NREL
NATIONAL RENEWABLE ENERGY LABORATORY

CAE Tool Overview

NREL Wind Turbine Modeling Workshop

March 2, 2012

NREL – Golden, CO

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NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Outline

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- Users & Support:
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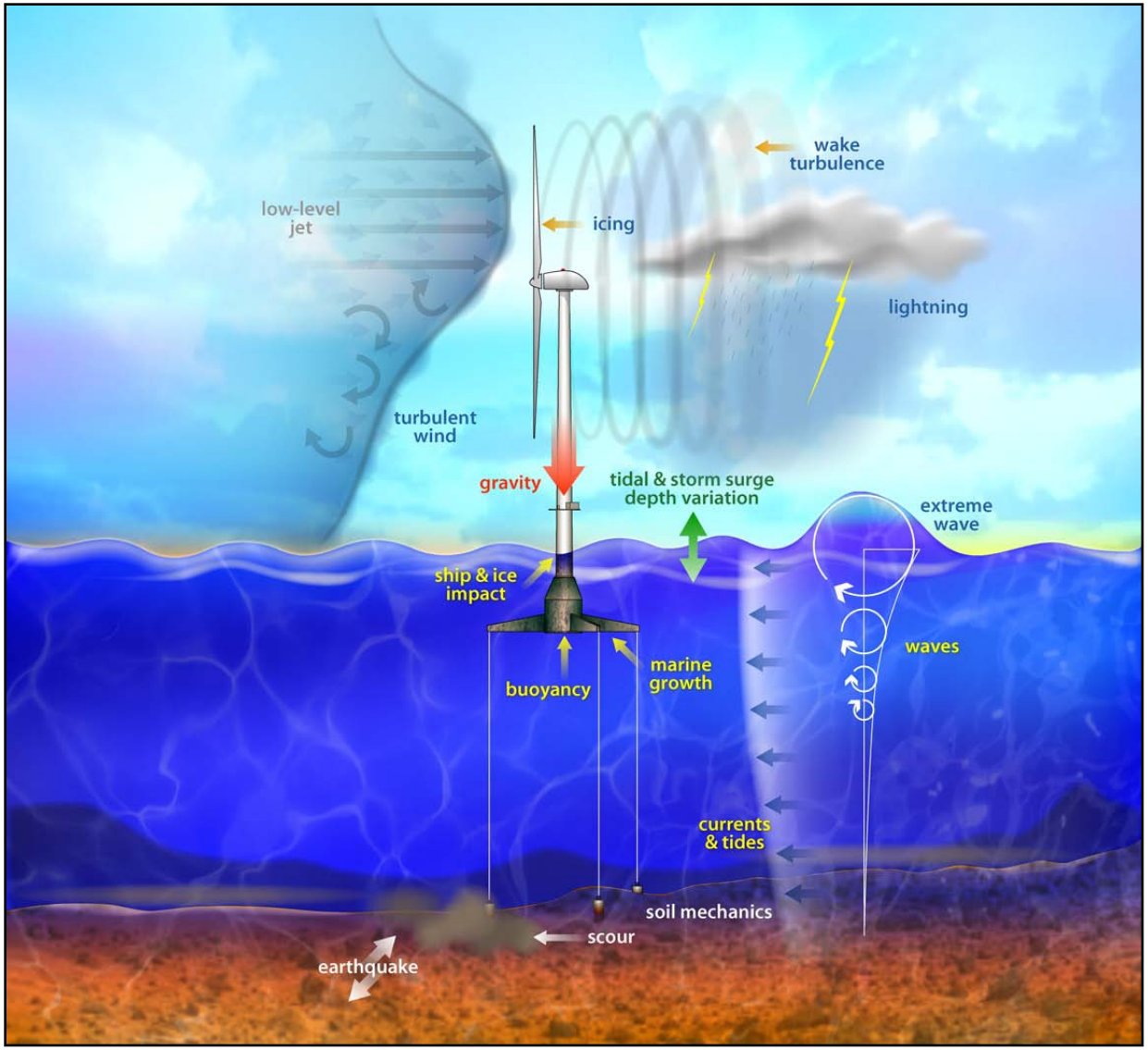
Introduction & Background

