NREL
NATIONAL RENEWABLE ENERGY LABORATORY

CAE Tool Overview

NREL Wind Turbine Modeling Workshop

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Bergen, Norway

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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.

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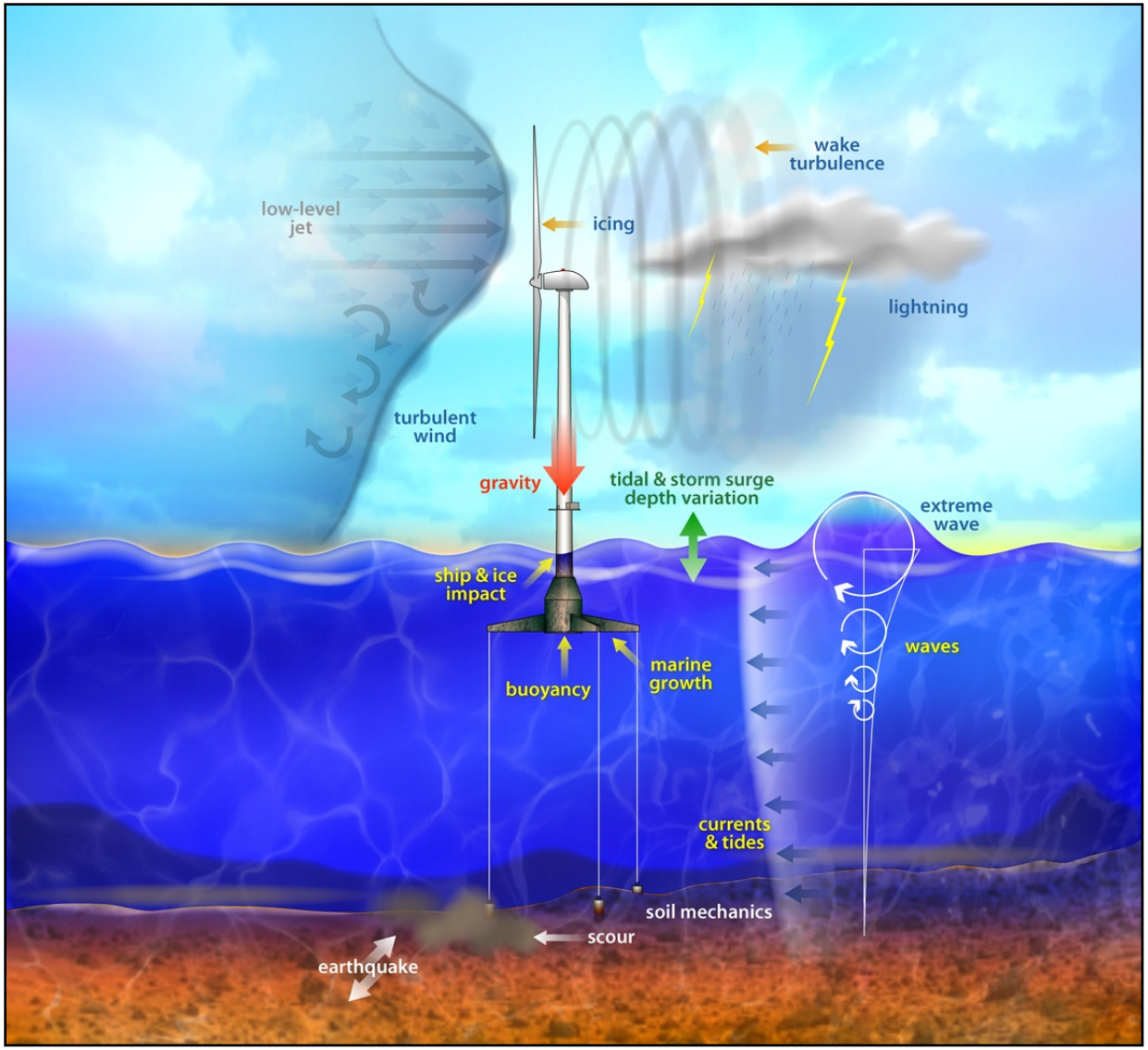
Introduction & Background

