Developing a Suite of Numerical Modeling Tools for Simulating Axial-Flow MHK Turbines

Contributors

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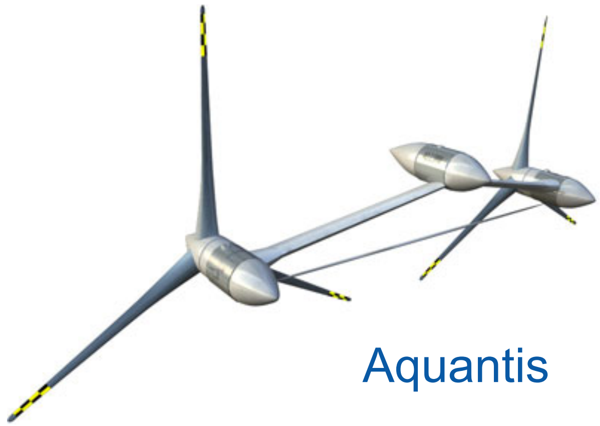
Presentation overview

Introduction and objective

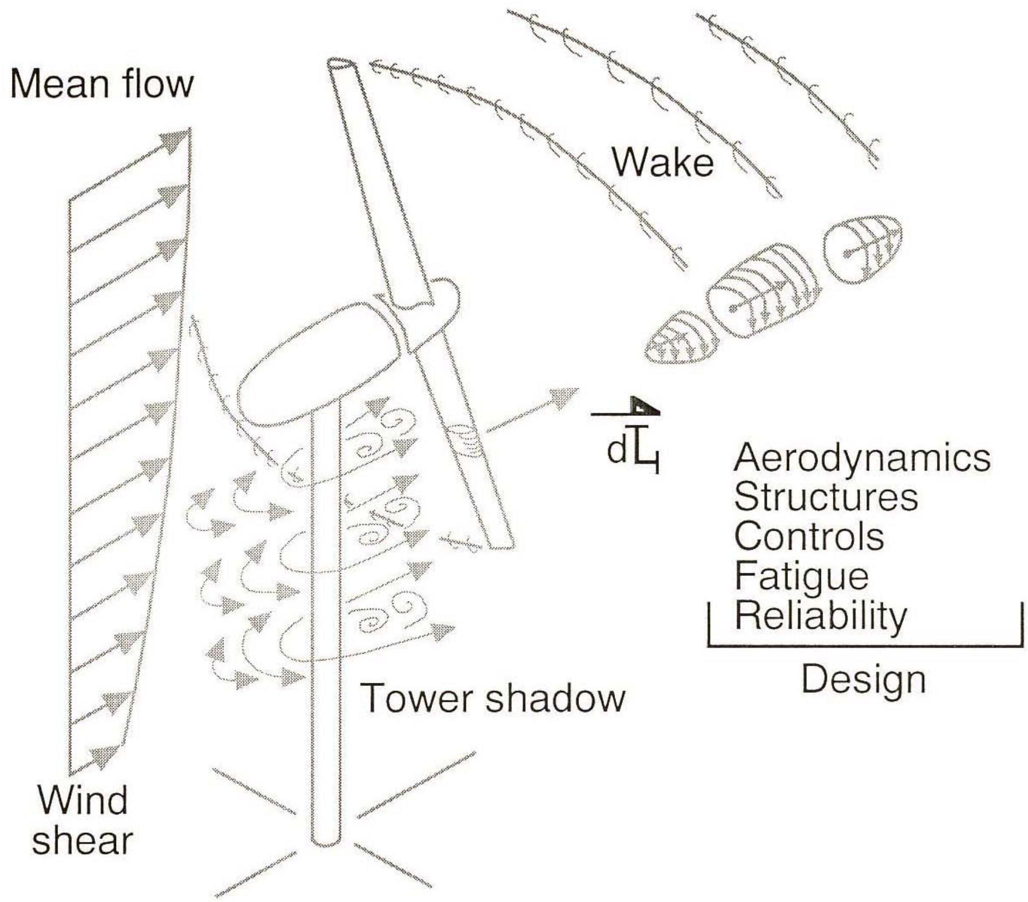
Development strategy

