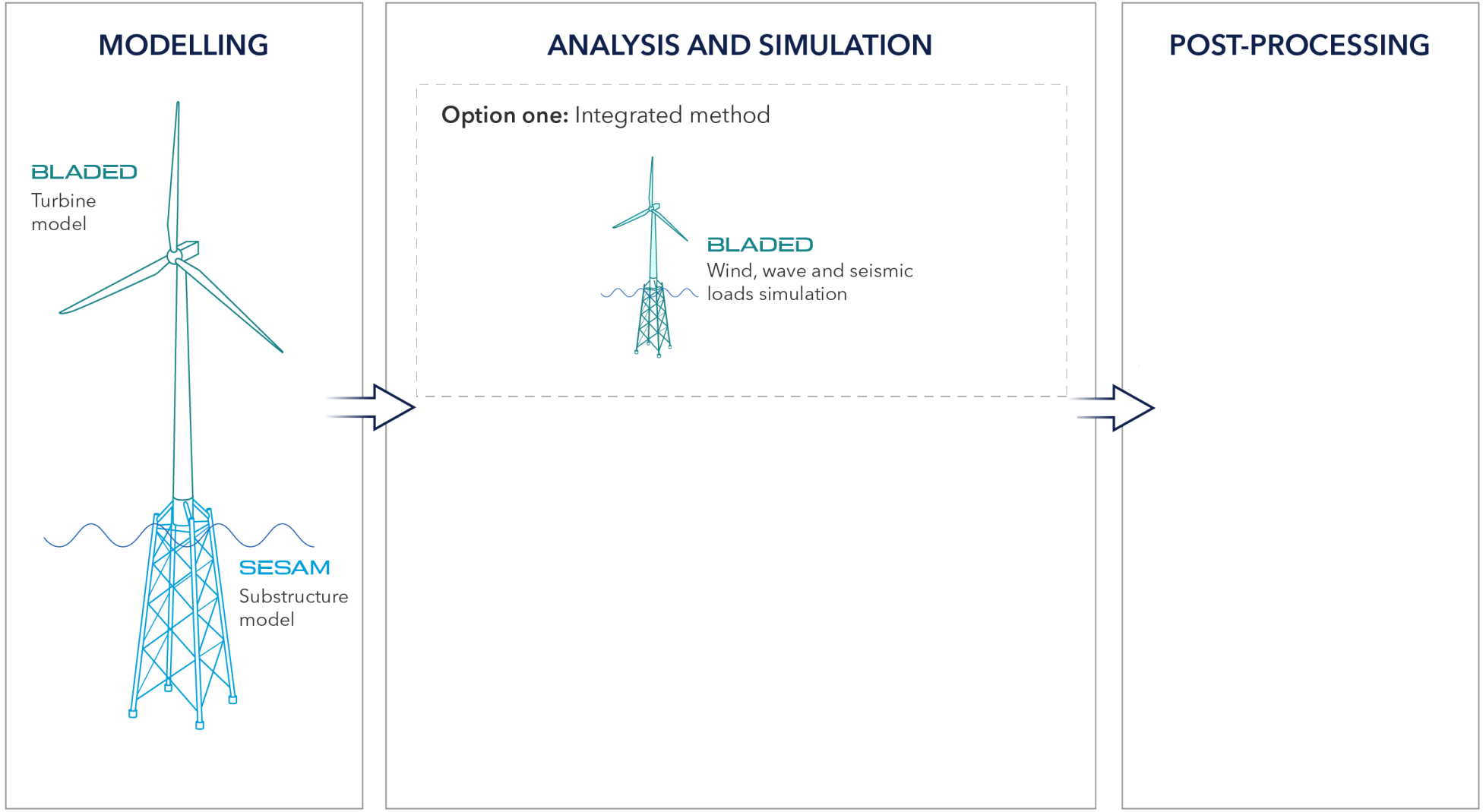
Natural frequency analysis