Modeling Requirements

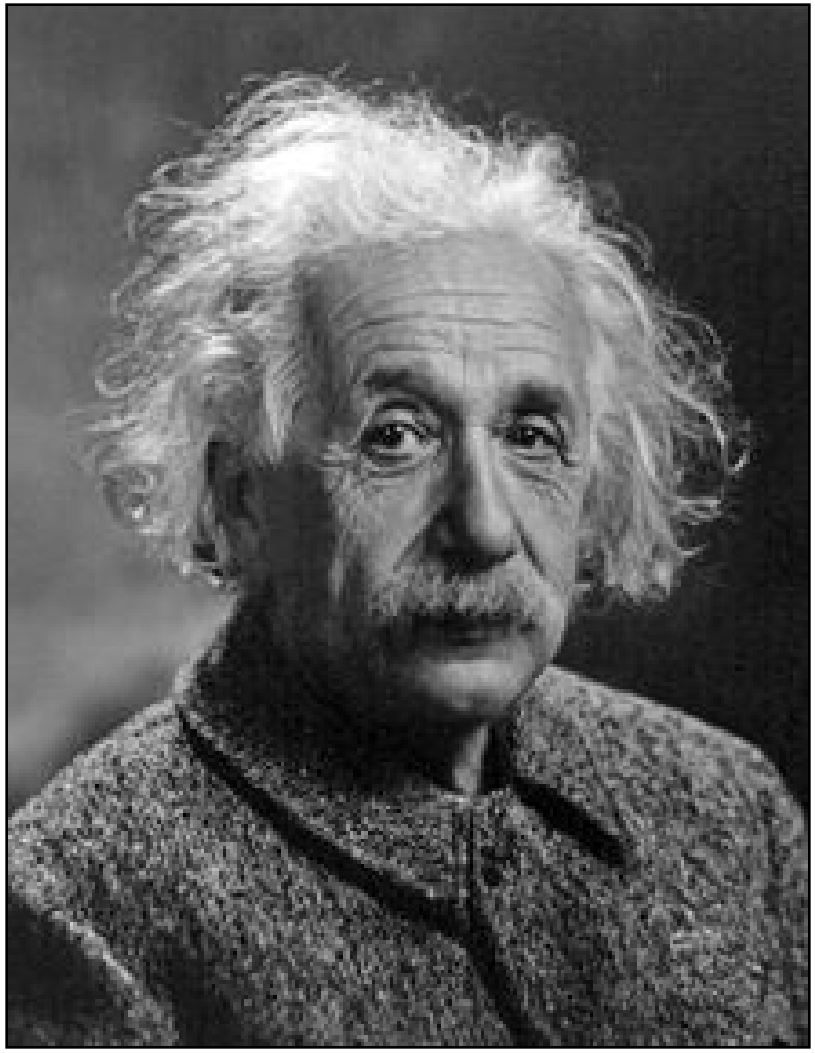


- Coupled aero-hydro-servo-elastic interaction
- Wind-inflow:
  - –Discrete events
  - –Turbulence
- Waves:
  - –Regular
  - –Irregular
- Aerodynamics:
  - –Induction
  - –Rotational augmentation
  - –Skewed wake
  - –Dynamic stall
- Hydrodynamics:
  - –Diffraction
  - –Radiation
  - –Hydrostatics
-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

Introduction & Background

Einstein Principle

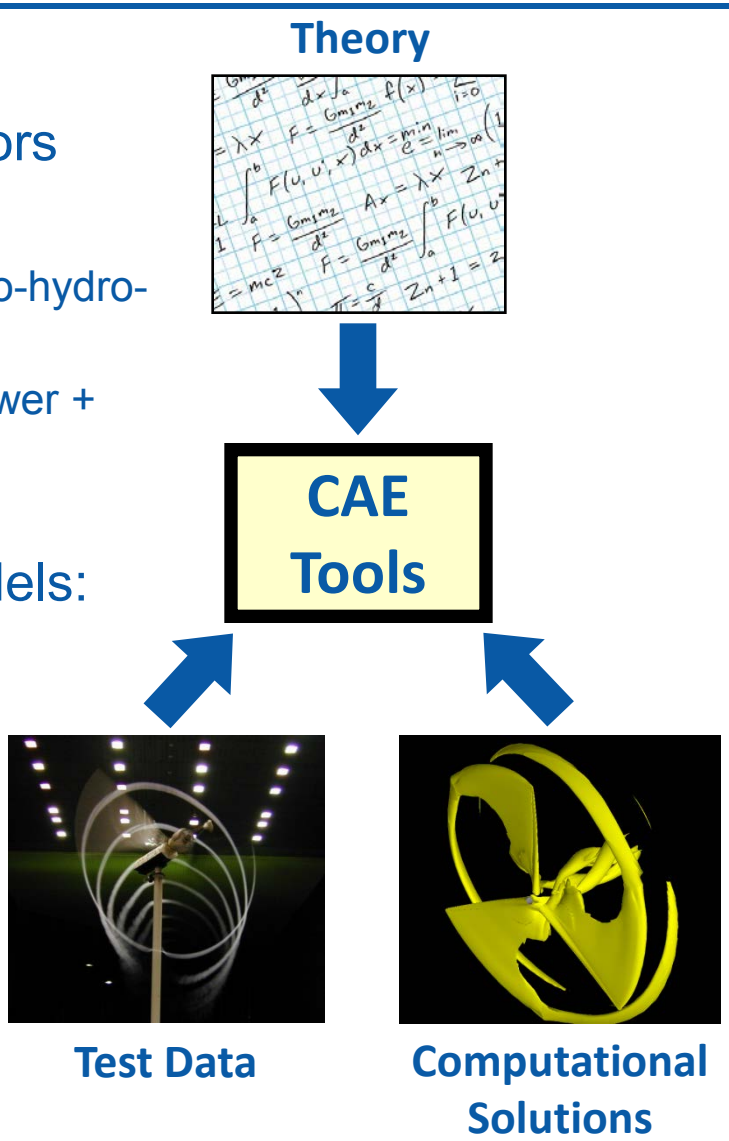
"A model should be as simple as possible, but no simpler."



Introduction & Background

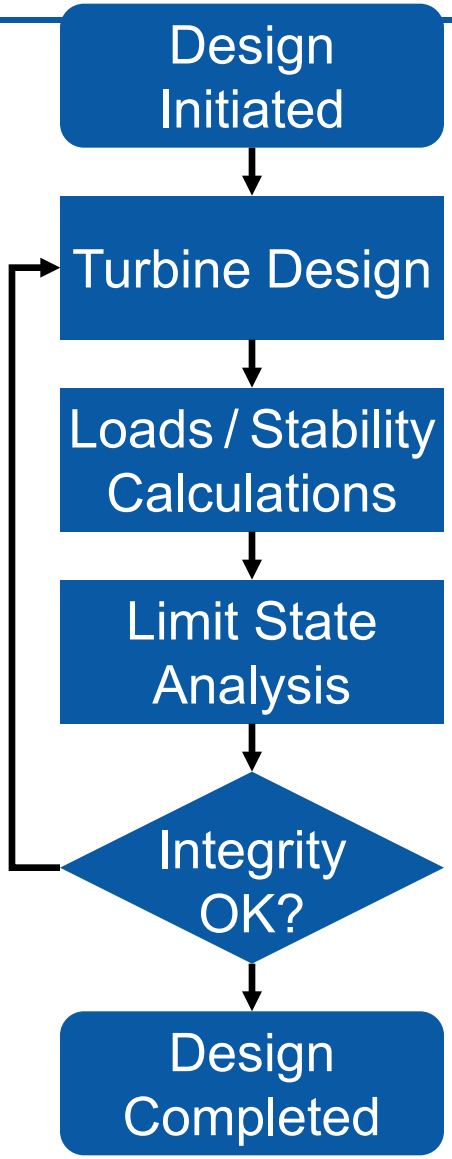
What Kind of Tools Are We Talking About?