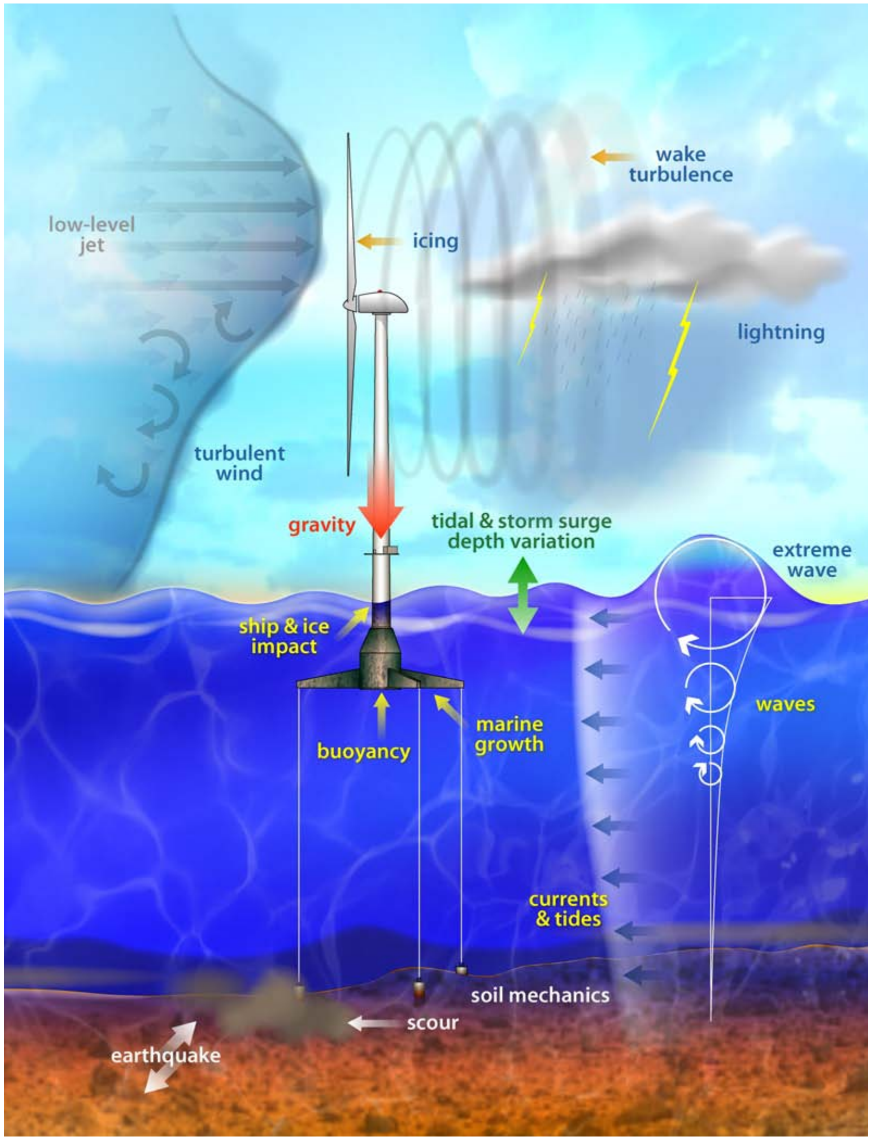
Summary of work to date
- HydroTurbSim (turbulence)
- MAP (mooring)
- HydroFAST (hydro-servo-elastic)

Path forward


Aquantis

What physical phenomena determine the performance and loads on hydrokinetic turbines?





Predicting performance, dynamic stability, and loads requires multi-physics simulations