Modeling Requirements

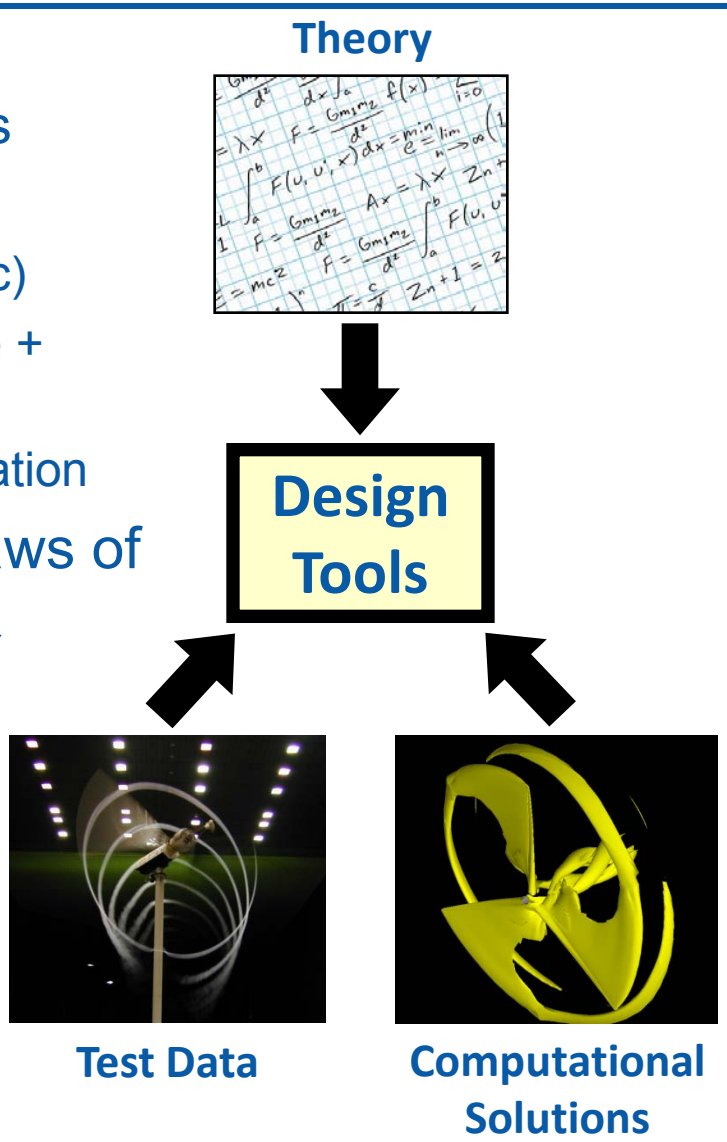


- Coupled aero-hydro-servo-elastic interaction
- Wind-inflow:
  - –Discrete events
  - –Turbulence
- Waves:
  - –Regular
  - –Irregular
- Aerodynamics:
  - –Induction
  - –Rotational augmentation
  - –Skewed wake
  - –Dynamic stall
- Hydrodynamics:
  - –Diffraction
  - –Radiation
  - –Hydrostatics
- Structural dynamics:
  - –Gravity / inertia
  - –Elasticity
  - –Foundations / moorings
- Control system:
  - –Yaw, torque, pitch

Introduction & Background

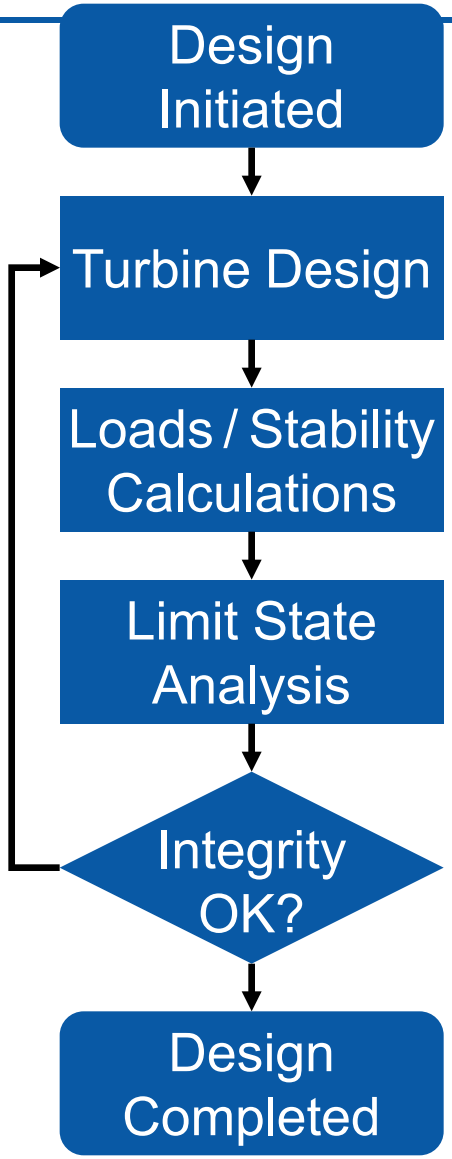
What Kind of Tools Are We Talking About?

- Tools applied in the design process
- Preprocessors, simulators, & post-processors
- The primary (simulation) tools are:
  - Multi-physics models (aero-hydro-servo-elastic)
  - Full system models (foundation + substructure + tower + nacelle + drivetrain + rotor)
  - Developed uniquely to the wind turbine application
- Tools derived from theory/fundamental laws of physics with appropriate simplifications & assumptions
  - Supplemented with computational solutions & test data
- Tools developed to run on standard PCs (not supercomputers)
- Tools whose accuracy is only as good as their inputs (often need "calibrating")