- Tools practical to engineering design
- Preprocessors, simulators, & post-processors
- The primary (simulation) tools are:
  - Nonlinear time-domain multi-physics models (aero-hydro-servo-elastic)
  - Full-system level (rotor + drivetrain + nacelle + tower + substructure + foundation)
  - Developed uniquely for the wind application
- Tools based on advanced engineering models:
  - 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”)

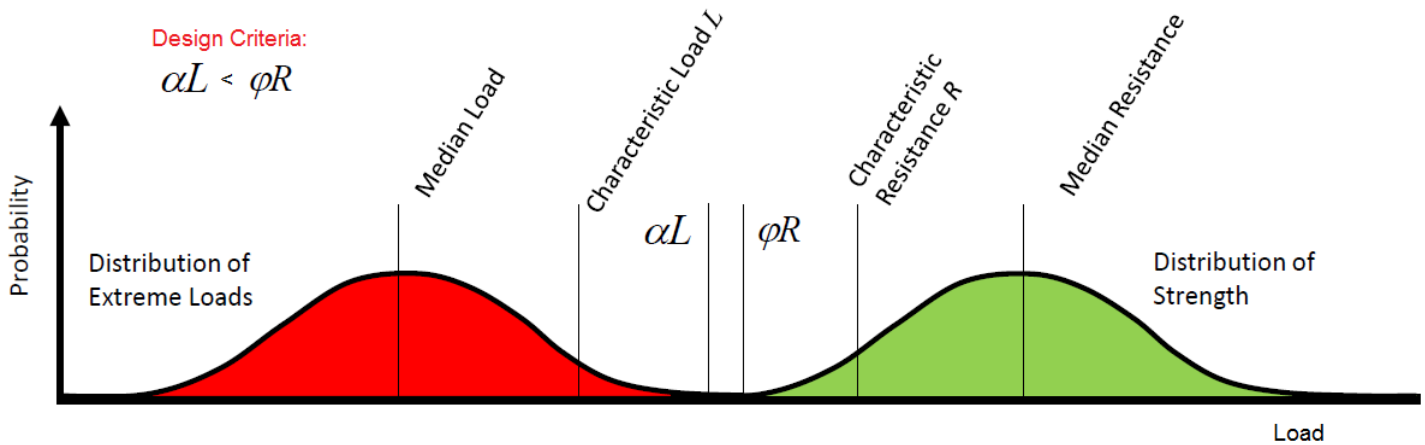


Introduction & Background

Wind Turbine Design Process



- Wind turbine design requires evaluation of response:
  - Ultimate loads for 50-yr extreme
  - Fatigue loads for 20-yr life
  - Aero-hydro-servo-elastic stability
- 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
- Iterated until structural integrity is achieved



Introduction & Background
Wind Turbine Design Process – Loads

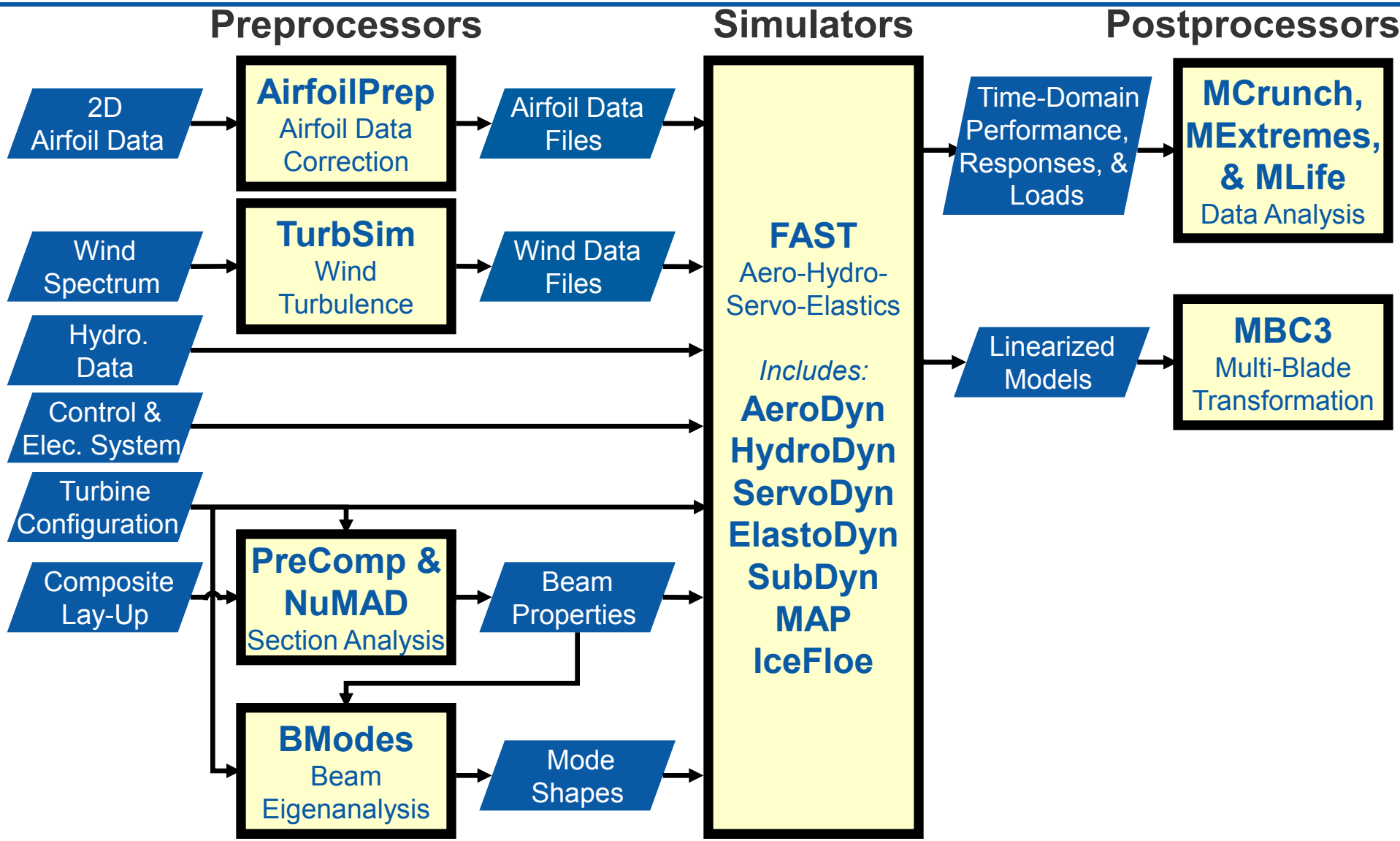
- Loads analysis involves running a large set of nonlinear time-domain simulations
- Design situations & conditions:
  - Turbulent & deterministic winds
  - Regular & irregular waves
  - Power production with control
  - Start-up & shut-down maneuvers
  - Idling & parked conditions
  - Control system faults
  - Earthquake excitation