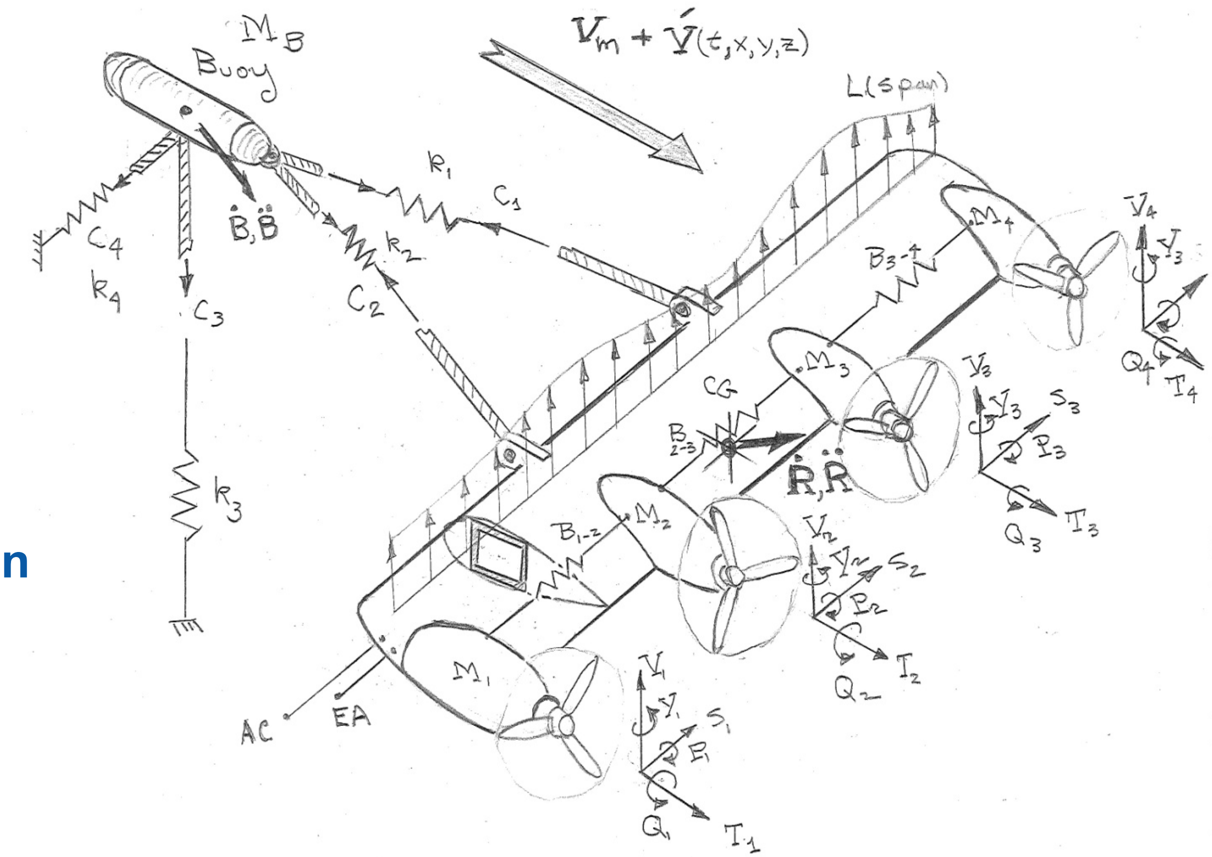
Modeling requirements

Device
- Rotor performance
- Loads and dynamics
- Waves and turbulence
- Control System

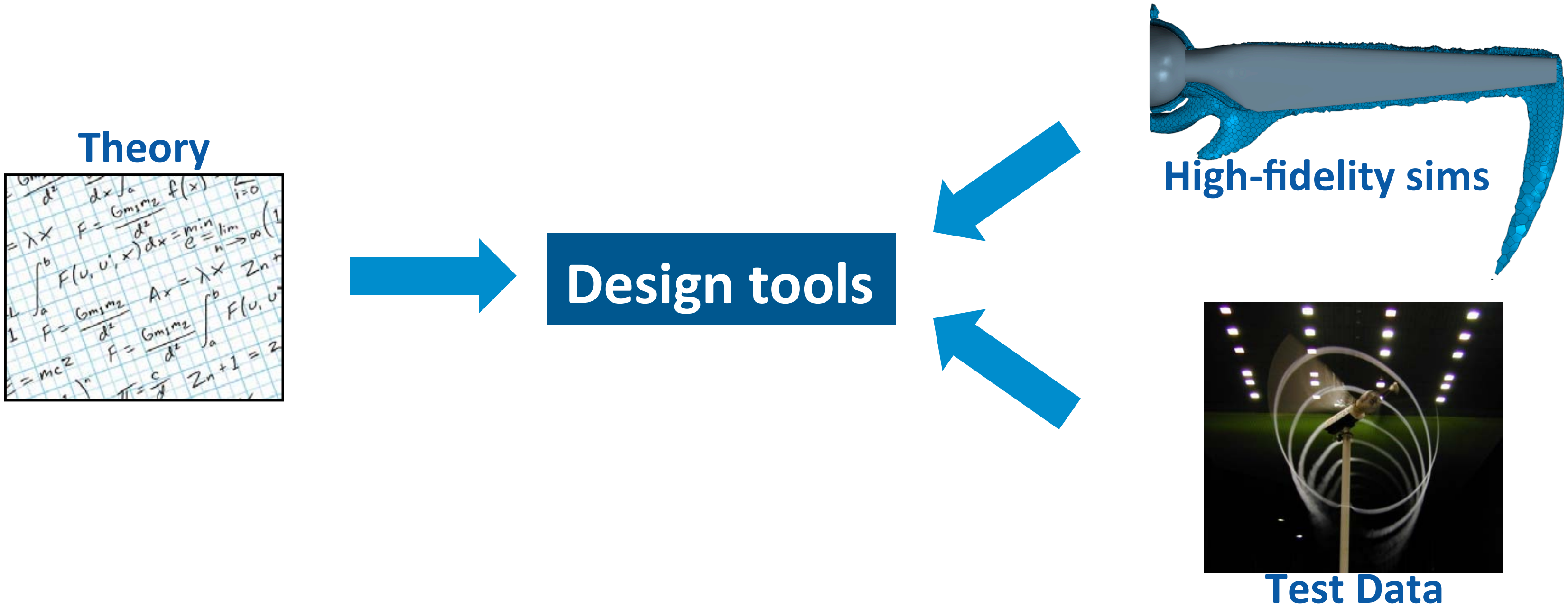
Mooring and anchor system
- Loads and dynamics
- Seabed interactions

Other important consideration
- Extreme events
- Off-design conditions
- Array effects

4 MW ocean current turbine concept



Objective: Develop an open-source suite of design tools that can be used to simulate and analyze hydrokinetic turbines



- Numerical tools derived from fundamental laws of physics with appropriate simplifications and assumptions → can be run on **standard PCs**
- Accuracy is only as good as inputs used for calibration
- Results used as inputs for high-fidelity design simulations (e.g. FEA and CFD)
- Open-source code will encourage customization and community contributions

