Block Island Wind Farm CVA

Status of verification activities

Presented by
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Senior Engineer

March 10, 2015

ABS Group

Overview of Phases

Design Verification

- Site Assessment – Complete
- Design Basis – Complete
- Load Simulation – in Process
- Detailed Design – in Process

Manufacturing Verification

- Jacket Fabrication – in process
- Wind Turbine Manufacturing – in process

Manufacturing Surveillance - WTG

Five blade sets, LM Windpower, Denmark – completed March 2014

Manufacturing Surveillance - WTG

Castings – Faw Foundry, China, Feb 2015

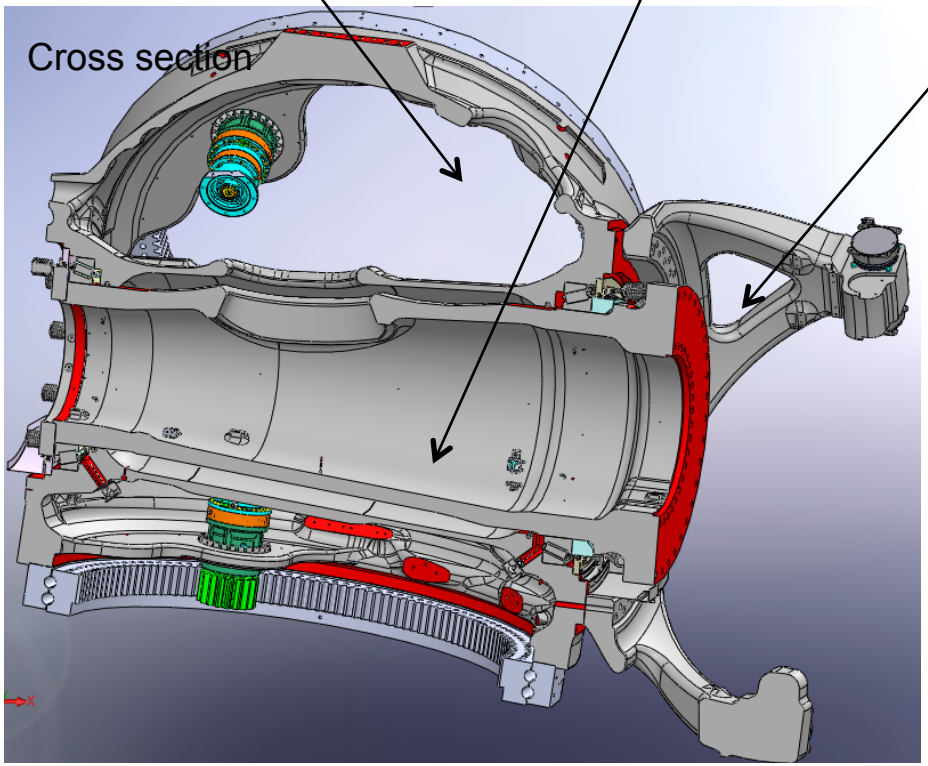
Diameter	width	weight
4 m	4.5 m	48.9 T

Manufacturing Surveillance - WTG

Hub

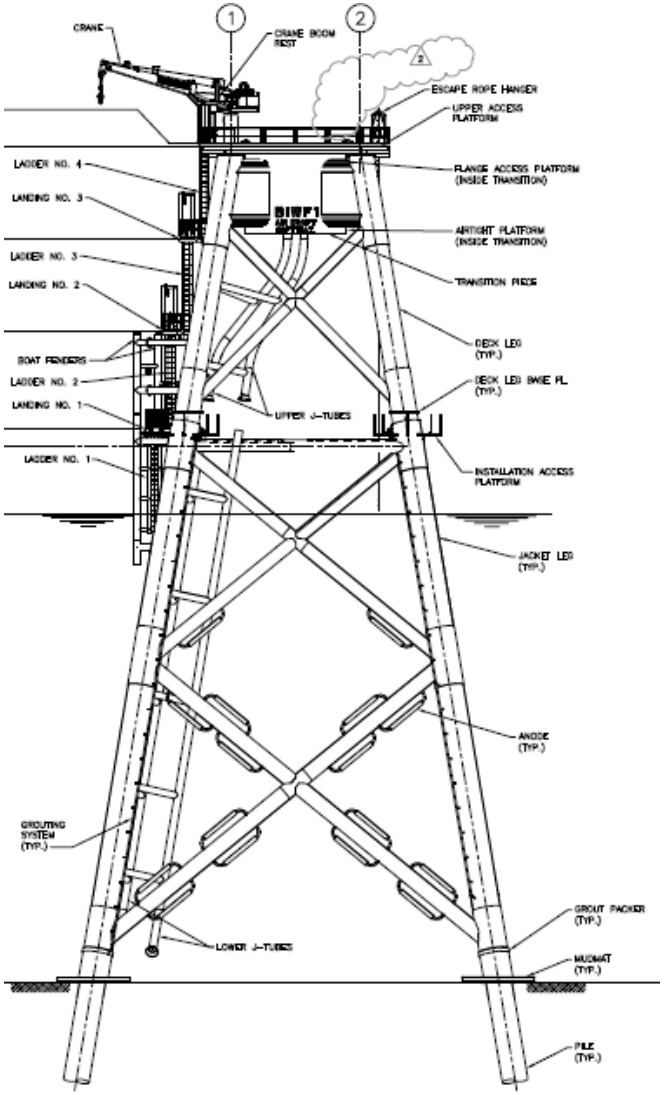
Front Frame

Coupling Arm (3x per set)