Design Situation	DLC	Wind Condition	Wave Condition	Directionality	Other Conditions	Type of Analysis
Power production	1.x					
Power production plus occurrence of fault	2.x					
Start up	3.x					
Normal shut down	4.x					
Emergency shut down	5.x					
Parked	6.x					
Parked with fault	7.x					
Transport, assembly, and maintenance	8.x					

Load Case Matrix

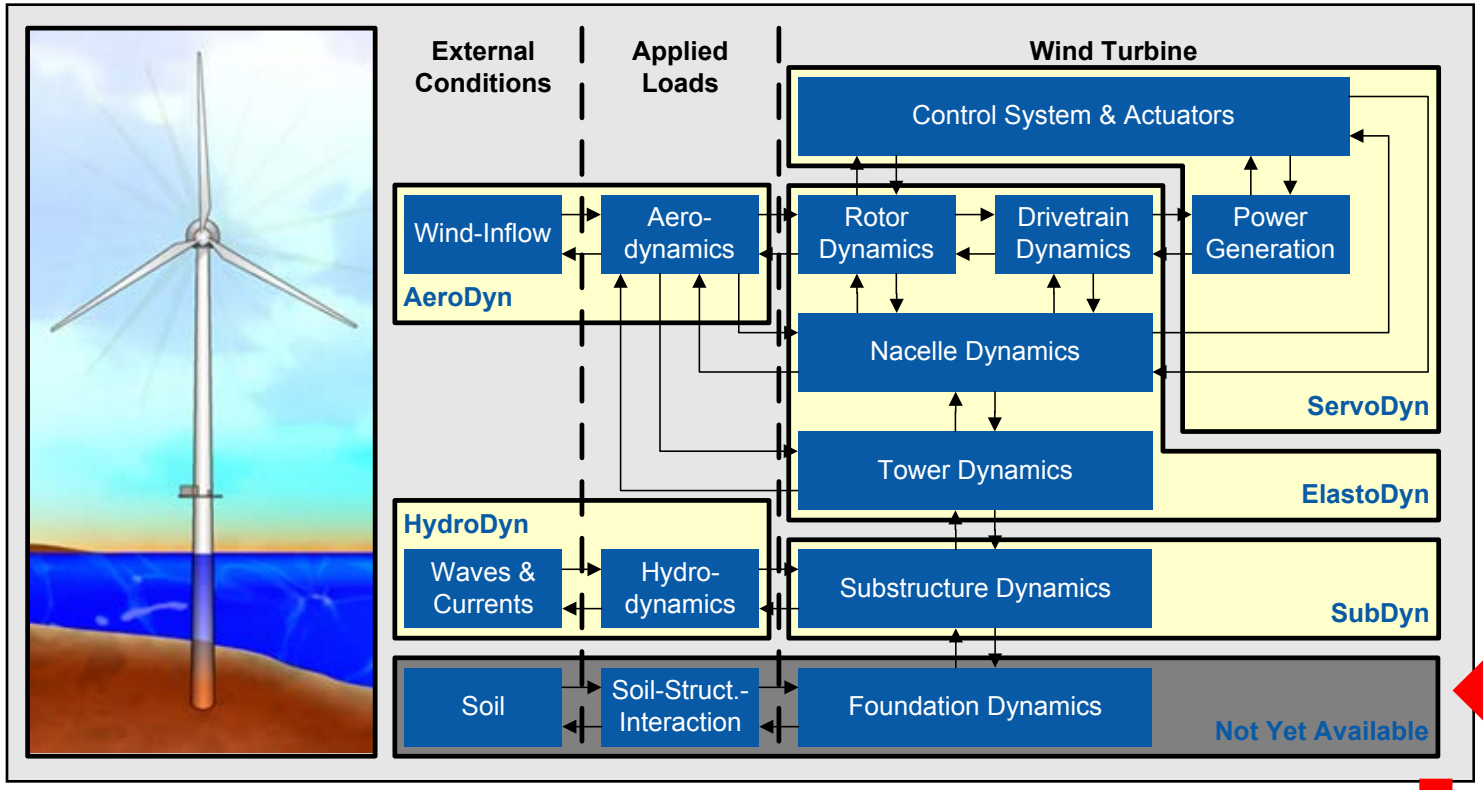
CAE Tools

Key DOE/NREL CAE Tools in the Design Process



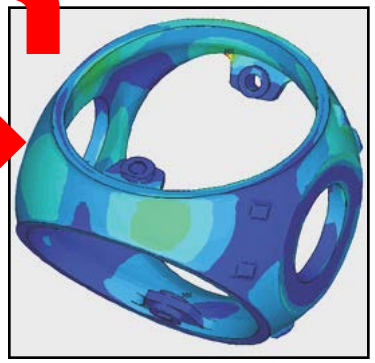
CAE Tools

FAST Module Control Volumes – Fixed-Bottom



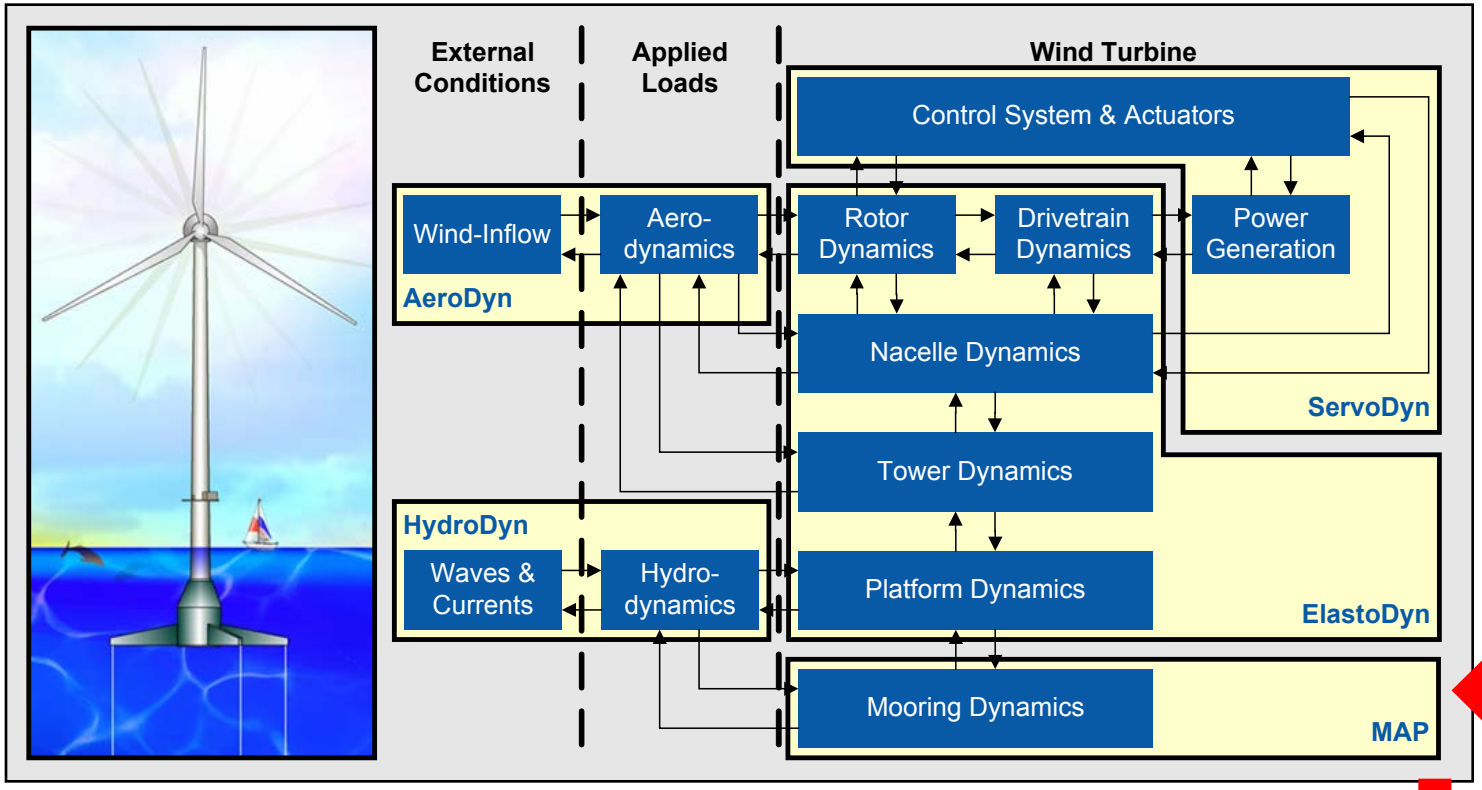
Full-System Level

Component Level