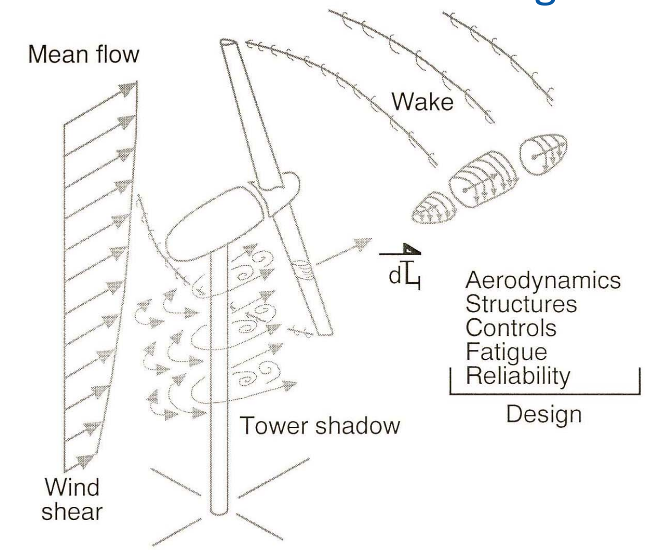
A two phase code development strategy is being used

Phase 1

- Adapt NREL's existing wind turbine modeling code, FAST, by incorporating added mass and buoyancy effects in the rotor model
- Develop a marine turbulence simulation tool (**HydroTrubSim**)
- Improve mooring simulation capabilities (**MAP**)
- Check the validity of the general-dynamic-wake

- Result: **HydroFAST**, a tool that can **ONLY** simulate turbines that resemble "standard" wind turbines

Traditional turbine design

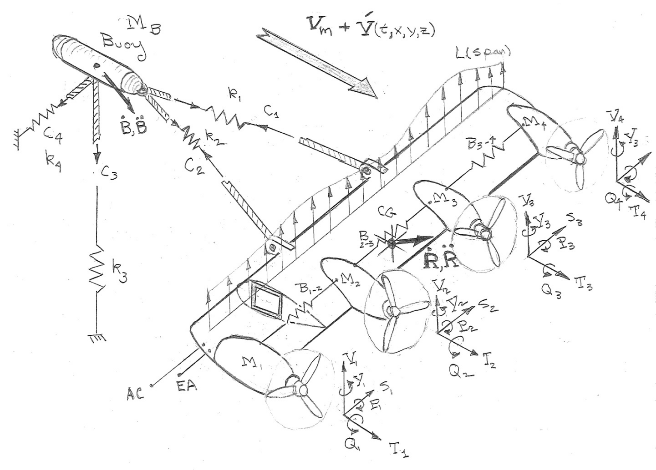


Phase 2 (future work as funding allows)

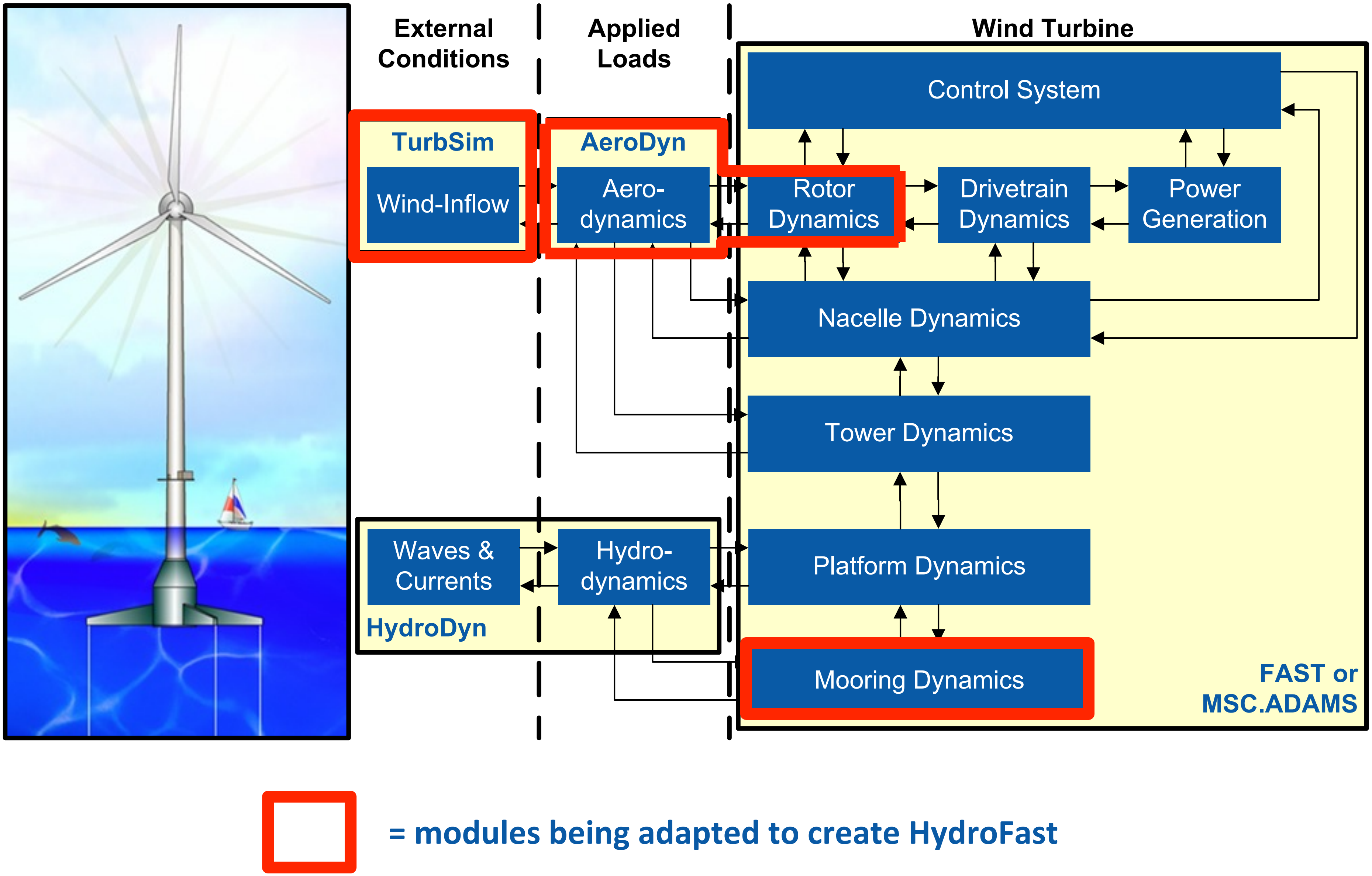
- Couple existing rotor, mooring, and turbulence models with a multi-body dynamics and structural simulation code (e.g. SimMechanics or ADAMS)

