

Overview of the HydroDyn Hydrodynamics Module



**NREL Wind Turbine
Modeling Workshop**

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UMASS – Amherst, MA

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Outline

- Overview:
 - HydroDyn – What Is It?
- Monopiles:
 - Waves, Currents, & Hydrodynamic Loads
- Floating Platforms:
 - Combining Computational Methodologies
 - Waves, Currents, & Hydrodynamic Loads
 - Mooring Systems
- Current & Planned Work
- Future Opportunities

Overview

HydroDyn – What Is It?

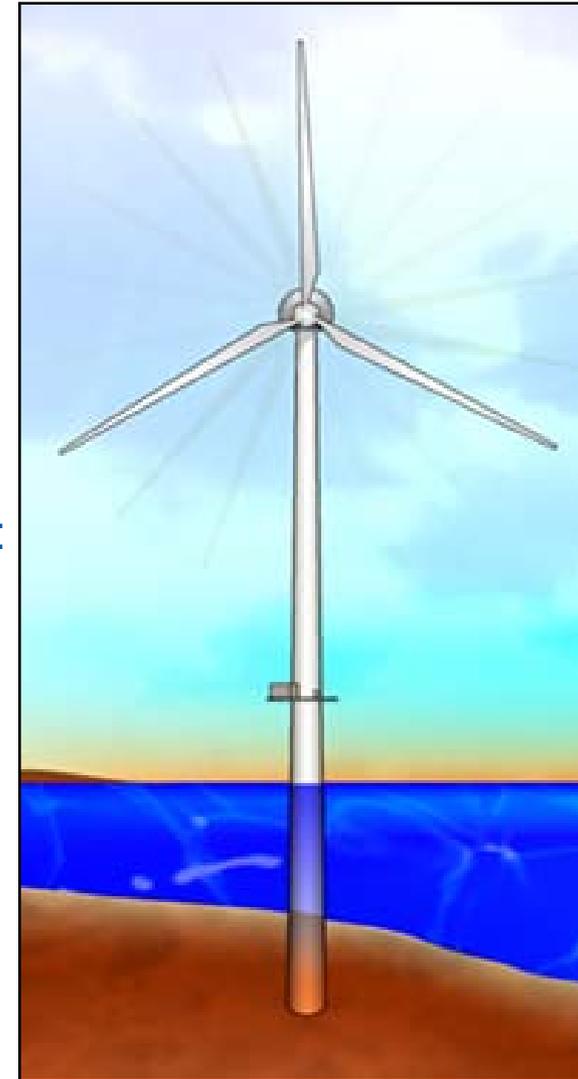
- Yet-to-be documented hydrodynamics routines for offshore wind turbines:
 - Currently an undocumented feature in **FAST**, **A2AD**, & **SIMPACK**
 - Input settings contained in **FAST**'s platform input file
 - Source code included in **FAST** v7.00.01a-bjj & newer
 - Interfaced to **MSC.ADAMS** via **A2AD** v13.00.00a-bjj & newer
- Support-structure types:
 - Monopiles
 - Floating platforms
- Theory Manual:
 - Jonkman Ph.D. Dissertation (2007)
 - Jonkman, *Wind Energy* (2009)