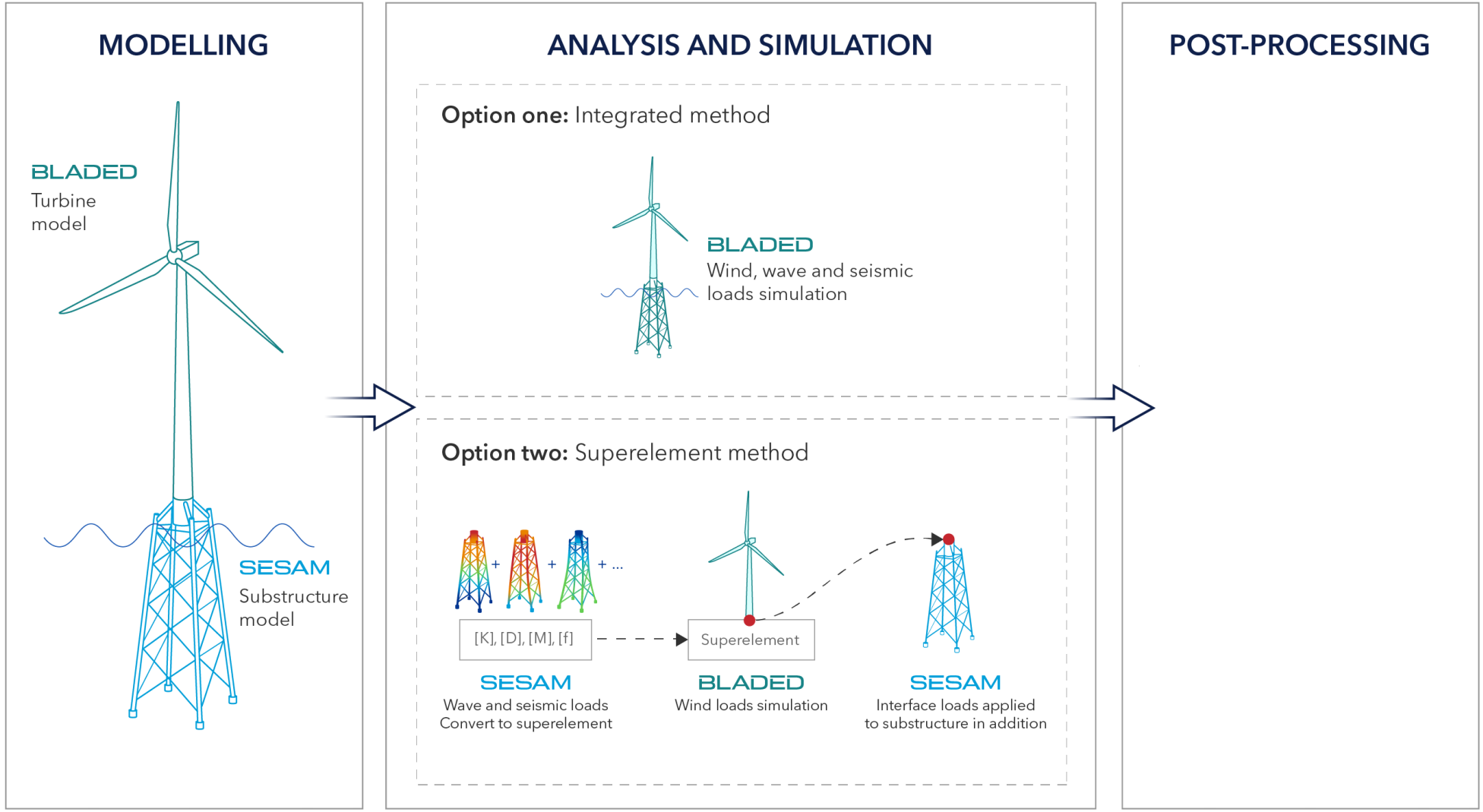
Member and joint checks for extreme loads