- Result: A robust tool that can simulate most hydrokinetic turbine designs

Arbitrary turbine design



The structure of the FAST wind turbine simulation code

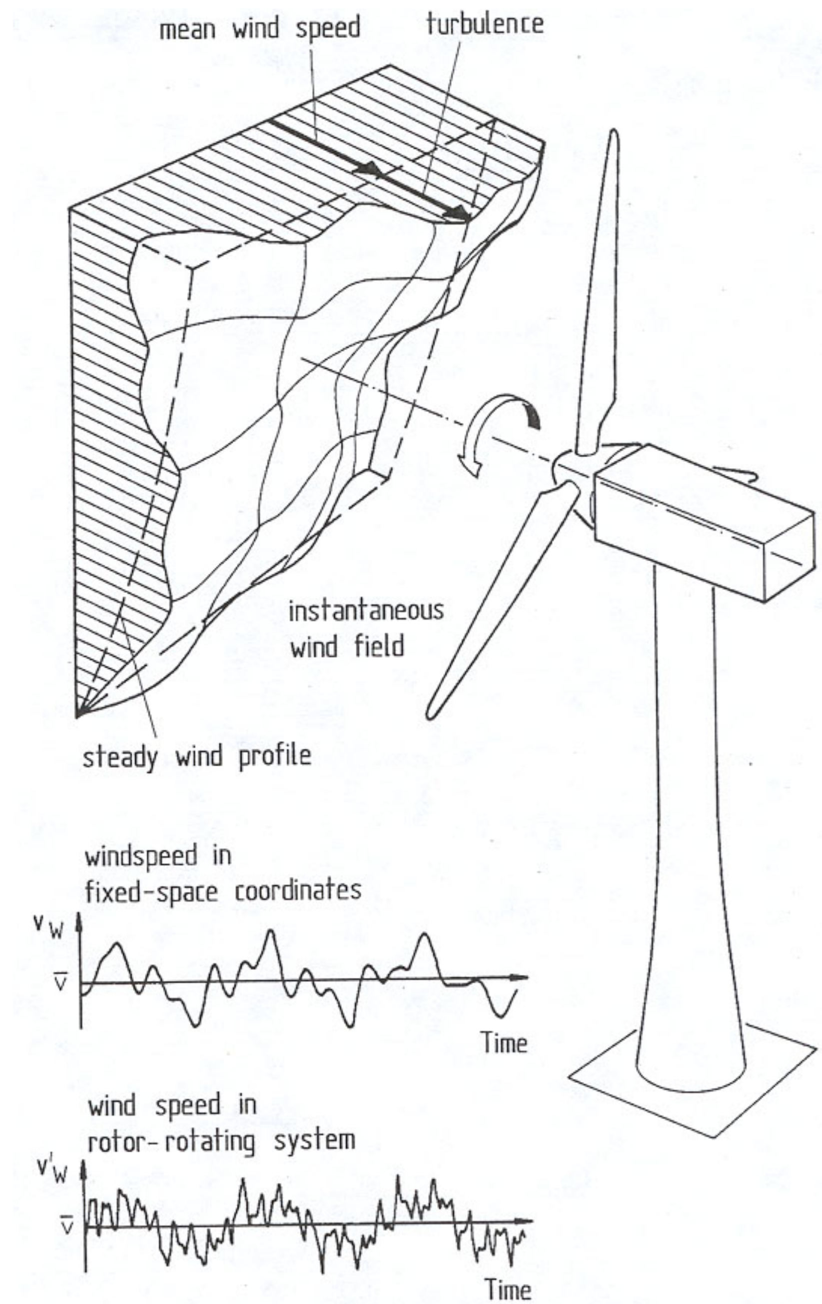


Turbulence significantly affects the performance of hydrokinetic turbines

Spinning rotor interacts with the turbulence inflow resulting in complex loading conditions → drives extreme and fatigue loads