Monopiles

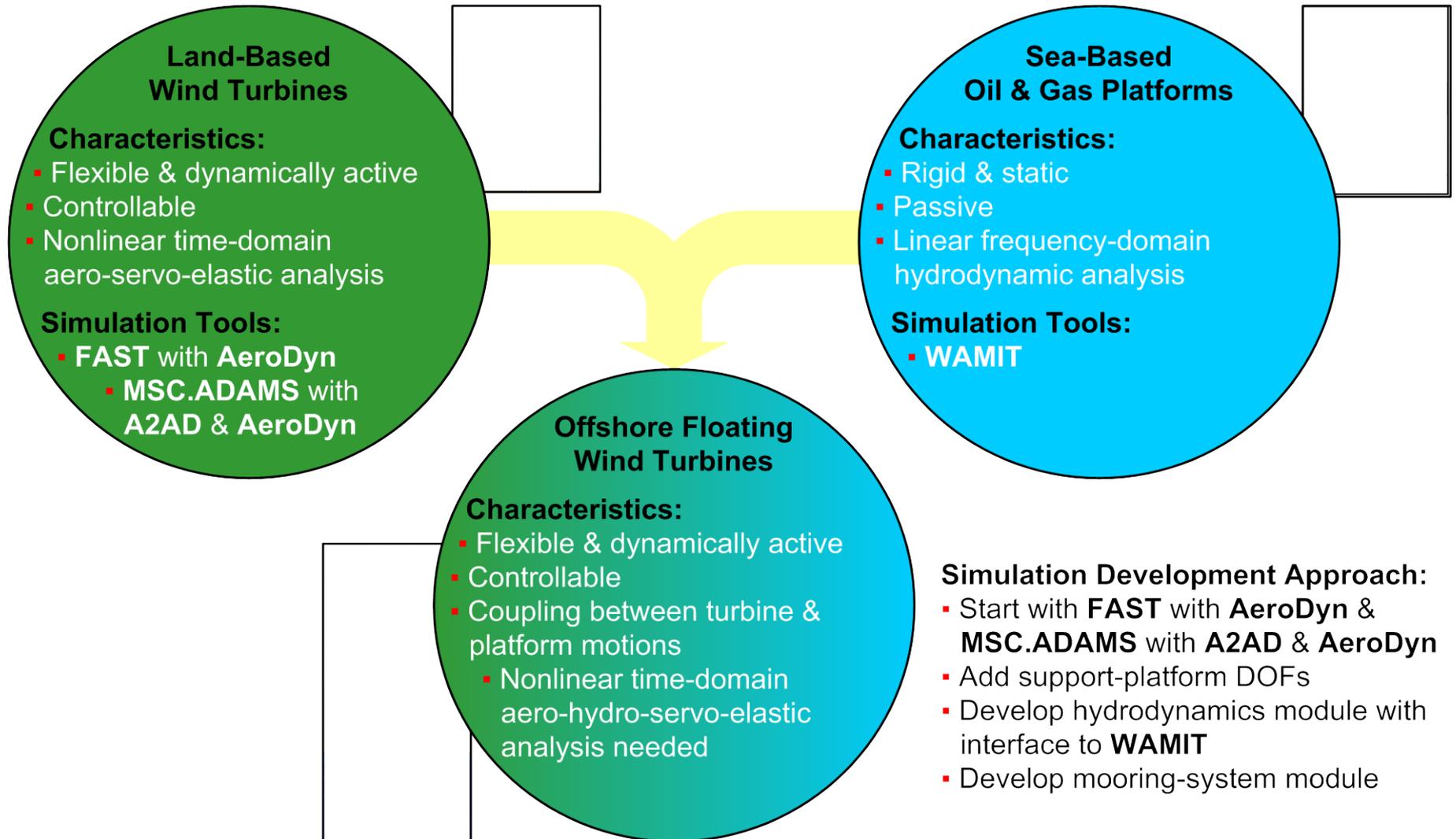
Waves, Currents, & Hydrodynamic Loads

- Wave kinematics:
 - Linear regular (periodic)
 - Linear irregular (stochastic):
 - Pierson-Moskowitz, JONSWAP, or user-defined spectrum
 - With optional stretching:
 - Vertical, extrapolation, or Wheeler
 - Arbitrary choice of wave direction, but no spreading
 - Or routine to read in externally generated wave data:
 - Nonlinear wave option available
- Steady sea currents:
 - IEC-style sub-surface, near-surface, & depth-independent
 - Or user-defined
- Hydrodynamic loads:
 - Relative form of Morison's equation
 - Calculated at each structural node along tower



Floating Platforms

Combining Computation Methodologies



Floating Platforms

Waves & Currents

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 - Linear regular (periodic)
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Floating Platforms