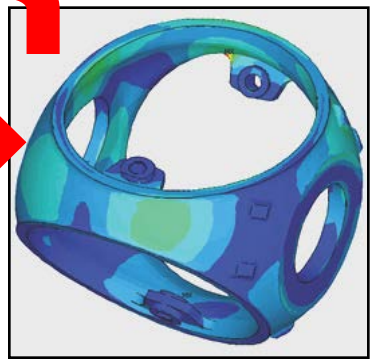
CAE Tools

FAST Module Control Volumes – Floating



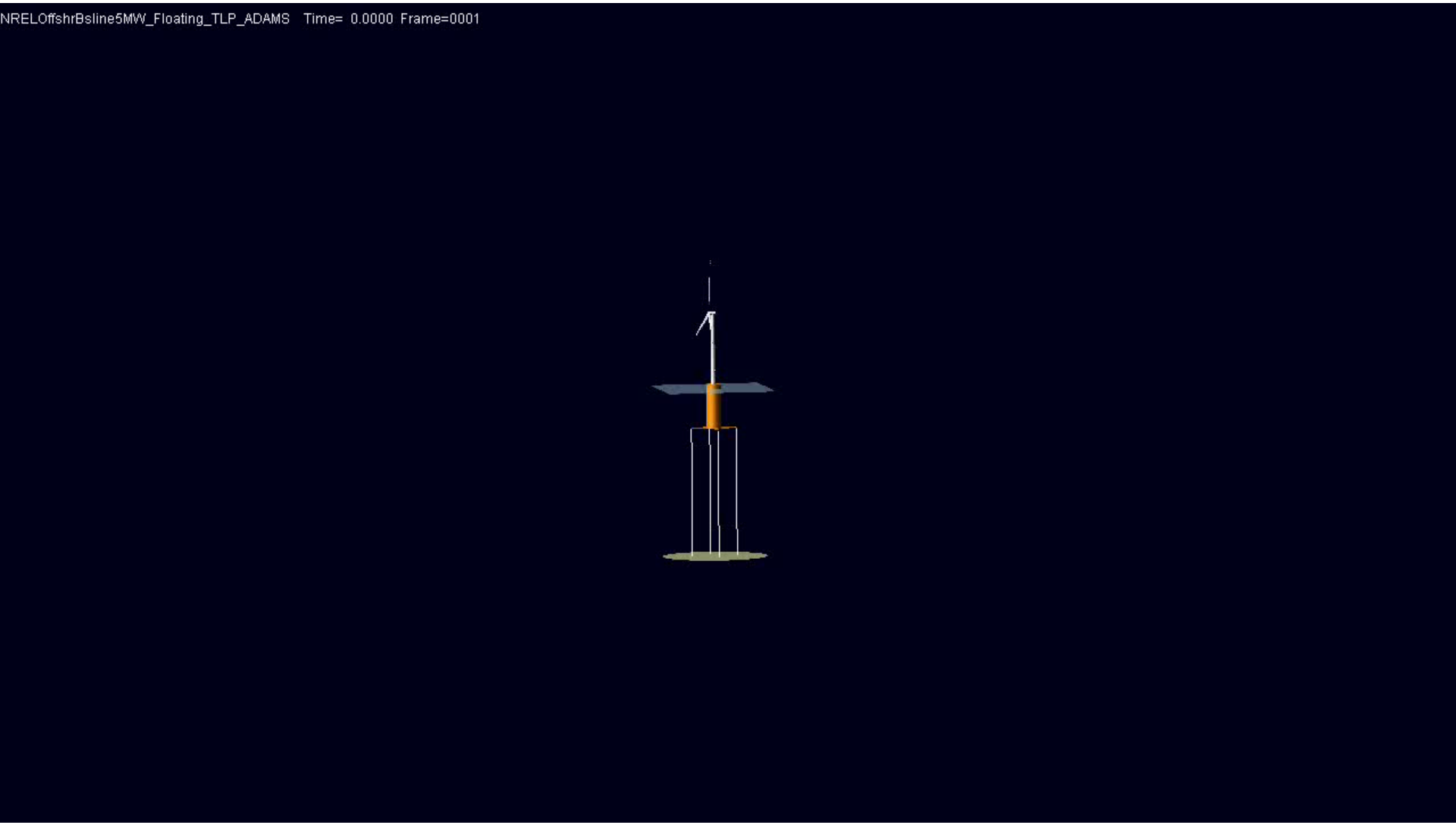
Full-System Level

Component Level



CAE Tools

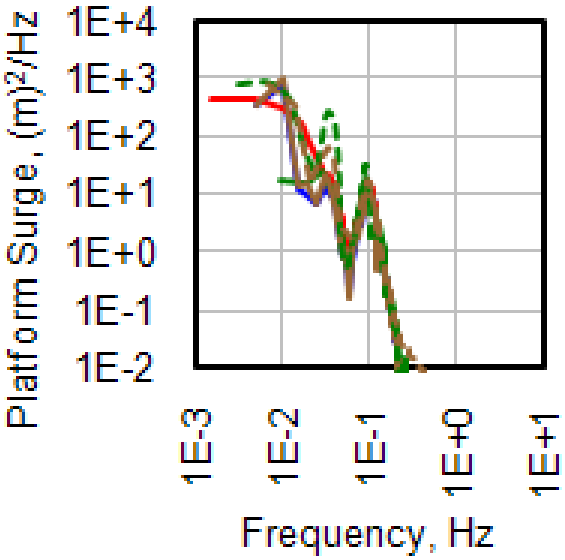
Sample MIT/NREL TLP Response



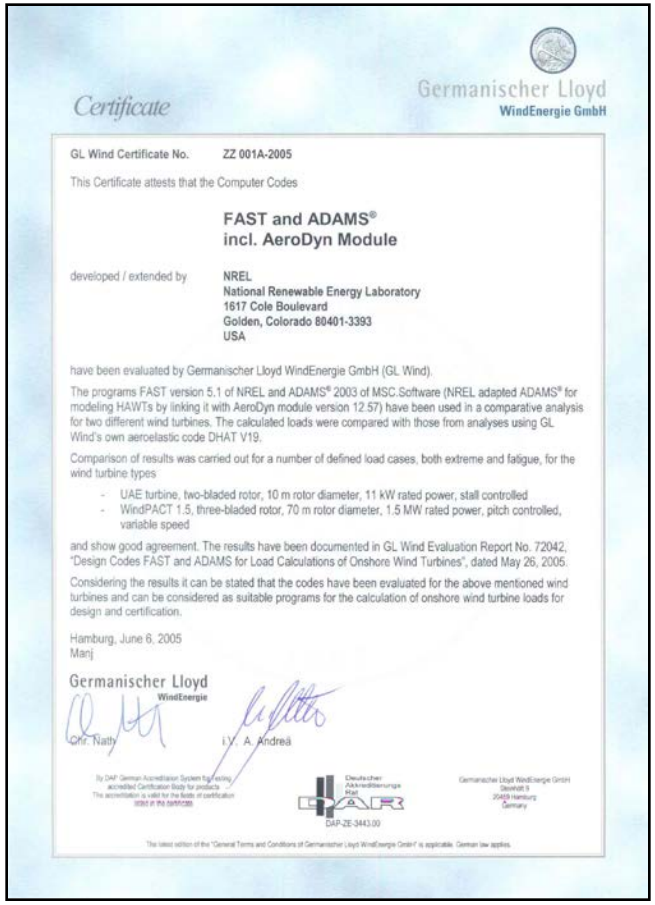
CAE Tools

Model Verification (Code-to-Code)