Introduction & Background

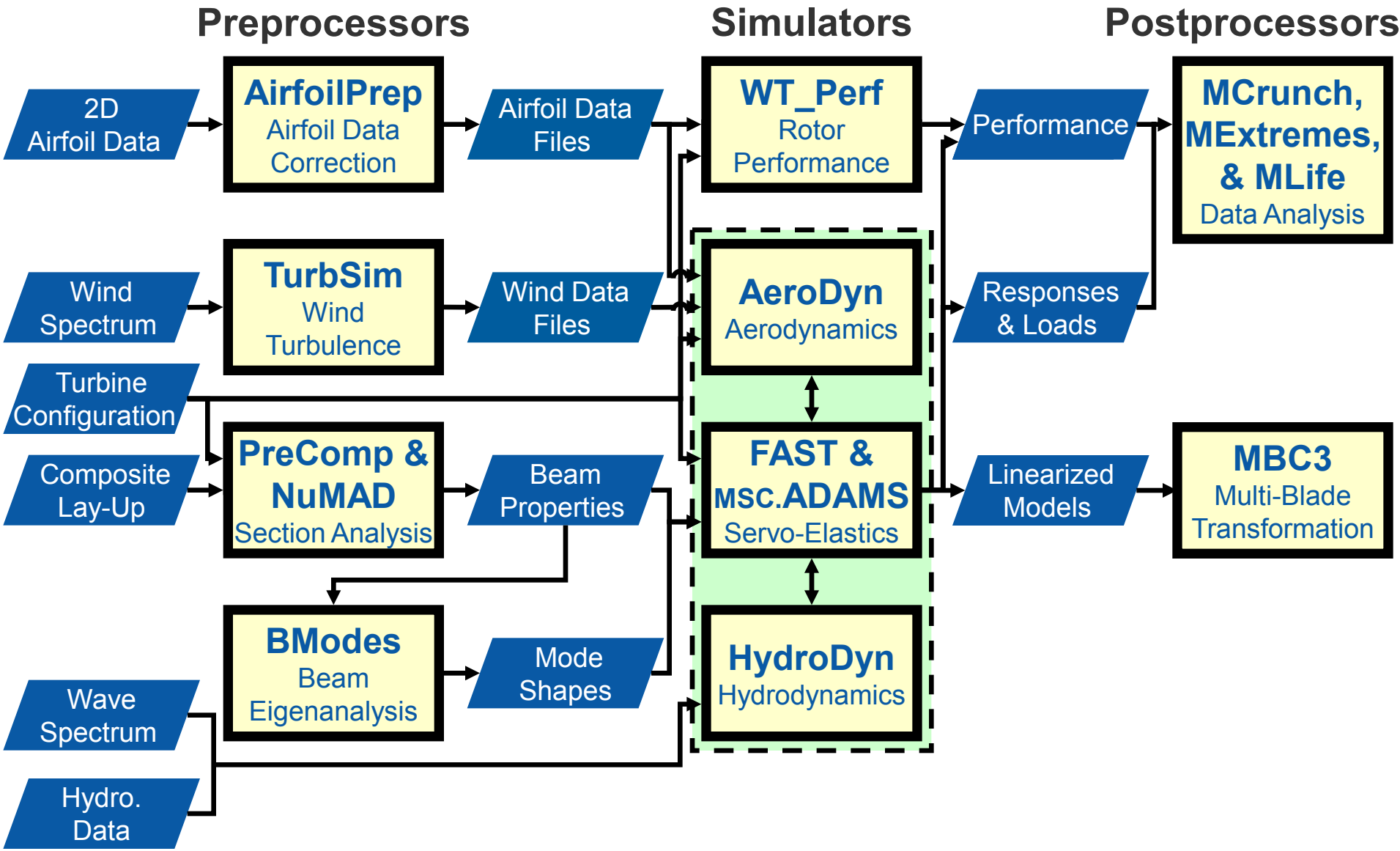
Wind Turbine Design Process



- A design is derived from a design basis, consisting of:
  - Design objectives
  - Environmental conditions
  - Analysis methods
  - Design standards
- Coupled aero-hydro-servo-elastic models of the full system are used to calculate loads / stability
- The loads are used within component models (e.g., FEA) to perform limit state analysis
- The design is iterated until structural integrity is achieved
- Structural integrity achieved when:
  Design Load ≤ Design Resistance