Manufacturing Surveillance - Substructure

Deck Legs – Gulf Island Marine, Houma, LA



Manufacturing Surveillance - Substructure

Jacket Flanges – Euskal Forging, Sistao Spain

Manufacturing Surveillance - Substructure

TP– EEW, Rostock, Germany

Manufacturing Surveillance - Substructure

Racetrack connection of Deck – Gulf Island Marine, Houma, LA

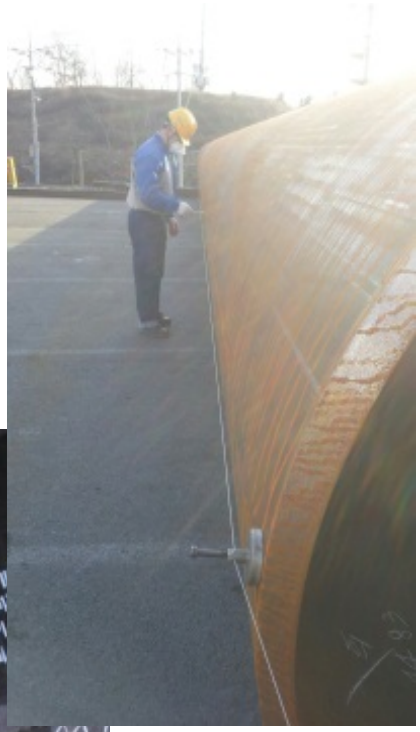
Manufacturing Surveillance - Substructure

