

# *CAE Tool Overview*



## **NREL Wind Turbine Modeling Workshop**

**August 7, 2012**

**UMASS – Amherst, MA**

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Senior Engineer, NREL**

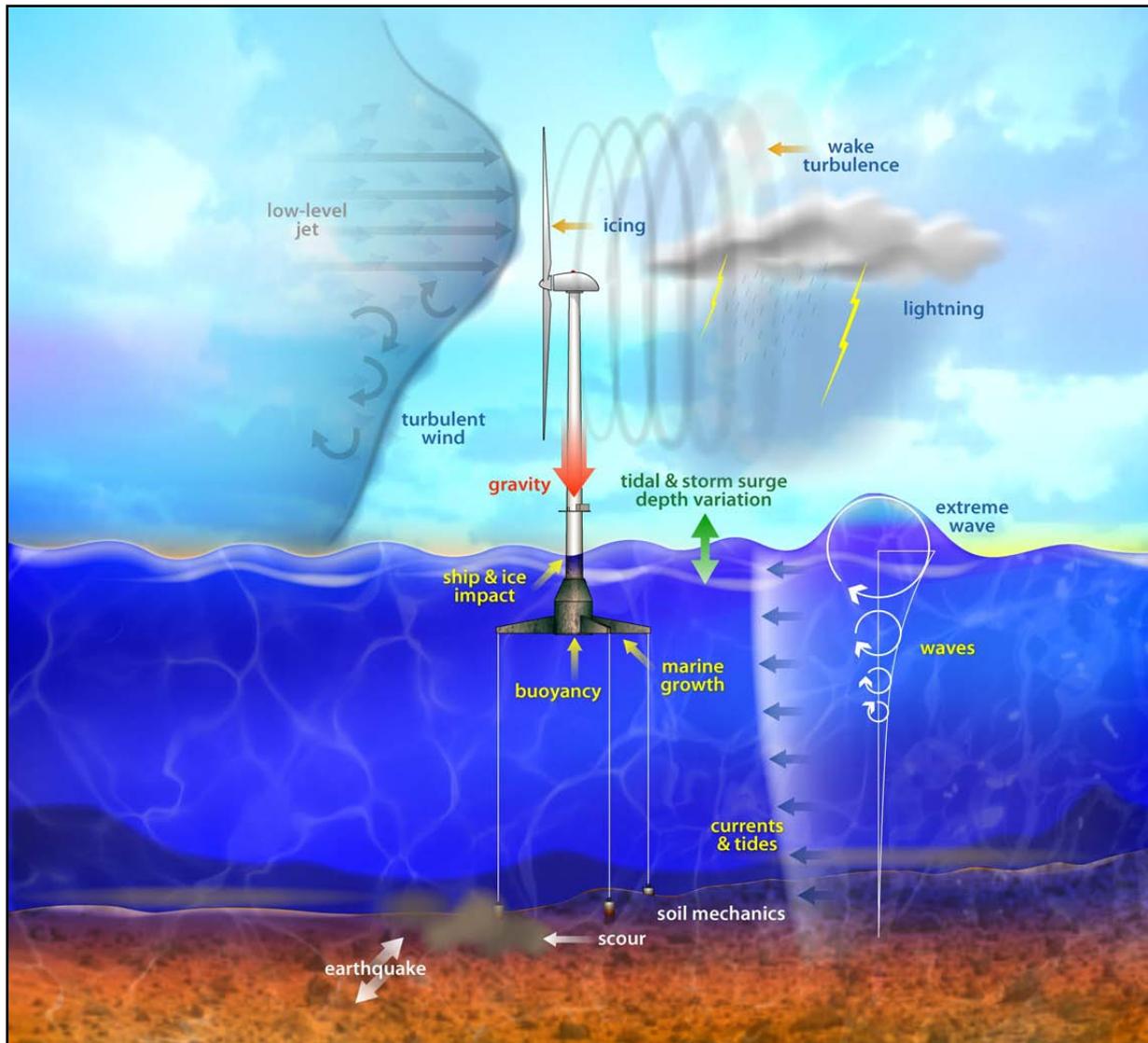
# Outline

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- Introduction & Background:
  - Modeling Requirements
  - What Kind of Tools Are We Talking About?
  - Wind Turbine Design Process
- CAE Tools:
  - Key NREL Tools in the Design Process
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  - Model Verification
  - Model Validation
- Users & Support:
  - Users of NREL-Developed Tools
  - Successful Applications
  - Website & Forum