DNV

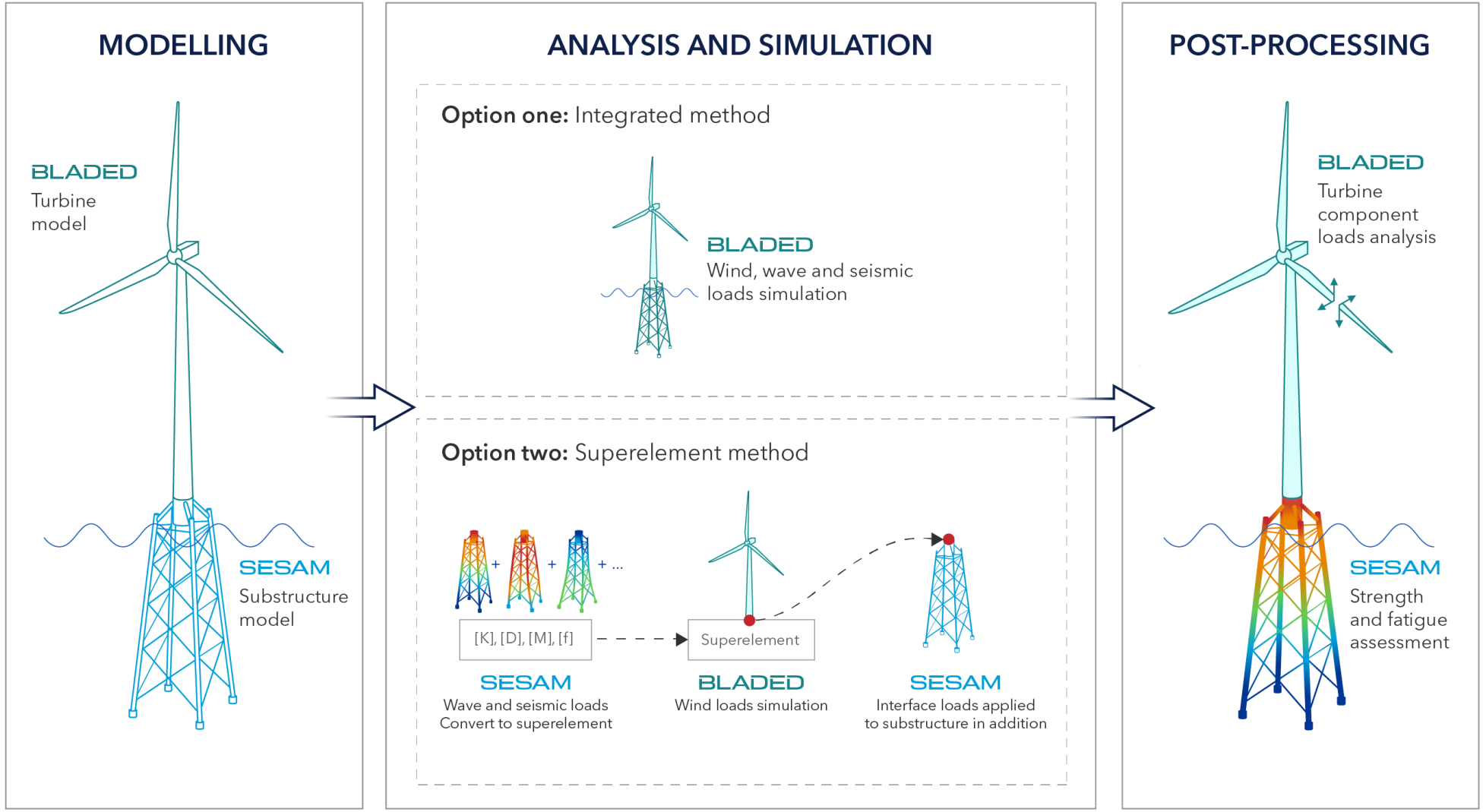
Sesam - Fixed Offshore Wind Workflows



Sesam - Fixed Offshore Wind Workflows



Sesam - Fixed Offshore Wind Workflows



Co-simulation with other tools

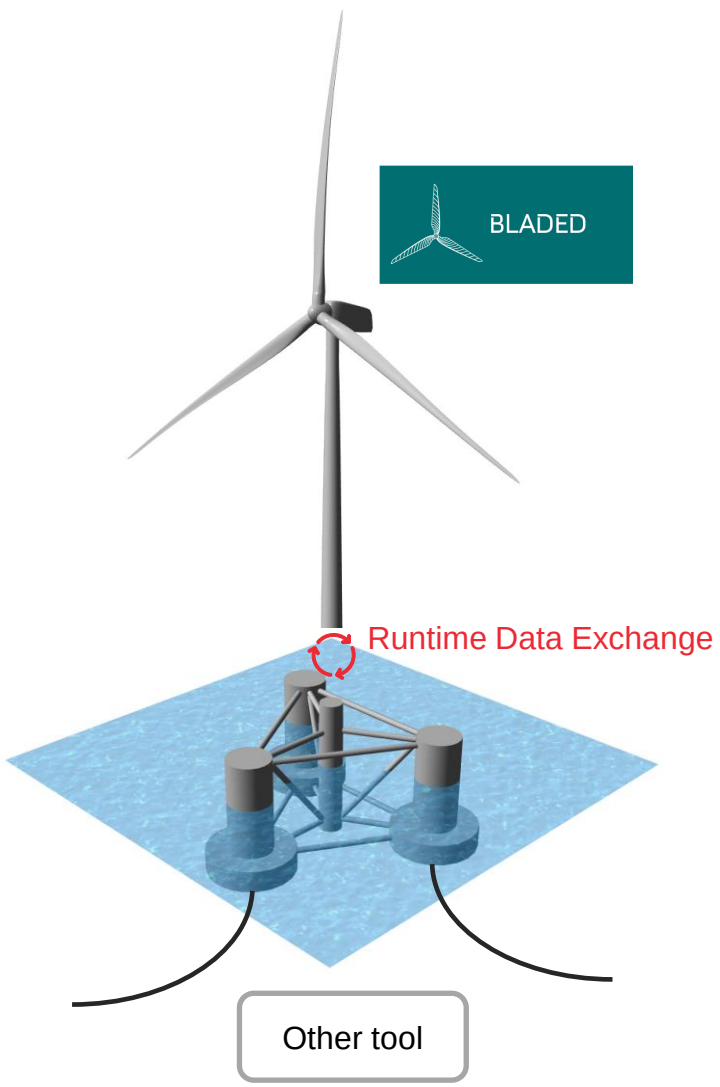