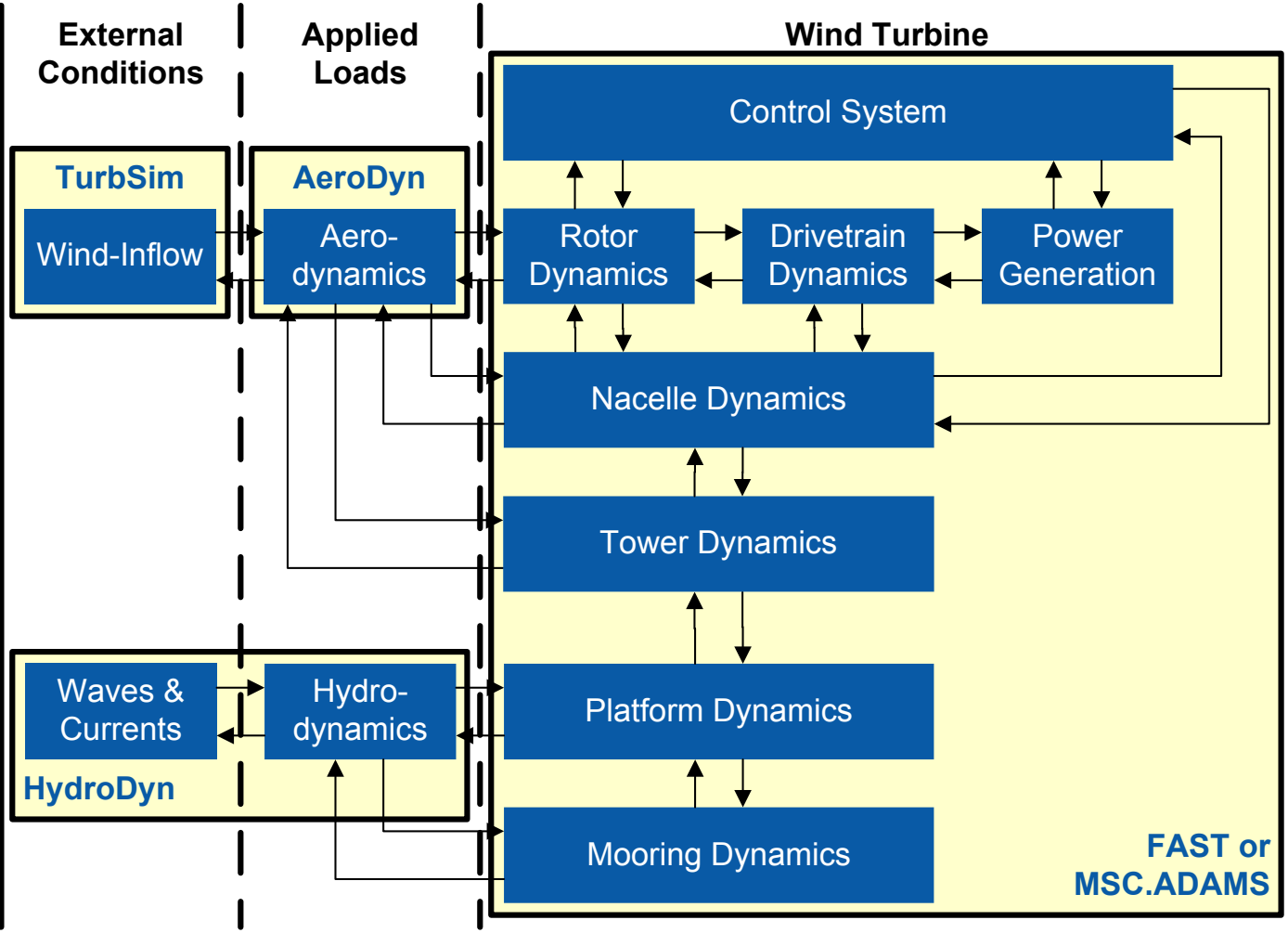
CAE Tools

Key NREL Tools in the Design Process



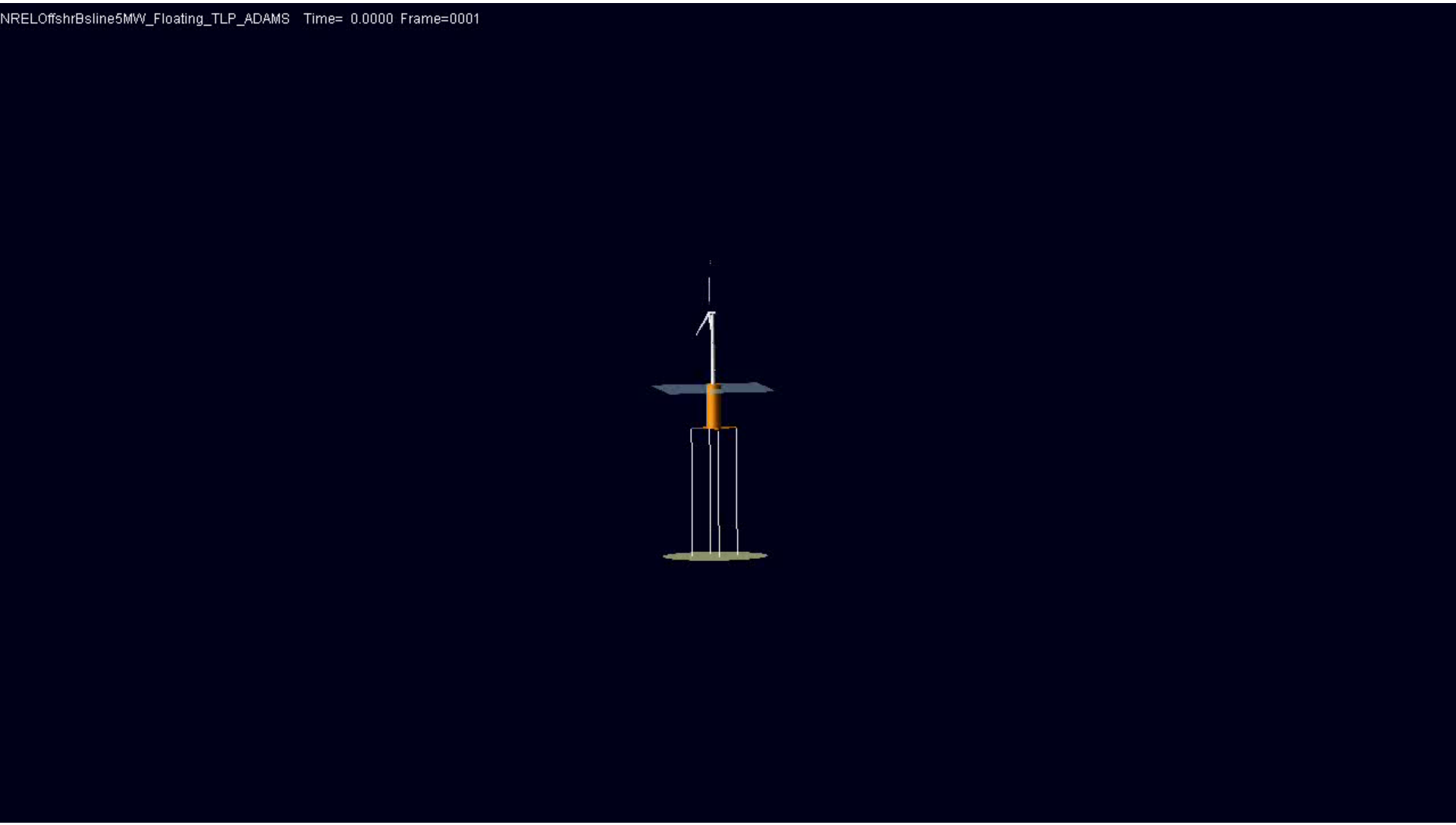
CAE Tools

FAST-AeroDyn-HydroDyn Coupling



CAE Tools

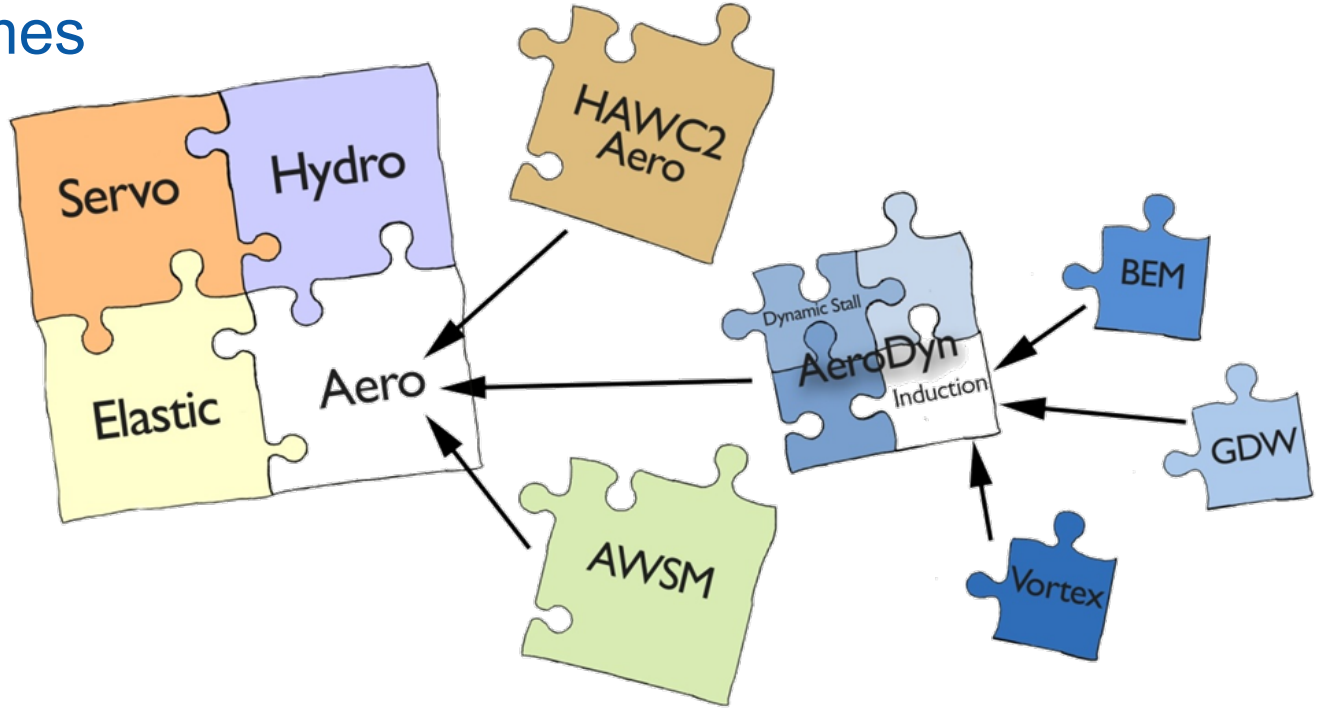
Sample MIT/NREL TLP Response



CAE Tools

Main Focus: Modularization & Coupled Simulation

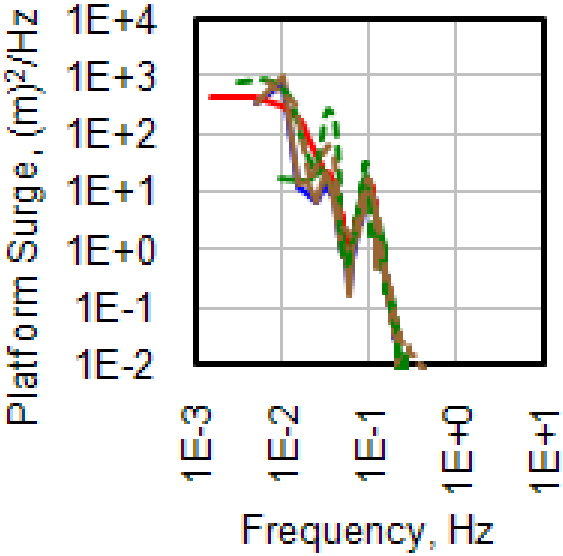