Manufacturing Surveillance - Substructure

Jacket Piles – EEW, Korea

UT check of longitudinal weld

bevel

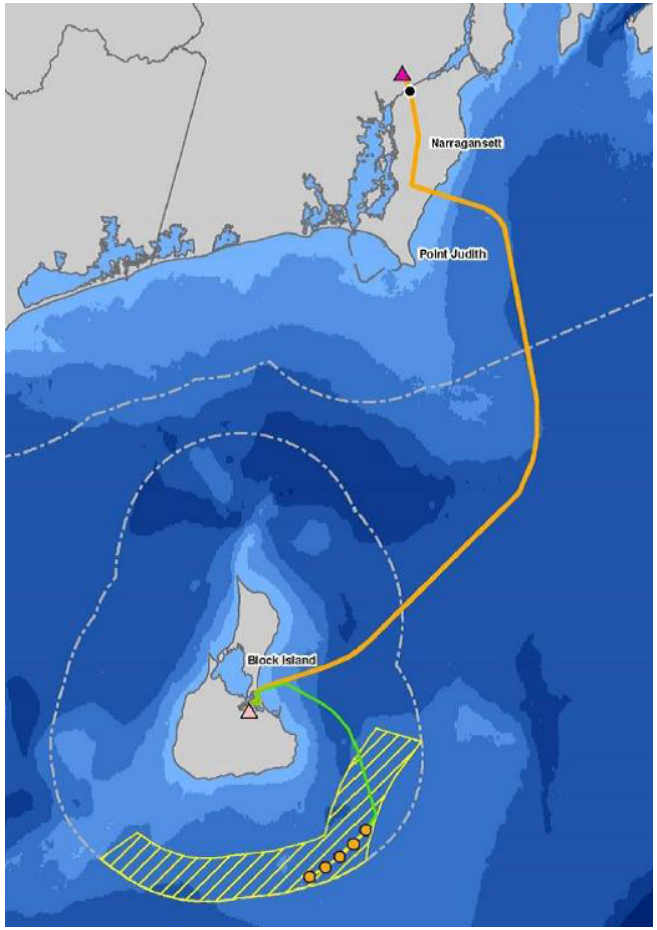


straightness

Site Assessment

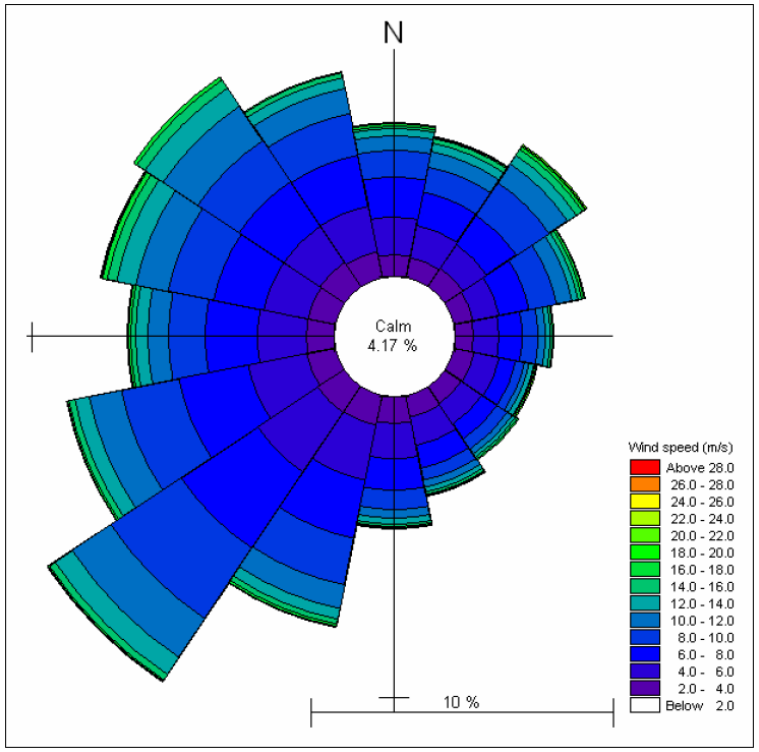
Inputs

- Meteorological Reports
- Metocean Reports
- Geophysical Survey
- Geotechnical Survey
- Geotechnical Interpretation Reports
- Applicable laws, lease and permits
- Interconnection requirements