Specialised offshore tools

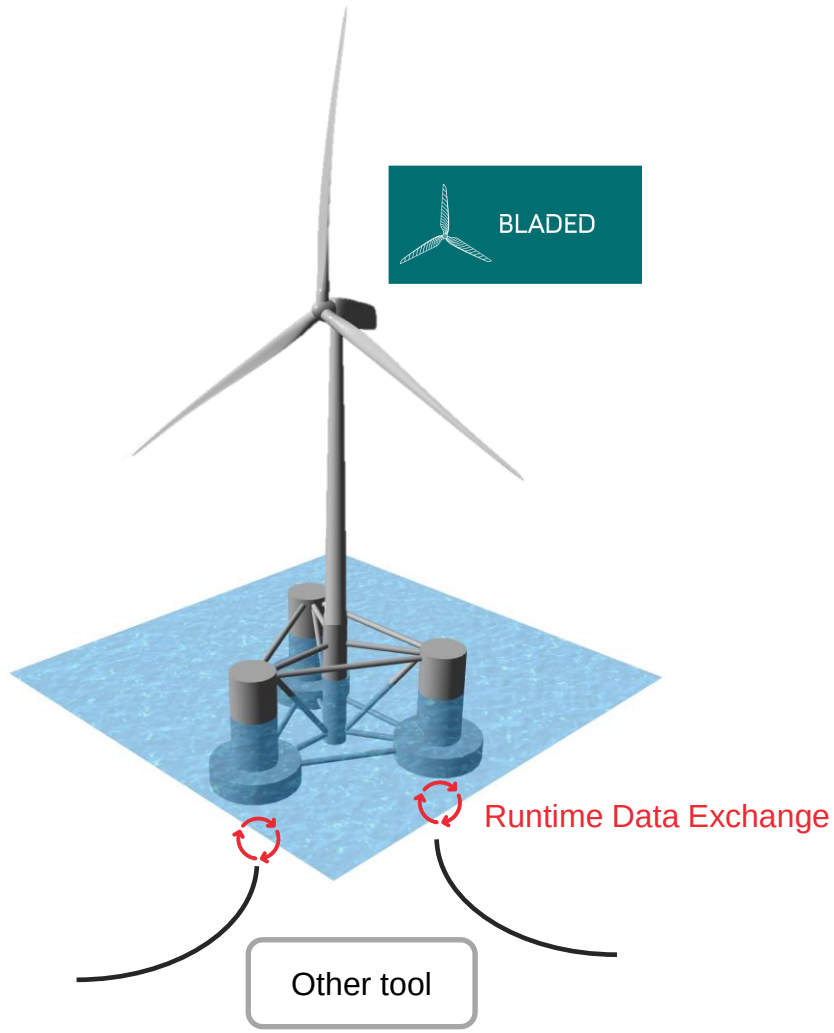
- Floating platforms
- Mooring systems

Save time on:

- Model alignment
- Verification

Loose couplings





Bladed 5

Why Bladed 5?