# Introduction & Background

## Modeling Requirements

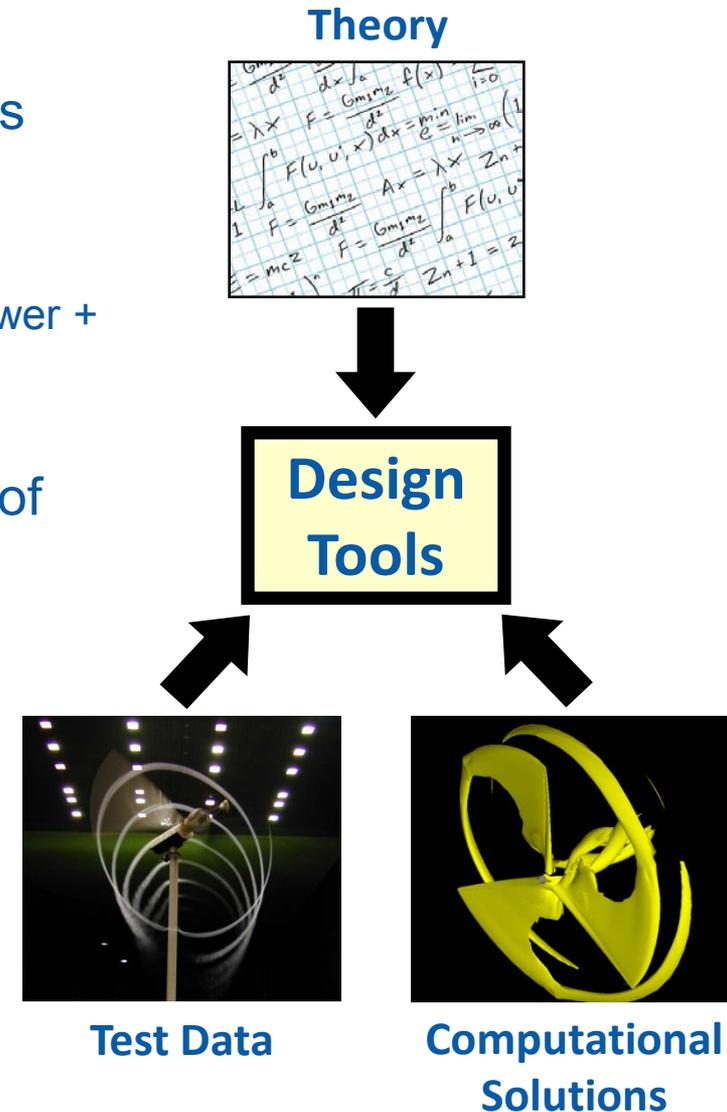


- Coupled aero-hydro-servo-elastic interaction
- Wind-inflow:
  - Discrete events
  - Turbulence
- Waves:
  - Regular
  - Irregular
- Aerodynamics:
  - Induction
  - Rotational augmentation
  - Skewed wake
  - Dynamic stall
- Hydrodynamics:
  - Diffraction
  - Radiation
  - Hydrostatics
- Structural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

# Introduction & Background

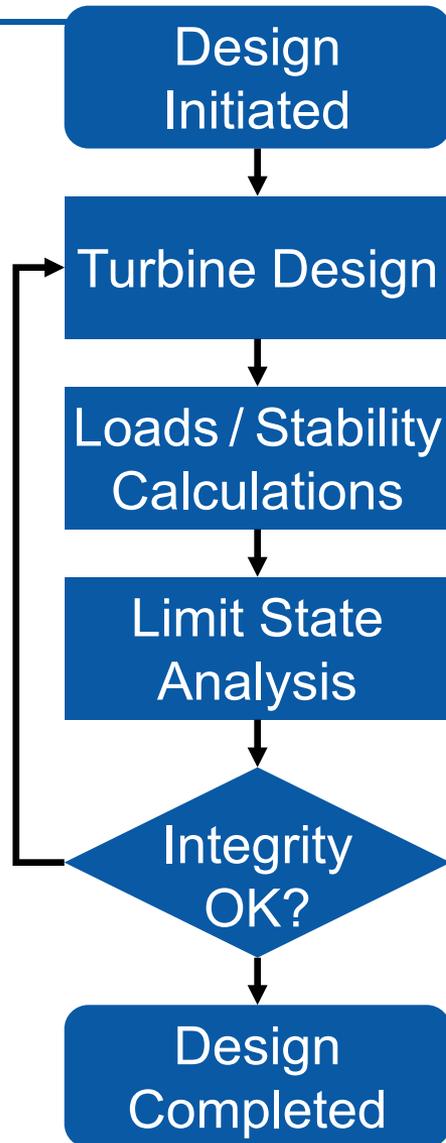
## What Kind of Tools Are We Talking About?