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



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

Dr. Nath i.V. A. Andreä

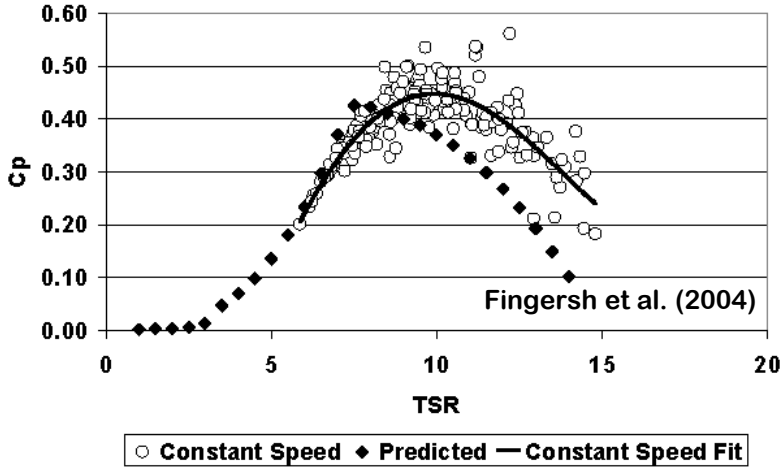
DAP-ZE-3443.00

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

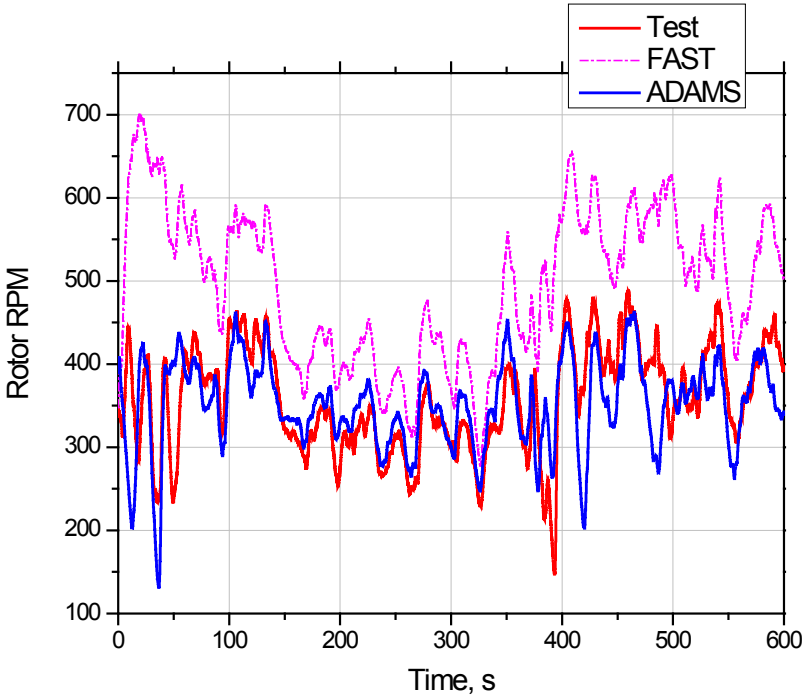
CAE Tools

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

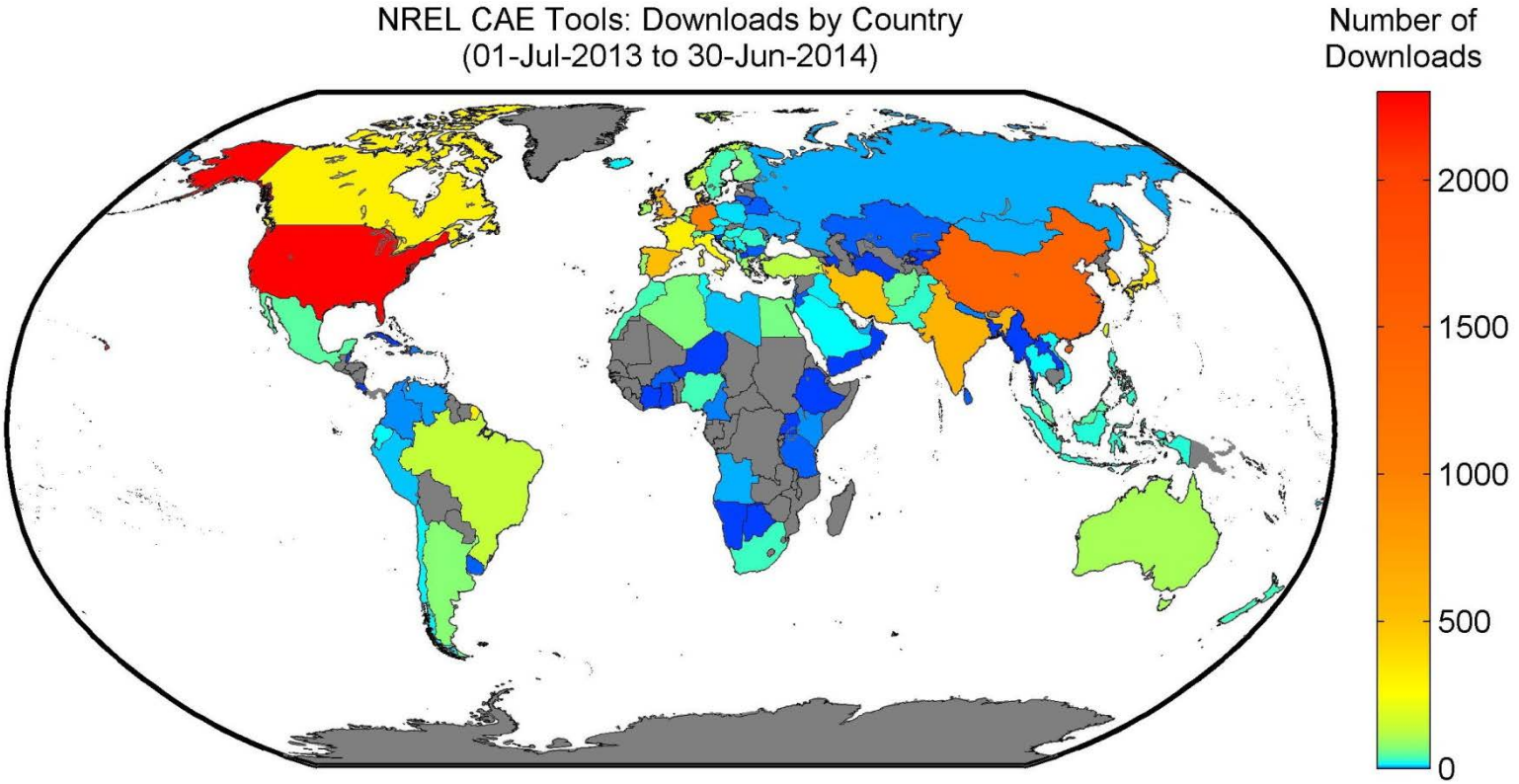
Disclaimer, Copyright, & Licensing

- NREL's CAE tool development is sponsored by the U.S. Department of Energy (DOE) Wind & Water Power Technologies Office
- The CAE tools are developed as free, publicly available, open-source, professional-grade products as a resource for the wind engineering community
- User's of the CAE tools must agree to NREL's disclaimer & licensing agreement:
  - Disclaimer: http://wind.nrel.gov/designcodes/disclaimer.html
  - New dual licensing arrangement:
    - Most CAE tools are being released under the Apache 2.0 open-source license: http://www.apache.org/licenses/LICENSE-2.0
    - When tied to some 3rd party code, some CAE tools are offered under the more restrictive GPL v3.0 open-source license: http://www.gnu.org/copyleft/gpl.html
    - Details are still being discussed by our legal team

Users & Support

Users of NREL-Developed Tools

- Used worldwide by wind turbine manufacturers, consultants, certifiers, researchers, educators, & students
- In last 12 months, there have been 12,491 unique downloads by 4,311 users from 1,840 organizations in 119 countries



Users & Support

Successful Applications (Only Subset Shown)

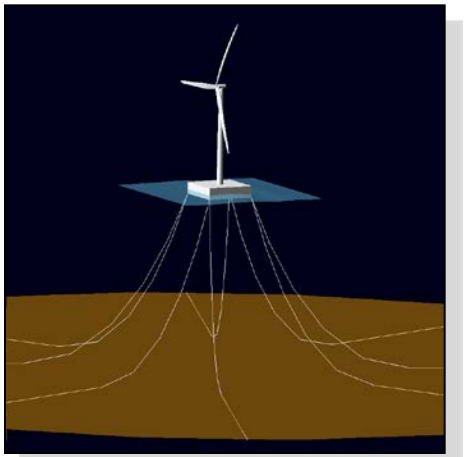
Southwest Windpower Skystream

CART2

Clipper 2.5-MW Liberty

NorthWind 100

GE 1.5 MW



NREL 5-MW Turbine on ITI Energy Barge

Users & Support

NWTC CAE Tools Website

NWTC Computer-Aided Engineering Tools (Introduction) - Windows Internet Explorer

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

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Computer-Aided Engineering Tools

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NWTC Portal

CAE Tools

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Introduction

Welcome to the NWTC Computer-Aided Engineering Tools web site. These computer codes are available in beta-test versions for those who wish to evaluate them. They are research tools that are subject to revision. Please read the explanations and warnings in the introductions before you decide to download a code.

This page is primarily for the benefit of the US Government and organizations that have contracts with the Department of Energy's Wind and Water-Power Program. Others are welcome to use the software, but we do not have the resources to support them

Users & Support

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Computer-Aided Engineering Software Tools Provide feedback, request enhancements, and get help with wind-turbine computer-aided engineering tools. Moderators: Marshall.Buhl, Andy.Platt	432	2093	by Jason.Jonkman Mon Mar 25, 2013 6:09 am
Rotor Aerodynamics	30	140	by Kisorthman.Vimalakanthan

Local intranet 100%

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Questions?

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