Flexibility

Greater control of your turbine modelling

Automation

JSON inputs for faster data interchange

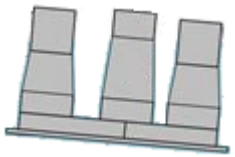
Collaboration

Share, store and distribute data efficiently

LCOE and Process Cost Reduction

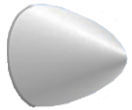
Flexible turbine assembly tree

Multimember Structure



Multimember Float

Nacelle (mainframe, drivetrain)



Hub

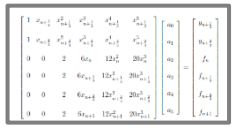
Mooring

Pitch System

Yaw System

Foundations/Pile

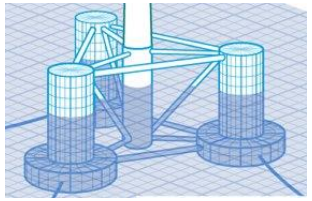
Tower (axisymmetric)

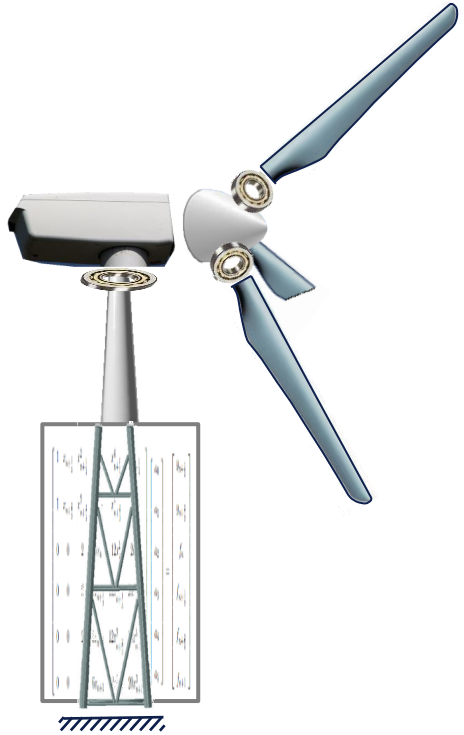


Superelement

Blade

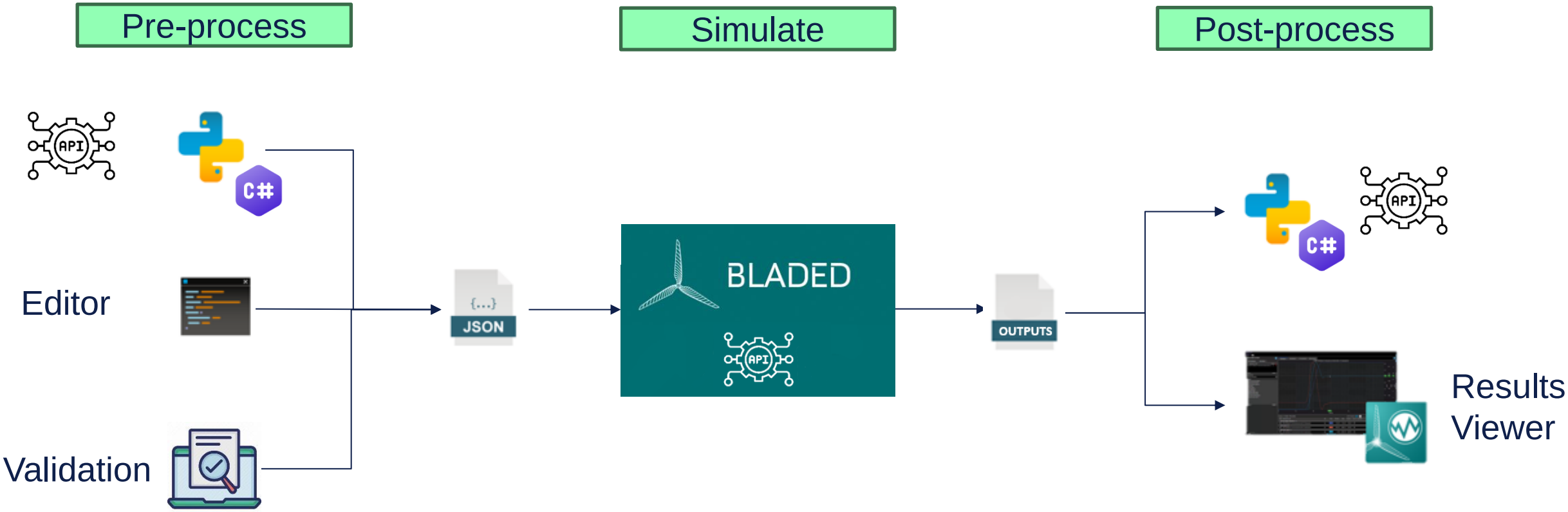
External Module





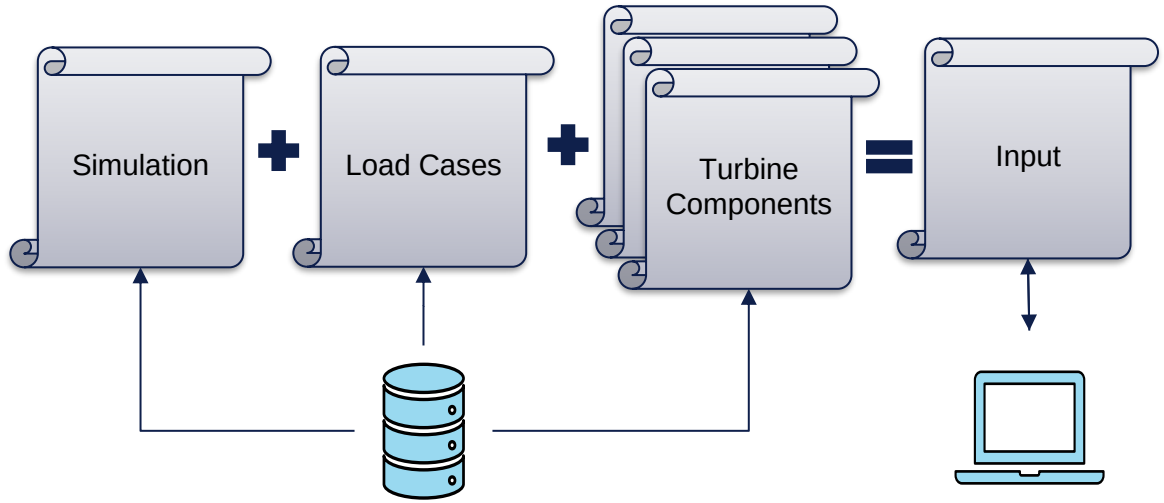
Superelement (jacket + transition piece)