Estimates of 3D turbulence fields are needed to inform simulation tools

HydroTurbSim

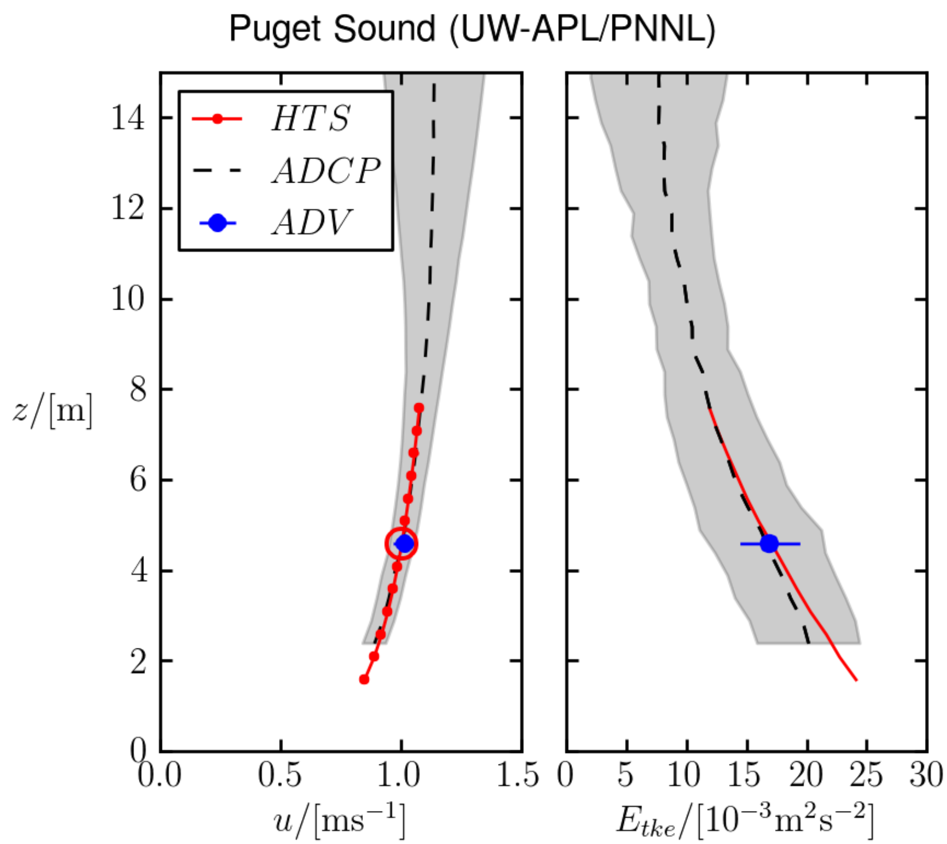


HydroTurbSim uses measured turbulence spectra to reconstruct time-domain turbulence fields

ADV and ADCP measurements were made in the East River and the Puget Sound

Data was parameterized using spectral analysis → used as inputs for HydroTurbSim

Alpha version of TurbSim produces results that agree with experimental measurements



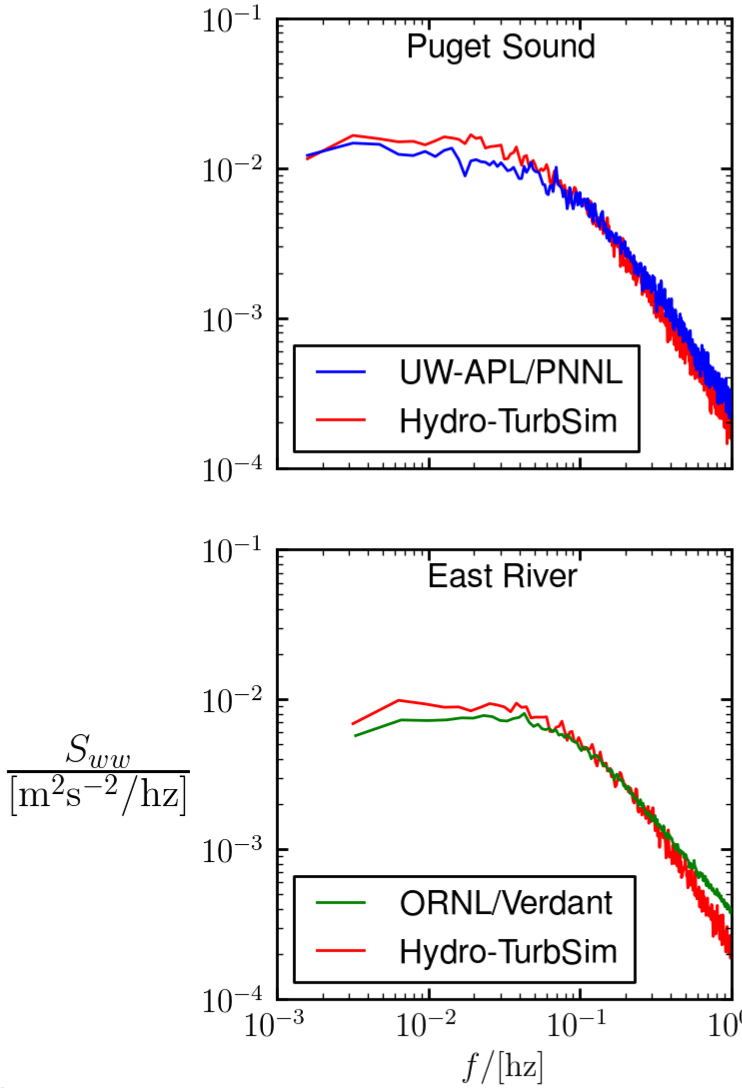
Gunawan, B., Neary, V.S. and McNutt, J.R. (2011) ORNL ADV post-processing guide and MATLAB algorithms for MHK site flow and turbulence analysis. ORNL/TML-2011/338.