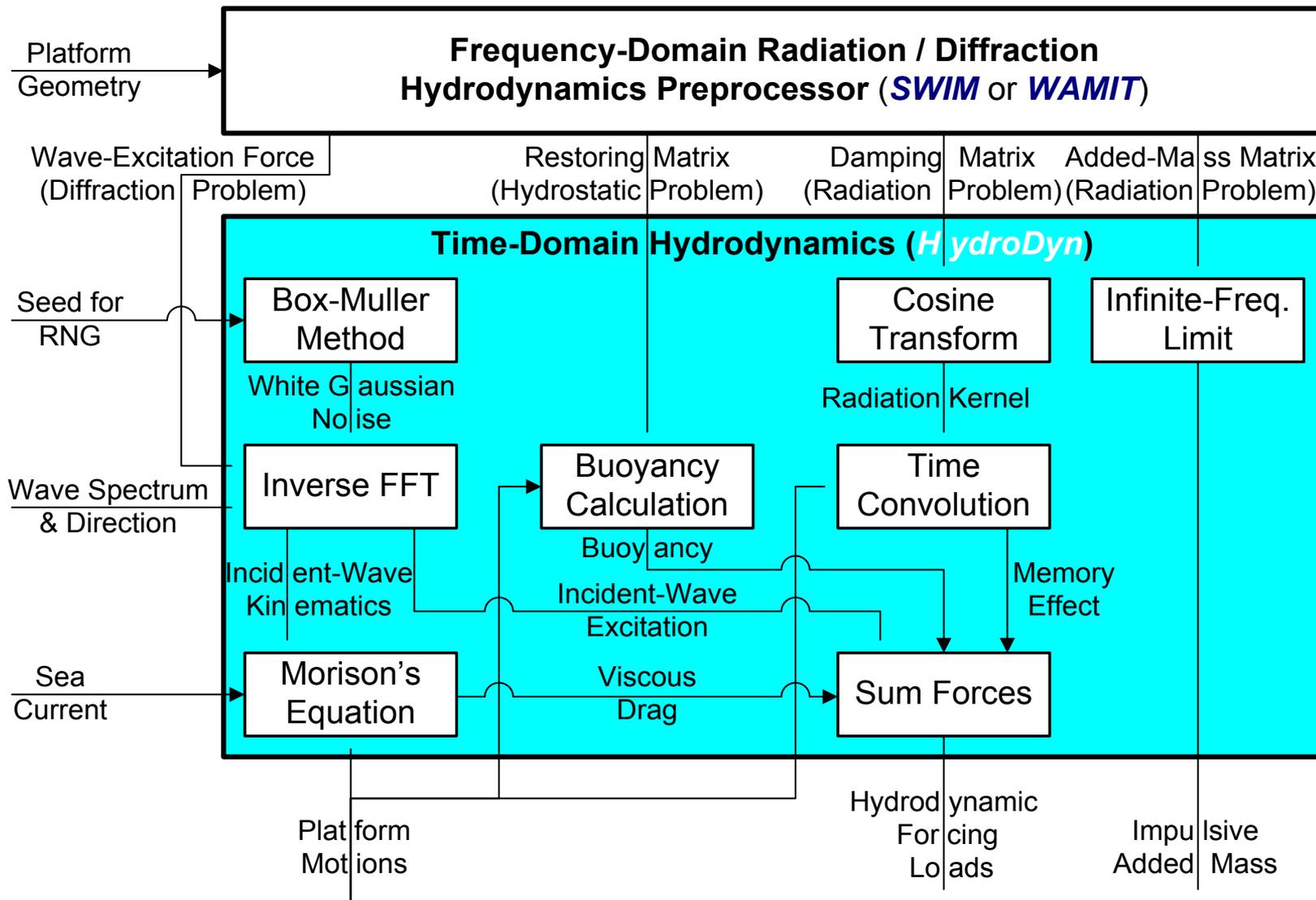
Hydrodynamic Loads

- Hydrodynamic loads:
 - Wave-body interaction with rigid platform
 - Arbitrary platform geometry
 - Linear frequency-domain radiation & diffraction solutions imported from **WAMIT** or equivalent:
 - Internal frequency-to-time domain conversion
 - Radiation “memory effect” accounted for by direct time-domain convolution
 - Linear hydrostatic restoring
 - Applied as 6-component (lumped) load on platform at reference point
 - 2nd-order (mean-drift, slow-drift, sum-frequency) effects neglected
 - Damping in surge, sway, roll, & pitch augmented with nonlinear viscous drag term from relative form of Morison’s equation:
 - Distributed along platform analysis nodes