- Motivation – Increasing complexity requires coupled analysis
- Benefits – Enables shared code development, increases maintainability, improves numerics, & eases integration of science advances
- Challenges – Establishing standardized interfaces & coupling schemes



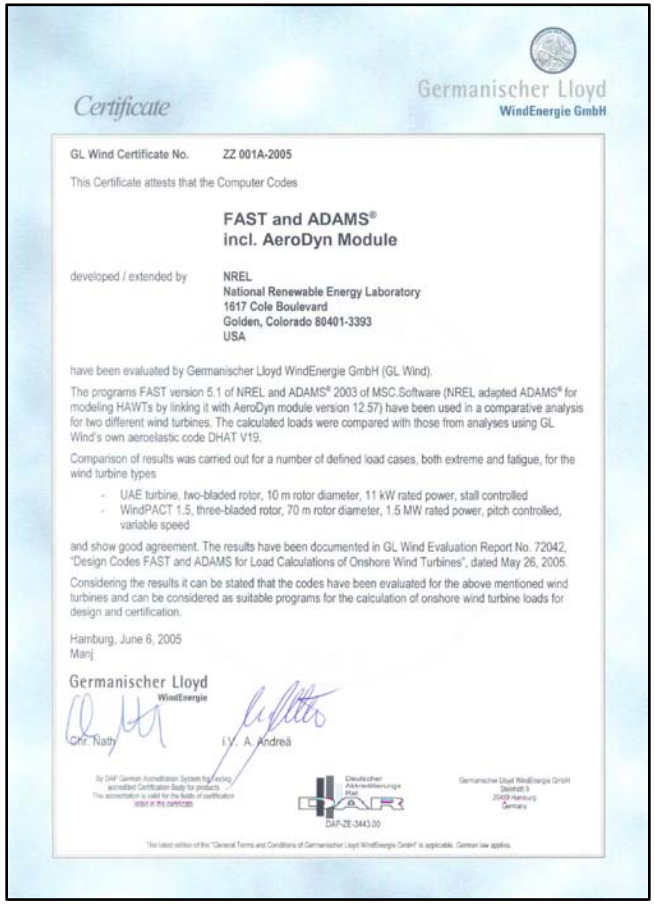
CAE Tools

Model Verification (Code-to-Code)