Simulated power spectra also agree with field measurements

Measurements at more deployment sites are needed to improve the code

Alpha version of HydroTrubSim code and documentation will be released in September 2012

Contact Levi Kilcher for a pre-release version of the code – Levi.Kilcher@nrel.gov

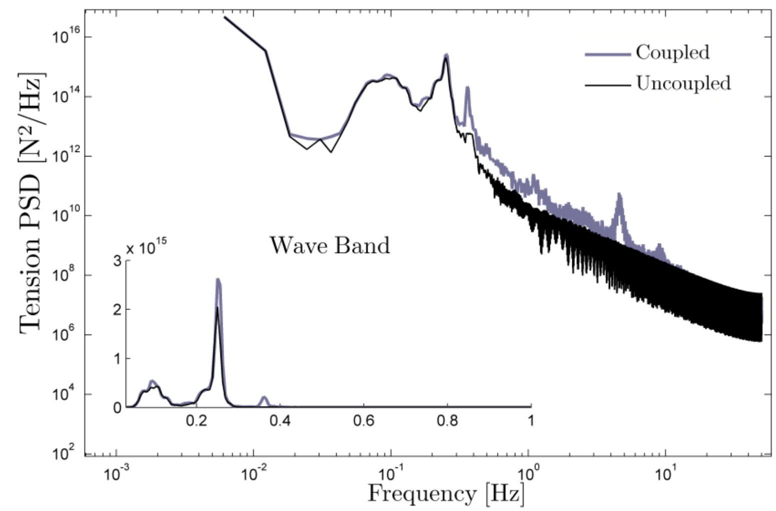


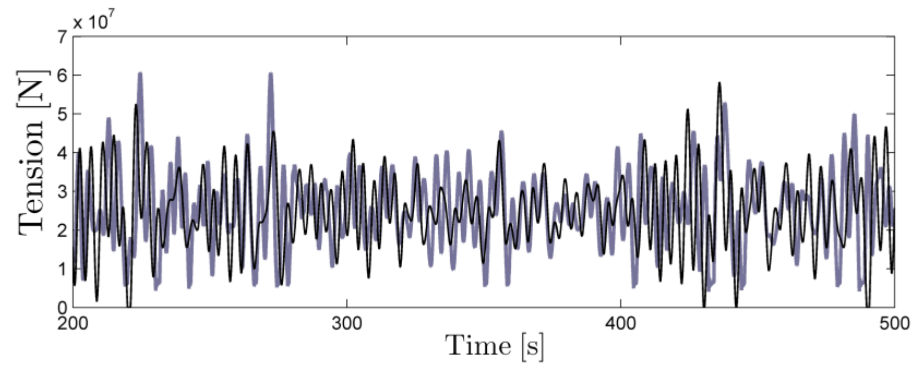
Dynamic interactions between the device and mooring system can significantly affect performance

NREL is developing a finite element mooring system simulation tool (**MAP**) in conjunction with the offshore wind program

MAP will model:

- Cable drag
- Internal damping and mooring inertia
- Snap loads the longitudinal vibrations
- Bending moments
- Fatigue

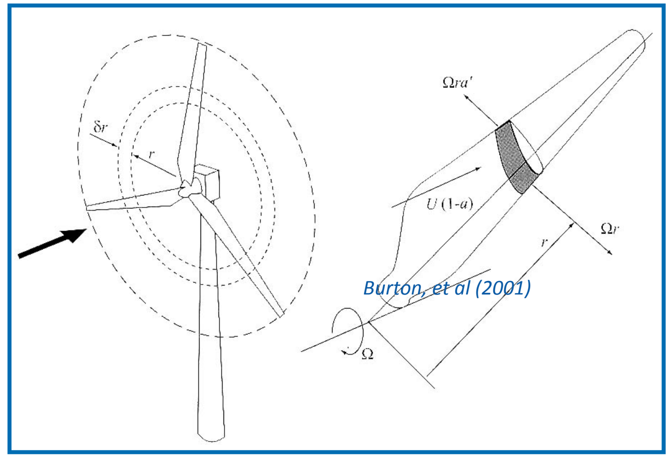




Added mass and buoyancy effects will be incorporated into FAST's rotor analysis module