Floating Platforms

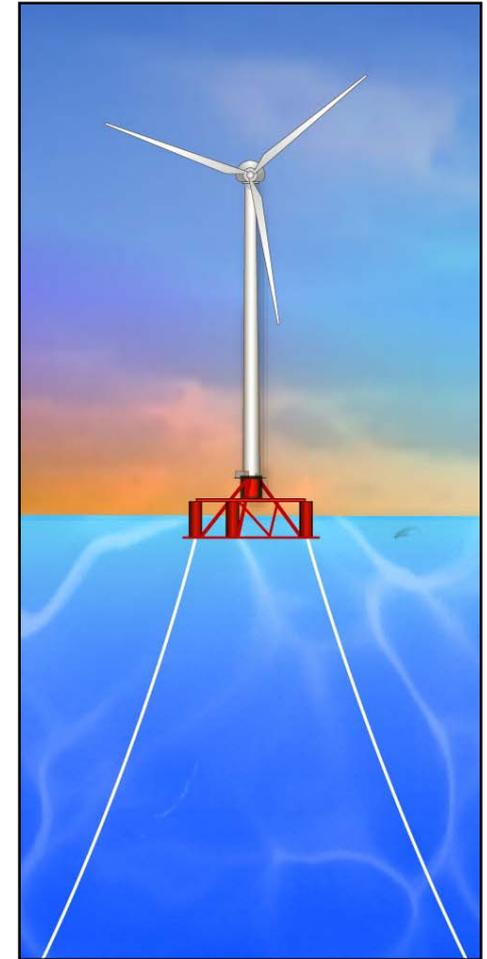
Hydrodynamics Calculation Procedure



Floating Platforms

Mooring Systems – Overview

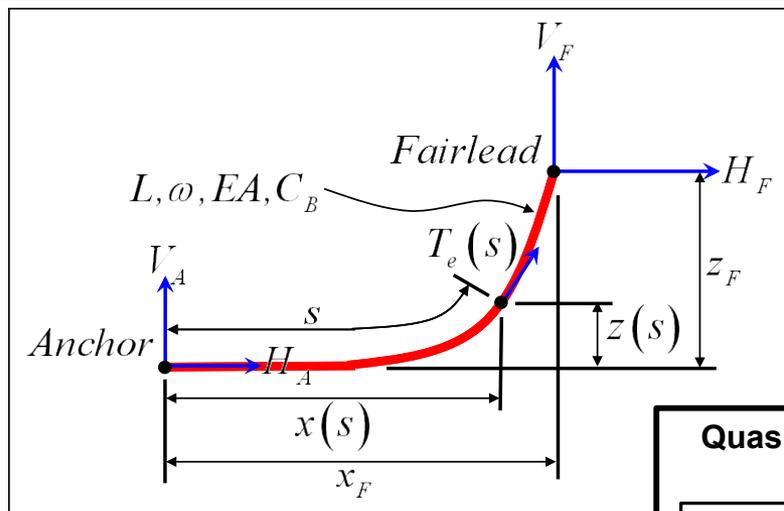
- Continuous quasi-static mooring system module implemented within **HydroDyn**:
 - Solves nonlinear analytical catenary equations
 - Fairlead tensions applied as reaction forces on platform
- Accounts for:
 - Array of homogenous taut or catenary lines
 - Apparent weight of line in fluid
 - Elastic stretching
 - Seabed friction
 - Nonlinear geometric restoring
- Neglects:
 - Line bending stiffness
 - Mooring system inertia
 - Mooring system damping