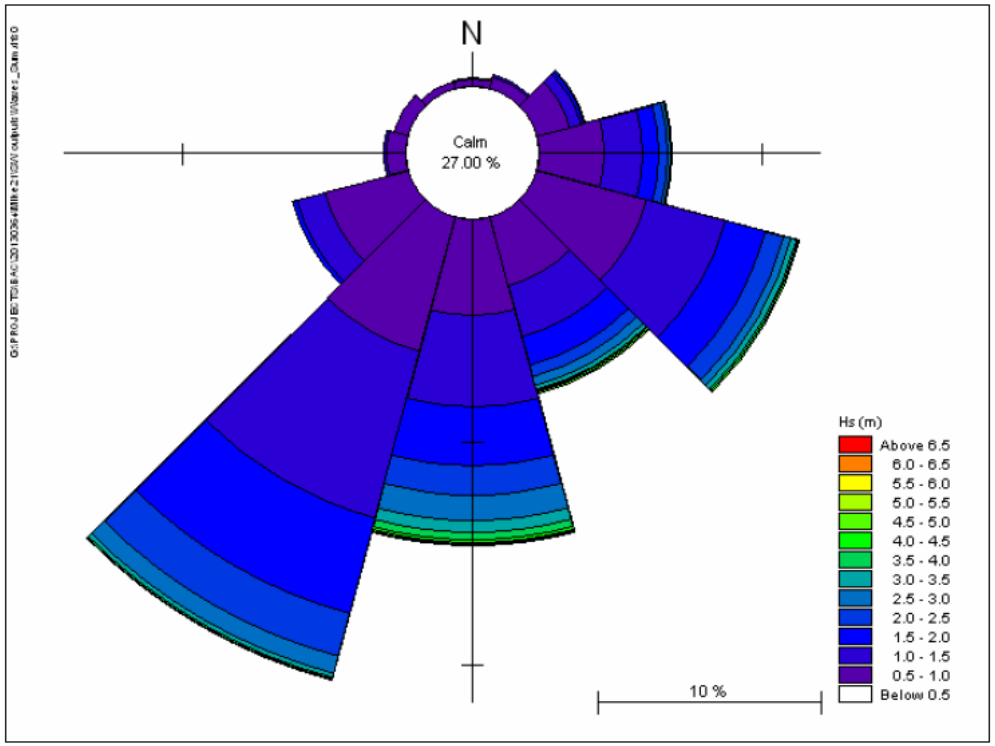


Metocean Conditions - Distributions

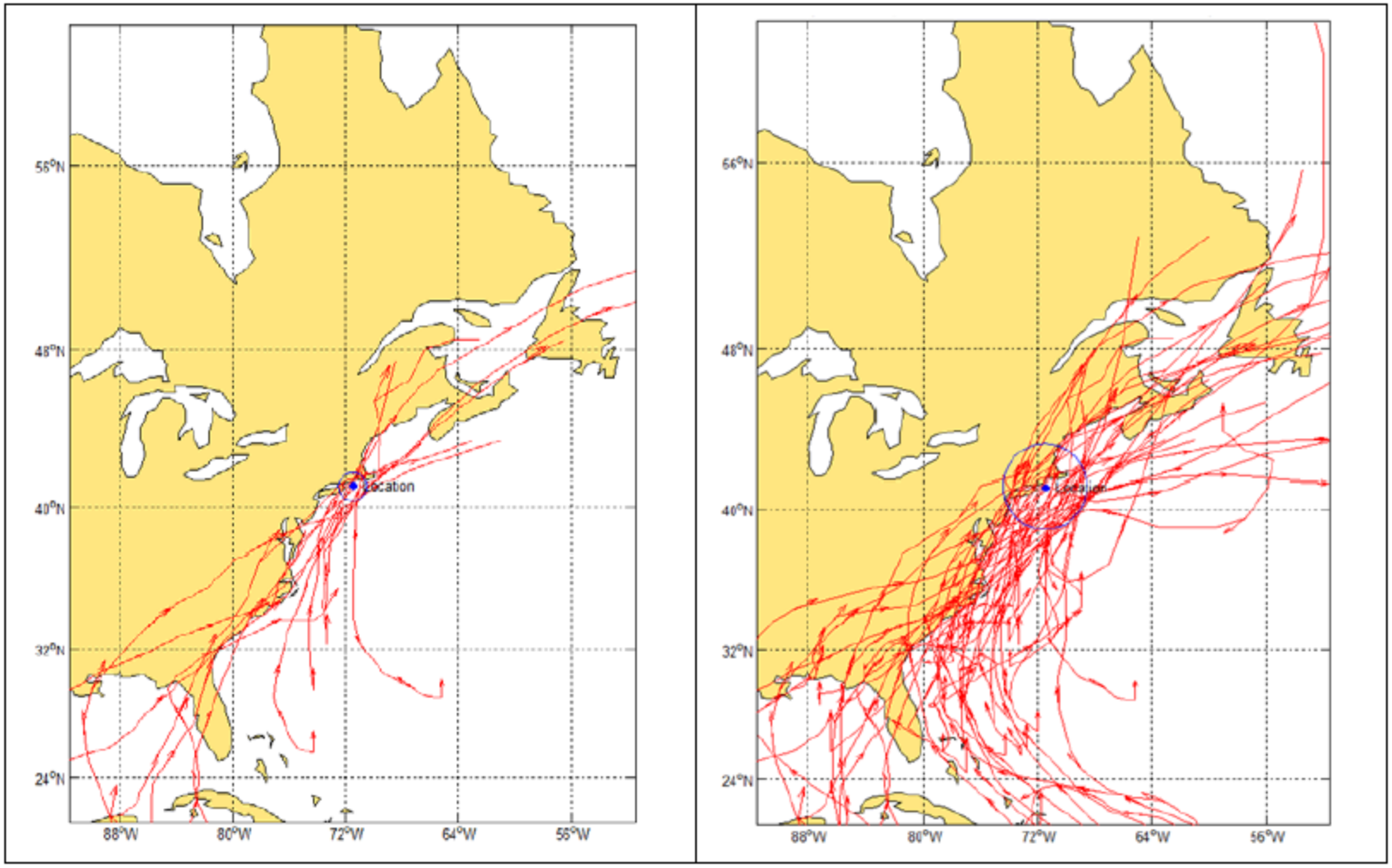
Wind Rosette



Wave Rosette



Metocean Conditions – Extreme Values



Site Assessment

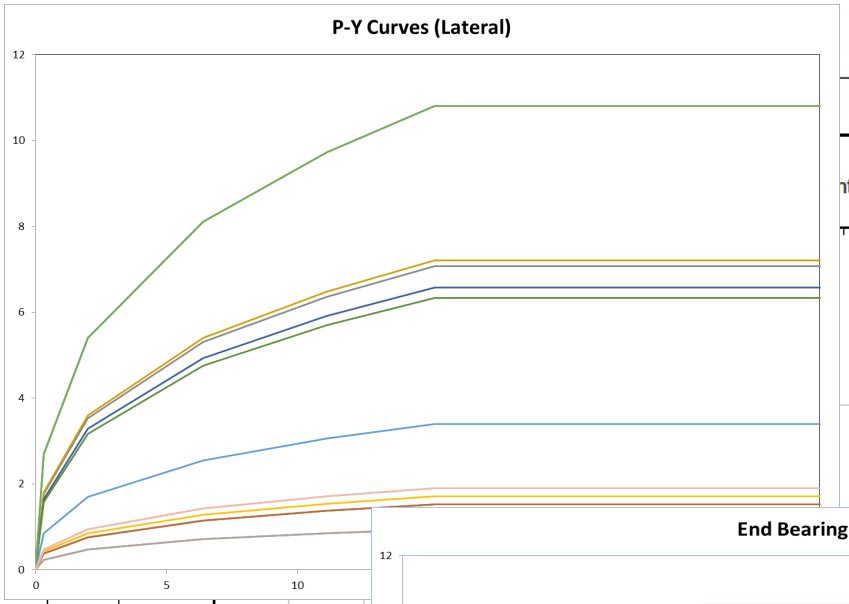
Analysis