- Ongoing comparisons of **FAST** to **MSC.ADAMS**
- Evaluated by GL against **GH Bladed**
- VEWTDC
- IEA Wind Task 23 OC3 & Task 30 OC4 projects
- Many one-on-one collaborations (e.g.):
  - GL GH
  - ECN
  - DTU Wind



OC3 Full-System Test



Certificate

Germanischer Lloyd
WindEnergie GmbH

GL Wind Certificate No. ZZ 001A-2005

This Certificate attests that the Computer Codes

FAST and ADAMS®
incl. AeroDyn Module

developed / extended by **NREL**
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401-3393
USA

have been evaluated by Germanischer Lloyd WindEnergie GmbH (GL Wind).

The programs FAST version 5.1 of NREL and ADAMS® 2003 of MSC.Software (NREL adapted ADAMS® for modeling HAWTs by linking it with AeroDyn module version 12.57) have been used in a comparative analysis for two different wind turbines. The calculated loads were compared with those from analyses using GL Wind's own aeroelastic code DHAT V19.

Comparison of results was carried out for a number of defined load cases, both extreme and fatigue, for the wind turbine types

- UAE turbine, two-bladed rotor, 10 m rotor diameter, 11 kW rated power, stall controlled
- WindPACT 1.5, three-bladed rotor, 70 m rotor diameter, 1.5 MW rated power, pitch controlled, variable speed

and show good agreement. The results have been documented in GL Wind Evaluation Report No. 72042, "Design Codes FAST and ADAMS for Load Calculations of Onshore Wind Turbines", dated May 26, 2005.

Considering the results it can be stated that the codes have been evaluated for the above mentioned wind turbines and can be considered as suitable programs for the calculation of onshore wind turbine loads for design and certification.

Hamburg, June 6, 2005
Manj

Germanischer Lloyd
WindEnergie

Chr. Nath i.V. A. Andreä

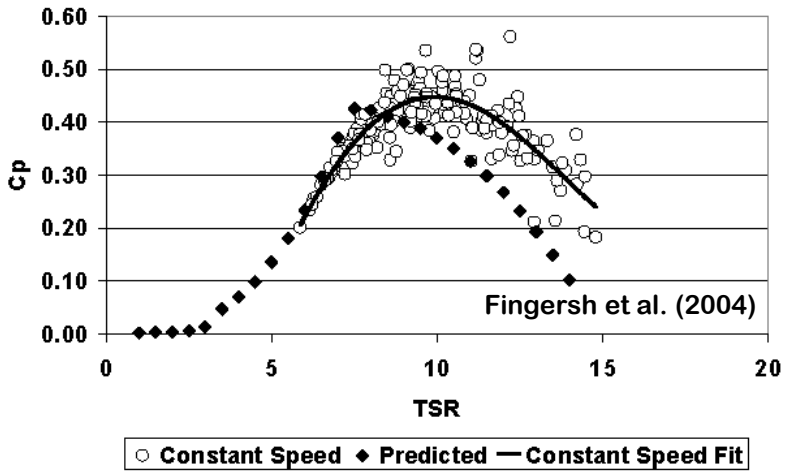
DAP-ZE-3443.00

GL Certificate Approving ***FAST*** *&* ***ADAMS*** *with* ***AeroDyn***

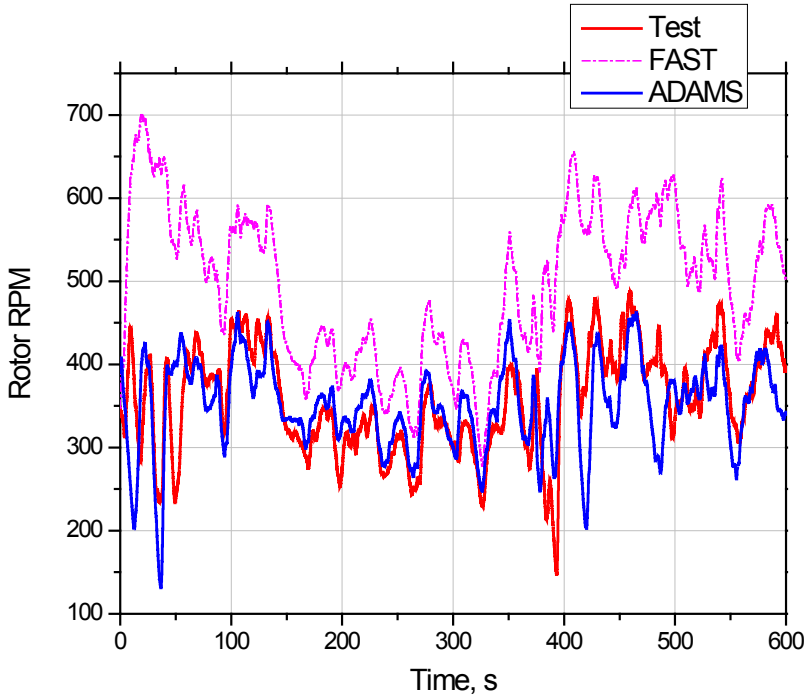
CAE Tools

Model Validation (Code-to-Data)

- UAE Phase VI
- SWRT
- CART2 & CART3
- Many industry wind turbines (confidential)
- Floating validation in progress