Current capabilities:

- Based on blade element theory
- Momentum & dynamic (GDW) wake
- Beddoes-Leishman dynamic stall model
- Turbulent inflow generated by TurbSim



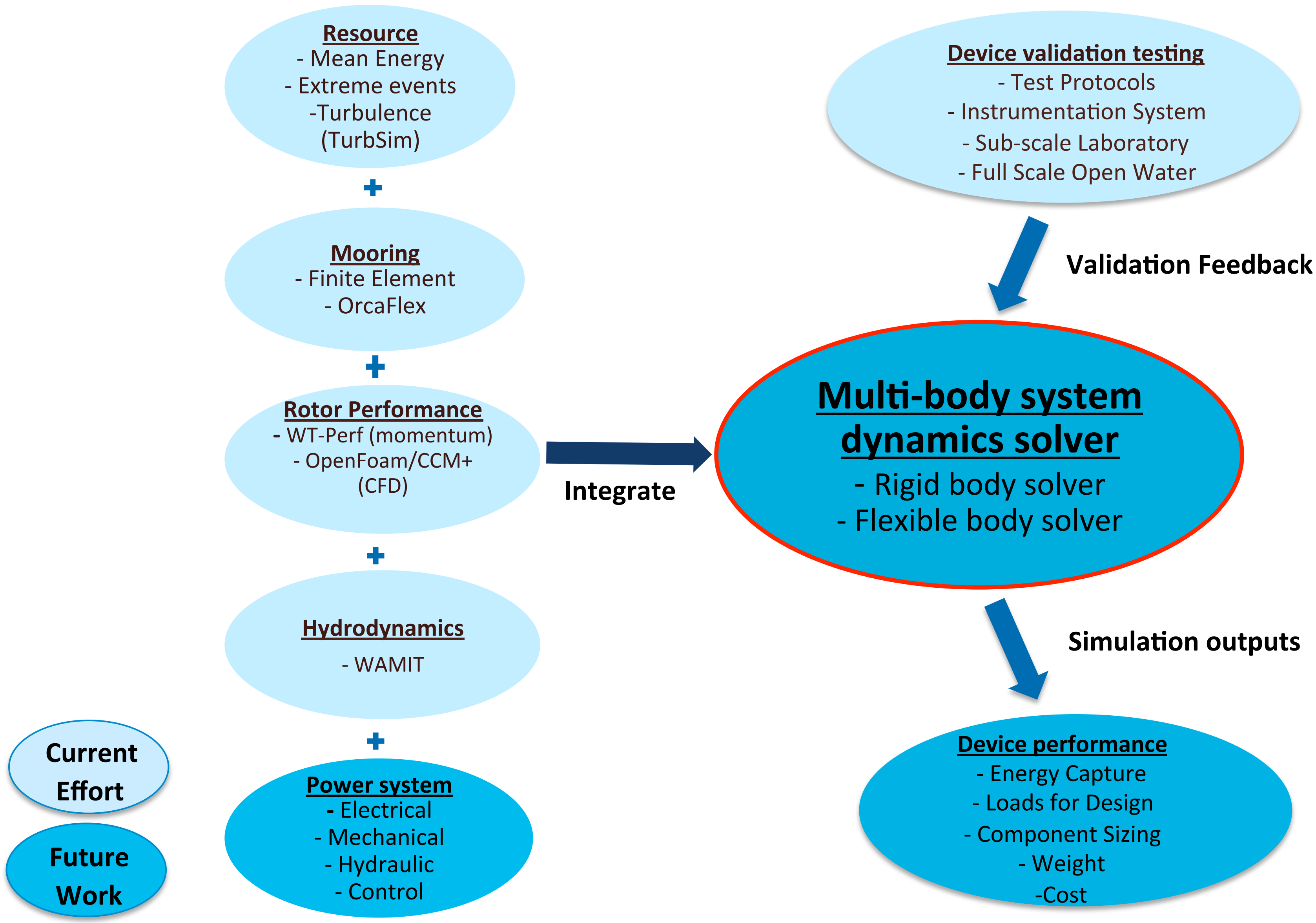
Added mass effects:

- Caused by acceleration and deceleration of blades
- Effectively lowers the natural frequency of the blades
- Blade mass matrix must be modified

Buoyancy effects:

- Buoyancy forces acting on the blades change as the rotor rotates
- Forces are significant due to the large density of water
- May affect fatigue loads

Phase 2: Developing a numerical tool that can simulate hydrokinetic turbines with arbitrary structural designs



Conclusions and future work

NREL's most popular wind turbine design and analysis code, FAST, is being modified so that it has the capability to simulate hydrokinetic turbines

HydroFAST will be capable of simulating hydrokinetic turbines with "standard" designs

An alpha version of HydroFAST will be released in 2013

We will investigating the possibility of coupling existing rotor dynamics codes with a multi-body dynamics code to provide the ability to simulate arbitrary device designs