Dutch Tri-Floater

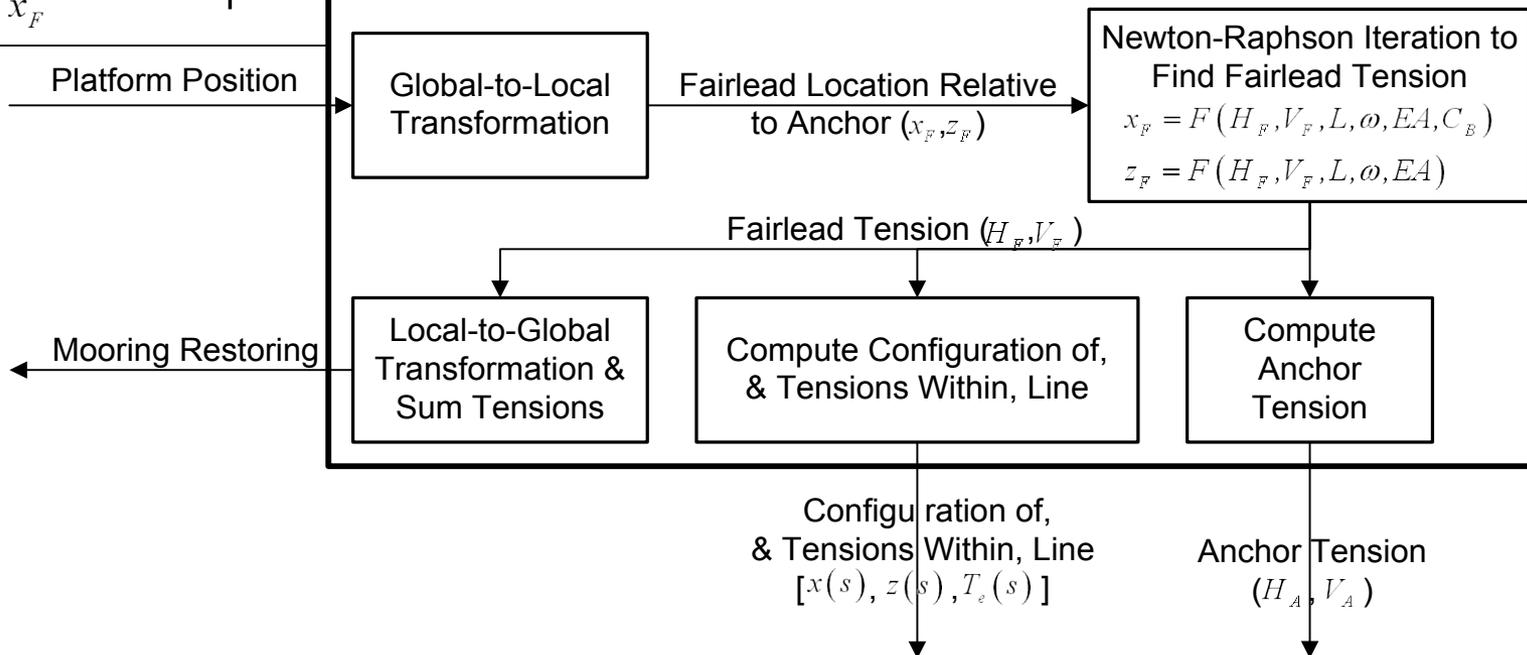
Floating Platforms

Mooring Systems – Calculation Procedure



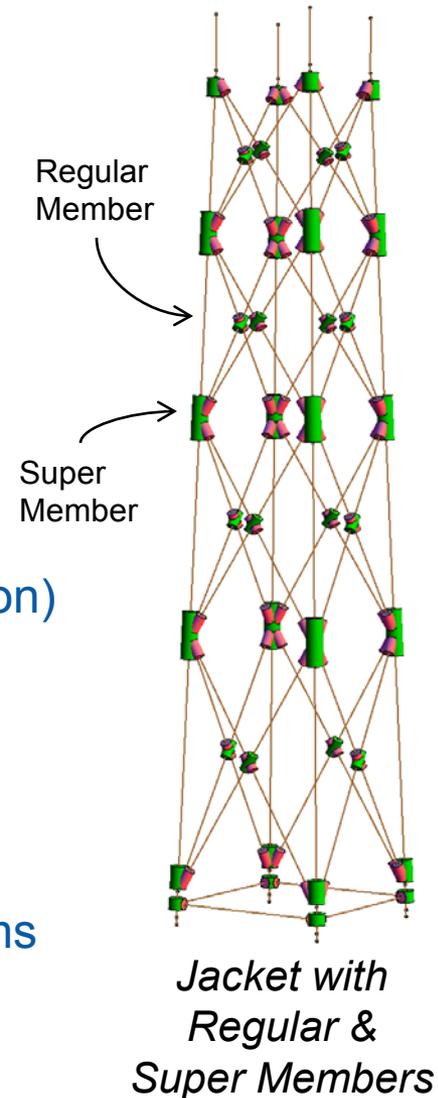
Mooring Line Properties
 (L, ω, EA, C_B)

Quasi-Static Mooring-System Module (Calculations Shown for Each Line)



Current & Planned Work

- Extend to space-frame support structures:
 - Features:
 - Multiple members & intersecting members at joints
 - Accurate calculation of overlap of intersecting members
 - Inclined & tapered members
 - Flooded & ballasted members
 - Marine growth
 - Hydrodynamic loads:
 - Distributed inertia, added mass, & viscous drag (Morison)
 - Distributed static buoyancy & dynamic pressure
 - Concentrated loads at member ends & joints
 - Applicable to:
 - Fixed-bottom tripod or jacket
 - Thin members (e.g., braces/spokes) of floating platforms
 - Verification under IEA Wind Task 30 (OC4)



Current & Planned Work (cont)

- Develop improved interface:
 - Making **HydroDyn**—including inputs—standalone, like **AeroDyn**
- Write **HydroDyn** user & theory manual & publically release
- Verify recent **FAST-OrcaFlex** coupling
- Further verify under IEA Wind Task 30 (OC4)
- Calibrate & validate floating functionality through:
 - DeepCwind – 1:50 scale of 5-MW atop spar buoy, TLP, & semisubmersible
 - SWAY – 1:6.5 scale of 5-MW downwind turbine atop a TLS
 - WindFloat – Vestas V80 2-MW atop a PPI semisubmersible
 - Hywind – Siemens 2.3-MW atop Statoil spar buoy