*Comparison of Uncalibrated **WT_Perf** Prediction to CART2 Data*

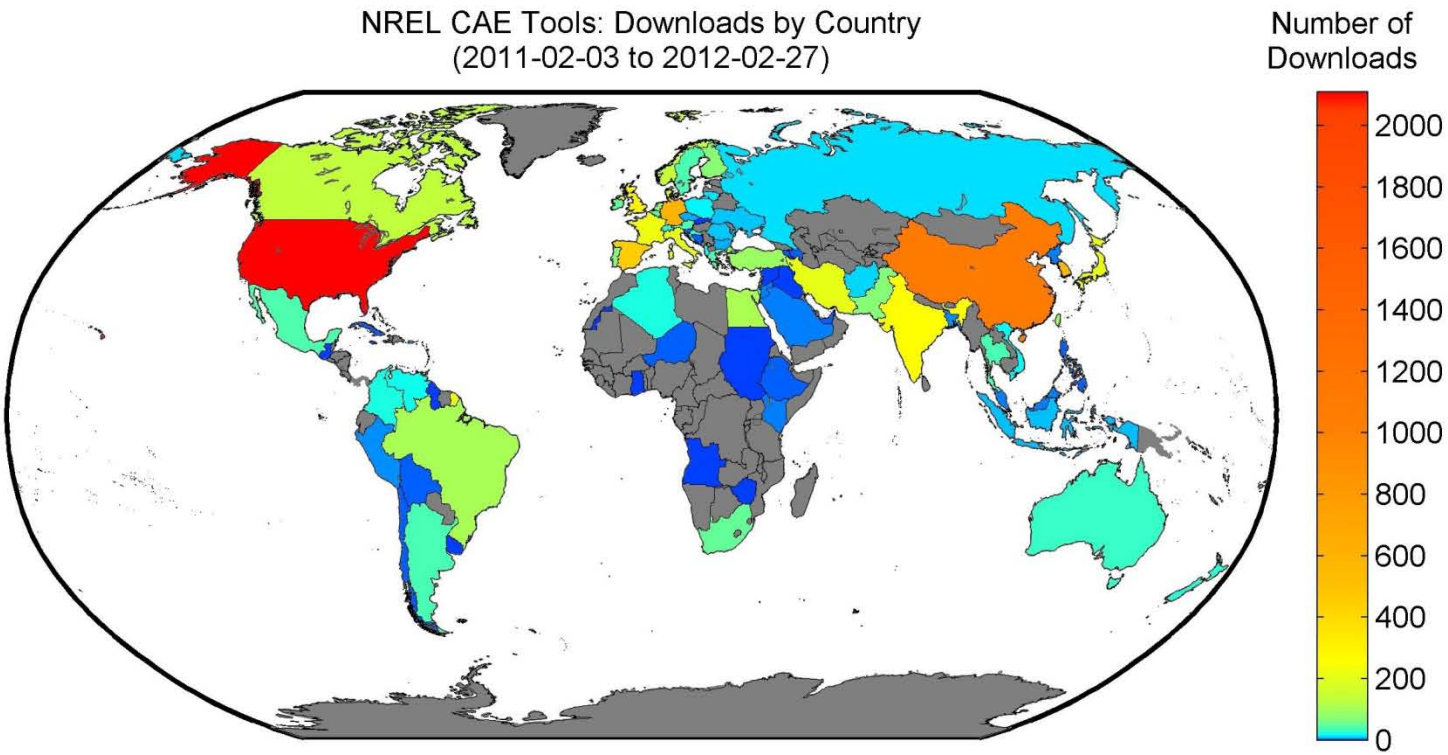


*SWRT in high winds – **ADAMS** has Blade Torsion, **FAST** doesn't*

Users & Support

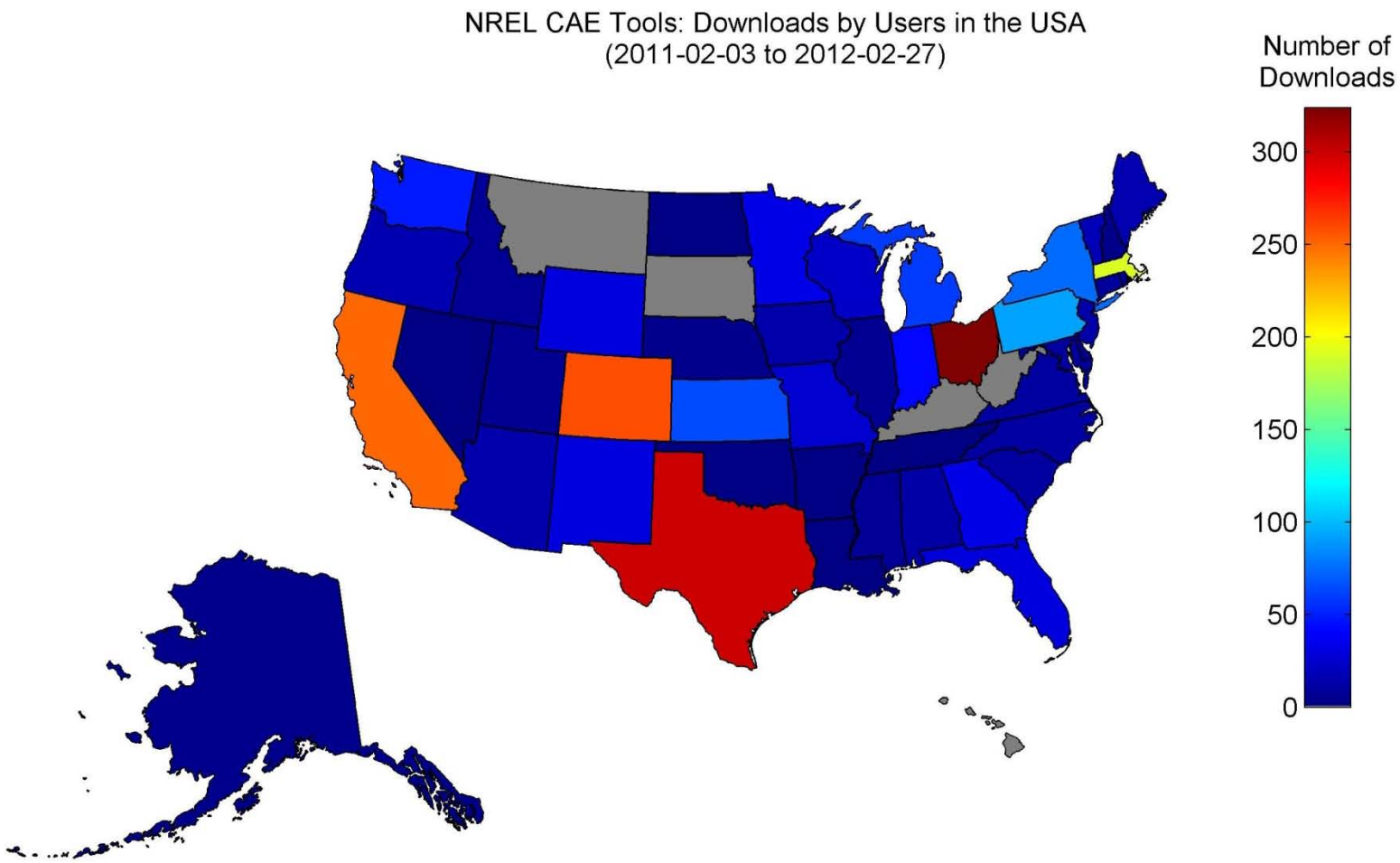
Users of NREL-Developed Tools

- Used worldwide by wind turbine manufacturers, consultants, certifiers, researchers, & educators
- Since 2/3/2011, there have been 8914 unique downloads by 2991 users from 1029 organizations in 94 countries



Users & Support

Users of NREL-Developed Tools (cont)



Users & Support

Successful Applications (Only Subset Shown)

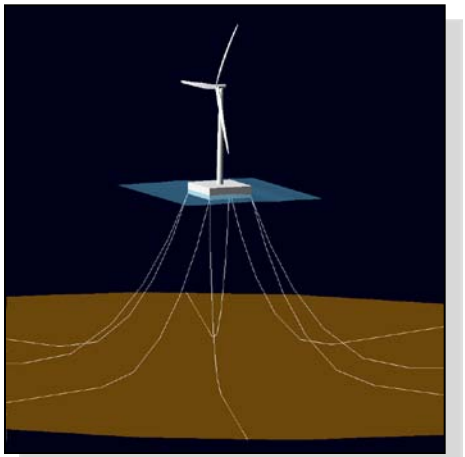
Southwest Windpower Skystream

CART2

Clipper 2.5-MW Liberty

NorthWind 100

GE 1.5 MW



NREL 5-MW Turbine on ITI Energy Barge

Users & Support

NWTC Design Codes Website

NWTC Design Codes (Simulators) - Windows Internet Explorer

http://wind.nrel.gov/designcodes/simulators/

Live Search

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NWTC National Wind Technology Center

NWTC Design Codes

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Other Links

Simulation Software

ADAMS2AD (v13.00.00a-bjj, 31-March-2010)

ADAMS2AD is a set of routines used to interface MSC.ADAMS® and AeroDyn.

AeroDyn (v13.00.00a-bjj, 31-March-2010)

AeroDyn is an aerodynamics software library for use by designers of horizontal-axis wind turbines. It is written to be interfaced with structural-dynamics simulators (MSC.ADAMS® and FAST).

BladeFS (v1.00.00a-mjd, 24-May-2010)

BladeFS (Blade Fatigue Static) is a MATLAB® script that was developed to determine loads and deflections associated with fatigue and static structural testing of wind turbine blades.