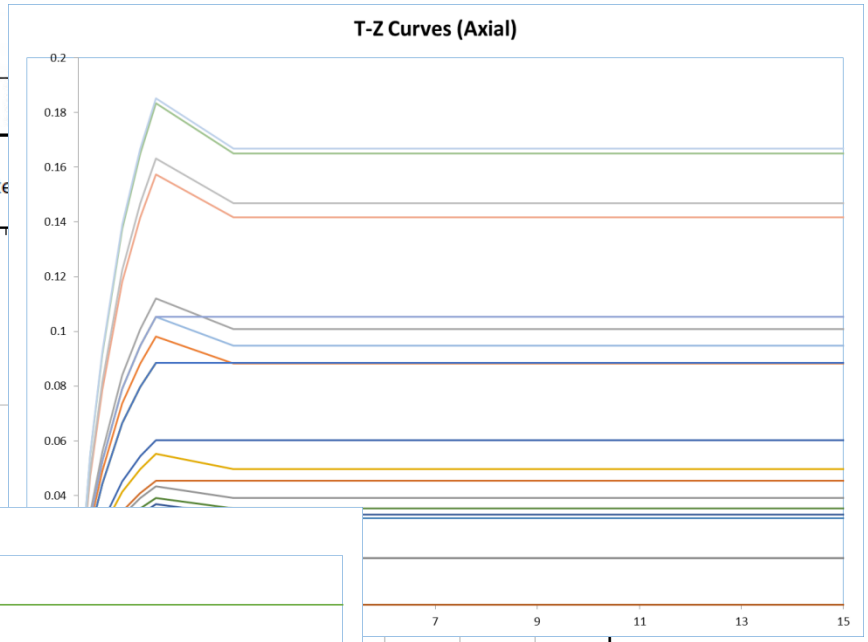
- Annual wind charcteristics
- Extreme event analysis
- Directional Joint probability analysis
- Geotechnical and Geophysical data collection
- Soil-Pile interaction: pile capacity, P-y, T-z, Q-z curves

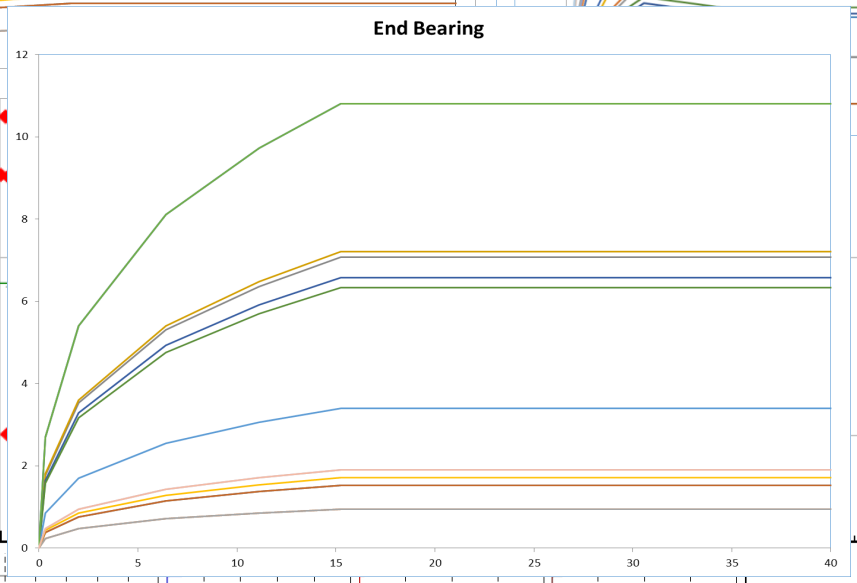