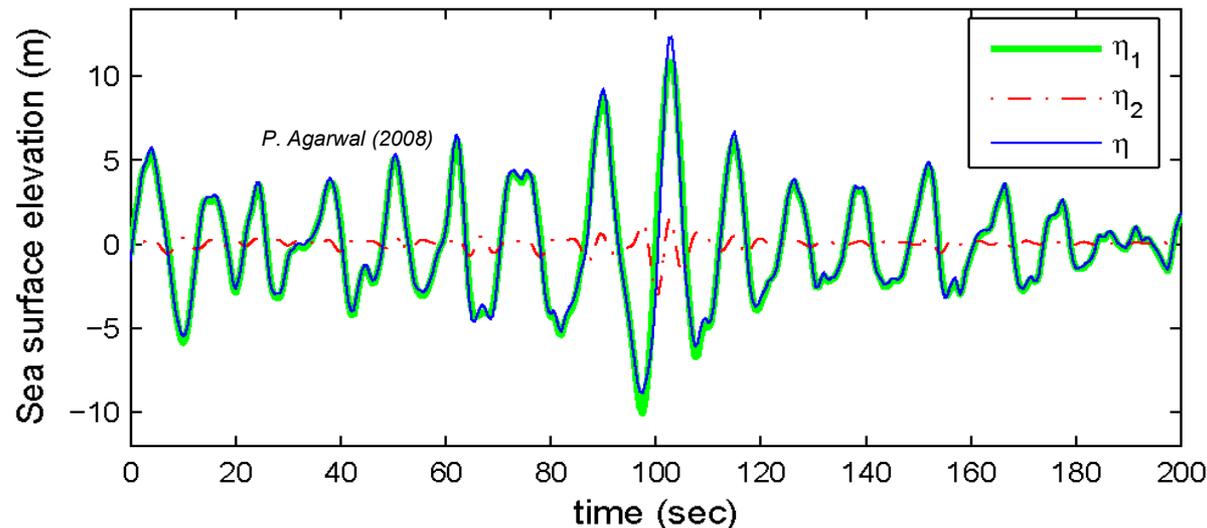
DeepCwind Test



Hywind Prototype

Current & Planned Work (cont)

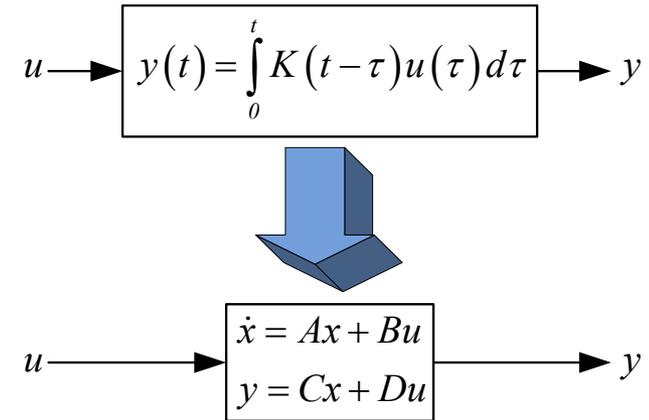
- Numerically improve how the stretched wave kinematics are interpolated at the free surface for fixed-bottom
- Assess & add 2nd-order hydrodynamic effects:
 - Add 2nd-order irregular waves for fixed-bottom (with UT-Austin)
 - Assess magnitude of mean-draft, slow-drift, & sum-frequency hydrodynamic loads for floaters (with ETH Zürich & CU-Boulder)
 - Add mean-draft, slow-drift, & sum-frequency hydrodynamic loads for floaters



*Sea-Surface Elevation (η) from the Combining of
1st- (η_1) & 2nd- (η_2) Order Waves*

Current & Planned Work (cont) & Future Opportunities

- Current & Planned Work (cont):
 - Add ability to prescribe wave time history for floaters
 - Add linear state-space-based radiation formulation
 - Interface **FAST** to an MIT-developed module with nonlinear fluid-impulse theory
 - Interface **FAST** to the TAMU-developed **CHARM3D** dynamic mooring code
 - Develop a standalone dynamic mooring system module (**MAP**)
- Future Opportunities:
 - Add nonlinear regular wave kinematics models for fixed-bottom
 - Floating platform hydro-elasticity
 - Pressure mapping for floaters



Reformulation of Radiation Convolution to Linear State-Space Form

Questions?



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