FAST (v7.00.01a-bjj, 5-November-2010; using AeroDyn v13.00.00a-bjj)

FAST is a medium-complexity code for nonlinear aero-servo-elastic analysis of horizontal-axis wind turbines. It can also extract linear state-space models for controls design and can be used to to generate MSC.ADAMS® models.

HARP_Opt (v2.00.00, 13-July-2010)

HARP_Opt (**H**orizontal **A**xis **R**otor **P**erformance **Opt**imization) is a MATLAB® script that utilizes a multiple-objective genetic algorithm and blade-element momentum (BEM) theory flow model

Users & Support

NWTC Forum

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https://wind.nrel.gov/forum/wind/index.php

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[Moderator Control Panel]

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WIND EXTERNAL	TOPICS	POSTS	LAST POST
Access Requests (READ THIS FIRST BEFORE CREATING AN ACCOUNT) Information on accessing our forums.	1	1	by Marshall.Buhl Mon Feb 25, 2008 11:58 am
General Topics of general, but wind-related interest.	11	32	by Ekaitz.Zulueta Wed Oct 27, 2010 2:25 am
Airfoils Discuss acquisition, use, and manipulation of airfoil data.	11	47	by Danny.Sale Thu Dec 02, 2010 12:00 pm
U.S. Standards AWEA Road-Mapping U.S. Standards to International Standards	4	76	by Arielle.Wolfe Wed Oct 20, 2010 1:33 pm
Design Codes Provide feedback, request enhancements, and get help with wind-turbine design codes.	207	959	by Jason.Jonkman Thu Feb 24, 2011 9:20 am
AeroDyn Development This forum is dedicated to discussions of the redevelopment of AeroDyn.	7	23	by Jason.Jonkman Tue Feb 08, 2011 12:02 pm

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Questions?

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