- Tower (axisymmetric)
  - Yaw System
    - Nacelle
      - Hub
        - Pitch System
          - Blade
        - Pitch System
          - Blade
        - Pitch System
          - Blade

Bladed 5 API First Workflow



Distributable Data

- Separate inputs into files
- Manage, store and share data effectively
- Build databases and libraries for e.g.
  - Blades, towers, hubs, etc..
  - Aerofoils
  - Load cases



Input validation and editing support

JSON format enables input files and programming APIs with:

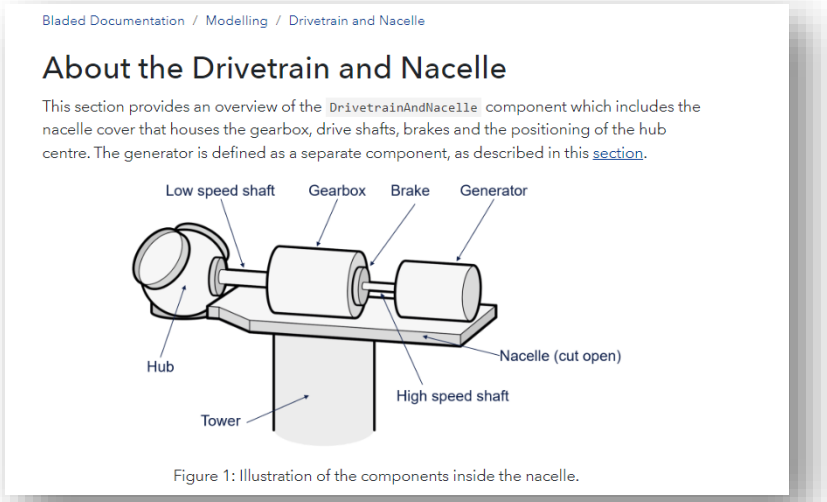
- Error highlights
- Auto-complete
- Mouse tip and docstring documentation
- Same data template across programming languages

```
3
4       "SteadyCalculation": {
5
6       }
7
8   }
```