ABS Deliverables

- ABS BIWF Report - Site Assessment Verification 2014-11-26-r0

Geotechnical Data Verification







Design Basis

Inputs:

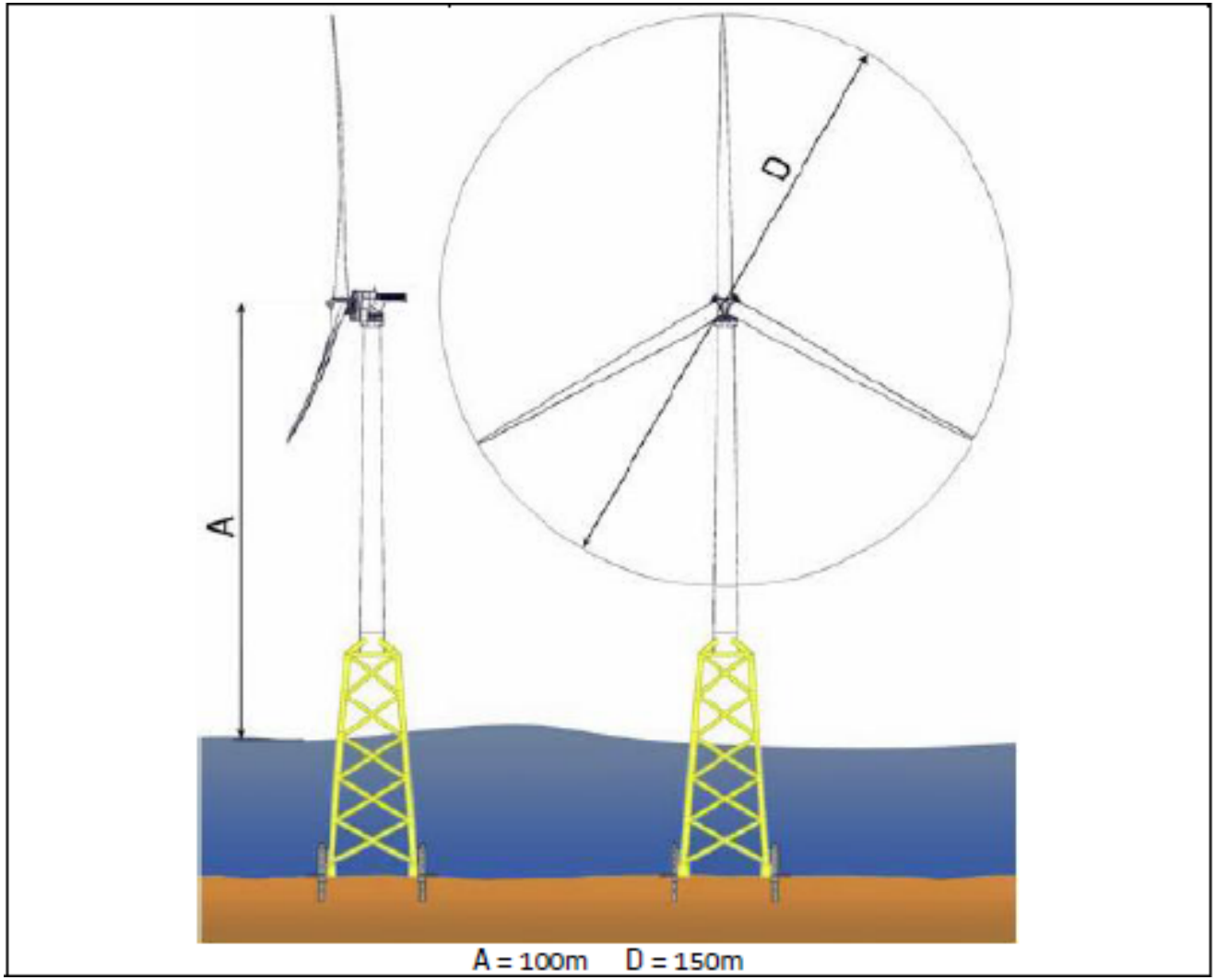
Designers' interpretation of design inputs based on site assessment