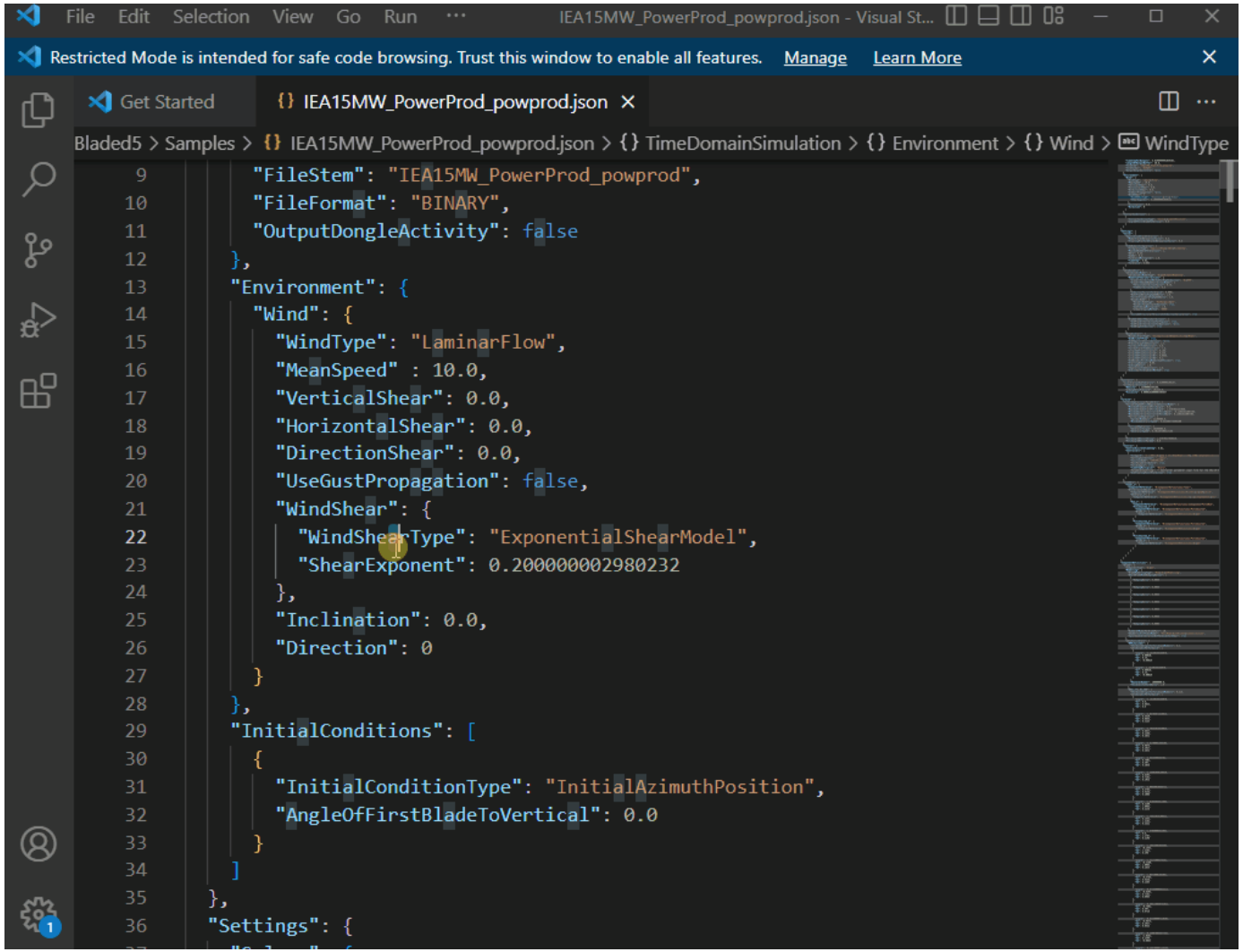
```
3
4       "SteadyCalculation": {
5           "SteadyCalculationType": "PerformanceCoefficients"
6       }
7   }
```

Services for validation of your model before simulation

Fully documented to take full control of your inputs



Wind Module


File Edit Selection View Go Run ···
IEA15MW_PowerProd_powprod.json - Visual St...
Restricted Mode is intended for safe code browsing. Trust this window to enable all features. Manage Learn More
Get Started
IEA15MW_PowerProd_powprod.json
Bladed5 > Samples > IEA15MW_PowerProd_powprod.json > {} TimeDomainSimulation > {} Environment > {} Wind > WindType
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"Direction": 0
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},
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"AngleOfFirstBladeToVertical": 0.0
}
]
},
"Settings": {

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