Preliminary Design

- Substructure – Keystone
  - Substructure Design Basis
  - Preliminary Design Report
  - Preliminary Design Drawings
- Wind Turbine – Alstom
  - Tower Structure Design Basis
  - Tower Internals Design Basis
  - Wind Conditions
  - Turbine General Description

1	Rotor Nacelle Assembly
2	Tower
3	Interface
4	Jacket
5	Foundation piles

Design Basis



Design Basis

Analysis

Review of regulations and standards applied

Review of concept design

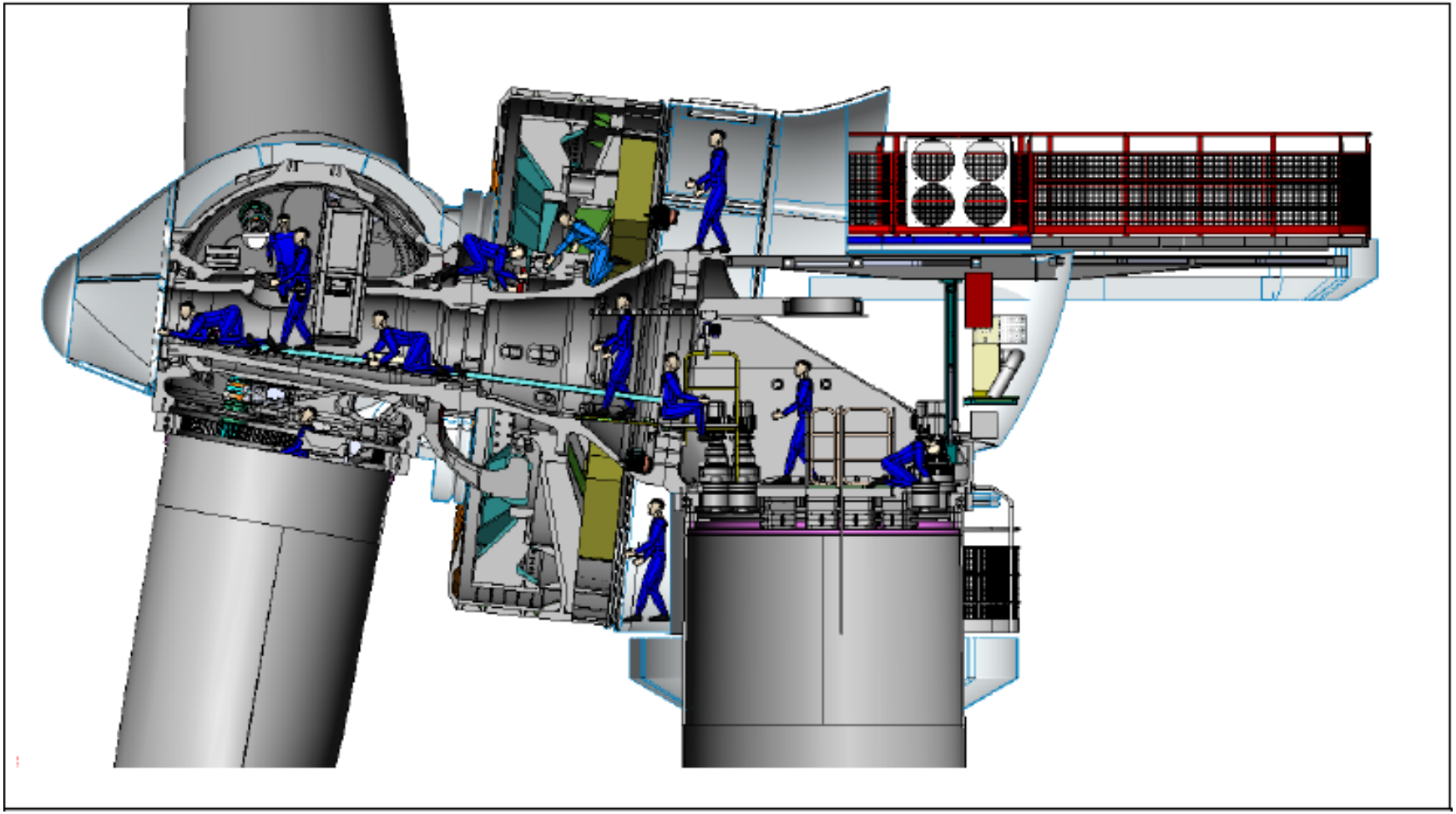
Reduction of wind and ocean data

- Wind bins and annual probability distribution
- Wind, wave, and current direction distribution
- Extreme event modeling

ABS Deliverables

ABS BIWF Report - Design Basis Review - 2014-12-08-r0

Design Basis



Detailed Design

Verification of Integrated Model

- Review of Design Load Case definitions
- Review of integrated load simulation methods
- Review and spot check of integrated load simulation results
- Check of site specific results against type-certification load envelope

Design evaluation of wind turbine

- Site specific loads
- Environmental conditions
- Local regulations
- Any changes from the type certified model
- Electrical and mechanical hazards to personnel
- Corrosion protection

Detailed Design

Design evaluation of sub-structure

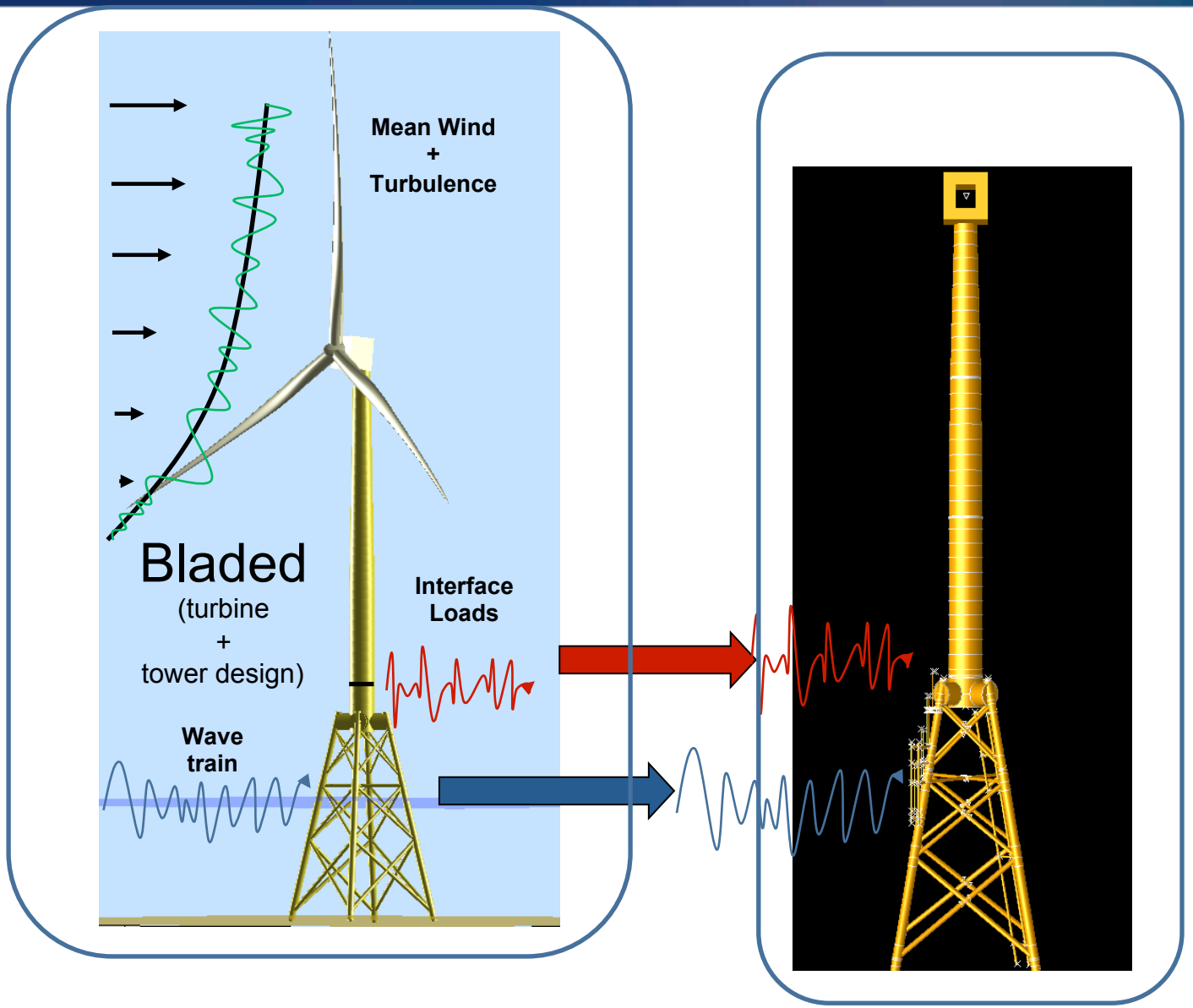
- Review of detailed strength calculation methods and results
- Review of manufacturing drawings, specifications, and instructions (compared to calculation assumptions and applicable standards)
- Review of O&M procedures (effect on structural integrity and design life)
- Finite element analysis
- Corrosion protection

Load Simulation – ABS Independent Modeling

Overview

- Turbine and structure are modeled in Bladed and SACS with different levels of detail
- Time domain simulations according to the DLC list
  - 1758 ULS simulations
  - 1272 FLS simulations
- Force time histories at the tower base flange are output from Bladed to SACS to apply turbine and tower aerodynamic and operational loads to the substructure
- Sea surface profiles are output from Bladed to SACS for identical wave definition

Load Simulation



Load Simulation – ABS Independent Modeling

Bladed

- Integrated turbine, tower, and jacket structure modeled as beam elements
- 3-d wind field
- Blade aerodynamic characteristics
- Combined wind and wave forces
- Turbine operational behavior modeled in detail
- Soil-structure interaction is modeled as a 3-d stiffness matrix
- Substructure complex members (grouted members, racetrack) are modeled with equivalent mass, stiffness, moments of inertia
- Full capture of combined environmental, operational, and dynamic loading
- Bladed results are used for tower site specific design

Load Simulation – ABS Independent Modeling

SACS

Integrated tower and jacket structure modeled as beam elements, RNA included as a point mass for natural frequency analyisis

Mode shapes include tower and RNA dynamics

Wave definition identical to Bladed

Piles and grouted members are included in structural model

Soil-pile interaction modeled with P-y, T-z, and Q-z curves applied along the pile

Wind, operational, and dynamic loading from RNA and tower is input from Bladed at the tower bottom flange

Hydrodynamic and dynamic loading on the substructure

Post processing for ULS and FLS of subsutructure members and joints

Load Simulation

Inputs

Substructure – Keystone

- DLC list
- Modeling and Analysis Methodology
- Data exchange with Turbine designer
- Model Calibration
- Natural Frequency Analysis to determine driving location
- SACS Input files
  - Structure, soil, wind, wave, and current definition, marine growth
- SACS Output files
- Load Reports

Load Simulation

Inputs

Wind Turbine – Alstom

DLC list

Modeling and Analysis Methodology

Data exchange with Substructure designer

Model Calibration

Bladed Input files

Structure, soil stiffness matrix, 3-d wind field,

wave and current definition, marine growth

Bladed time series

sea surface profile, interface loads

Load Reports

Load Simulation

Analysis

- DLC list – consistency with site assessment data
- Modeling and Analysis Methodology
  - Best practice
  - Best available tools
  - Simplification– acceptable when results are conservative
- Detailed comparison of SACS and Bladed models
  - Structural properties
  - Wind, wave, and current definition
  - Dynamic response
  - Loop 1 – errors found – soil coordinate systems, export SACS to Bladed
  - Corrected in Loop 2
- Results
  - Compare ULS and FLS results from Loop 2

ABS Deliverables

- ABS BIWF - Calibration Verification Report
- ABS BIWF – Load Report – Expected March 2015

Load Simulation – ABS Independent Modeling

Bladed
Use Alstom .prj file with encrypted blade
Use Alstom encrypted turbine and pitch controller .dll
RNA and controller must be consistent with type certified design
Tower is site specific design by Alstom
Substructure is site specific design by Keystone

ABS Reports

Design Phase

ABS BIWF Report - Site Assessment Verification 2014-11-26-r0
ABS BIWF Report - Design Basis Review - 2014-12-08-r0
ABS BIWF Report – Calibration Verification 2014-02-23-r0
ABS BIWF Report – Load Simulation - Pending

Manufacturing Phase

ABS BIWF Report – Blade Manufacuring Verification
ABS BIWF Report – Jacket Flange Manufacuring Verification
ABS BIWF Report – TP Manufacuring Verification
ABS BIWF Report – Jacket Pile Manufacuring Verification - Pending
ABS BIWF Report – Casting Manufacuring Verification - Pending

Next Steps

March-April

- Complete Verification of Loads, Detailed Design
- Facilities Design Report
- Fabrication and Installation Report
- Continue Manufacturing Verification of WTG and Substructure

June

- Loadout and Transportation of Jacket
- Continue Manufacturing Verification of WTG

August-September

- Installation of Jacket
- Continue Manufacturing Verification of WTG…

Summer 2016

- Installation and Commissioning of WTG