- 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

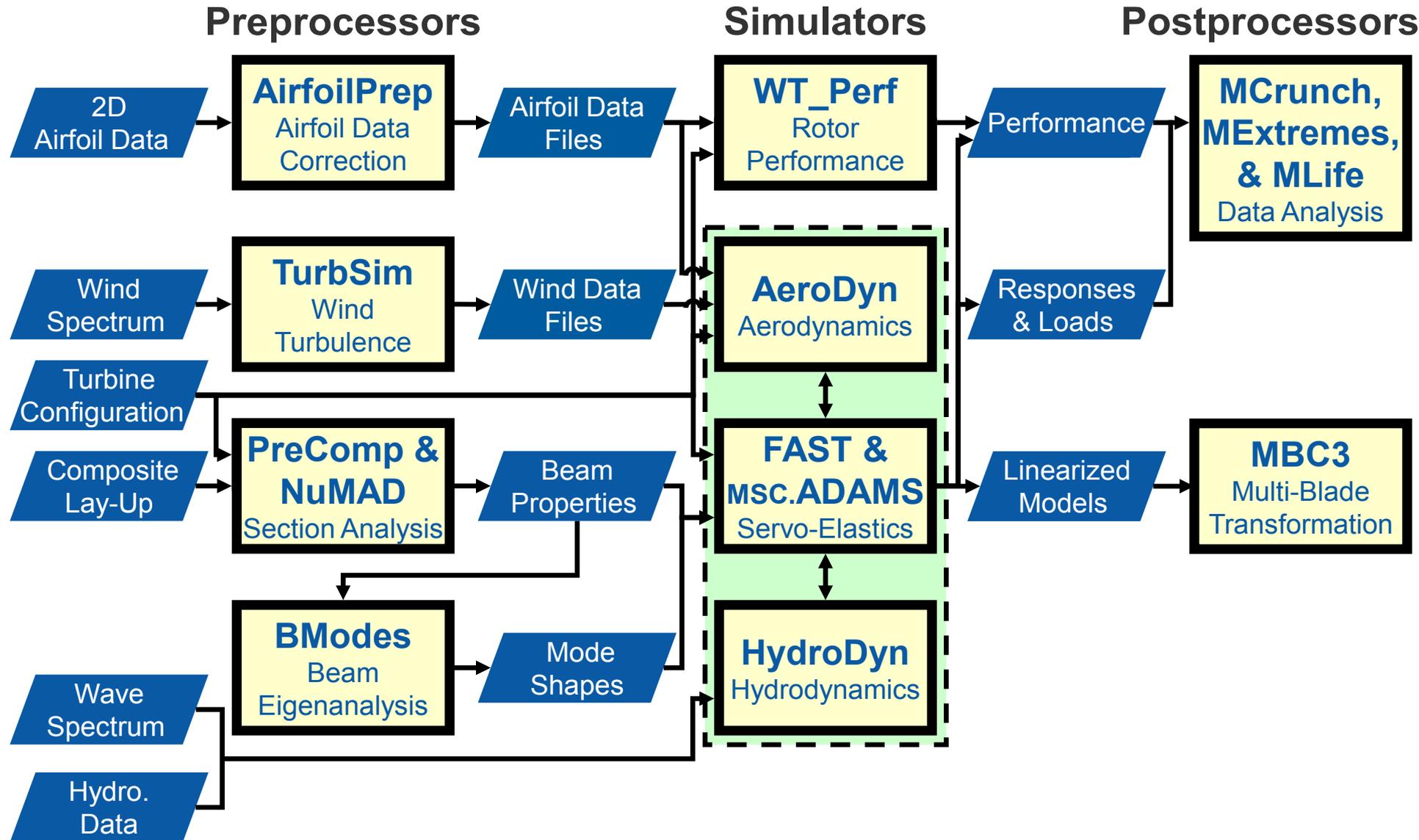
## Wind Turbine Design Process



- 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:  
 $\text{Design Load} \leq \text{Design Resistance}$

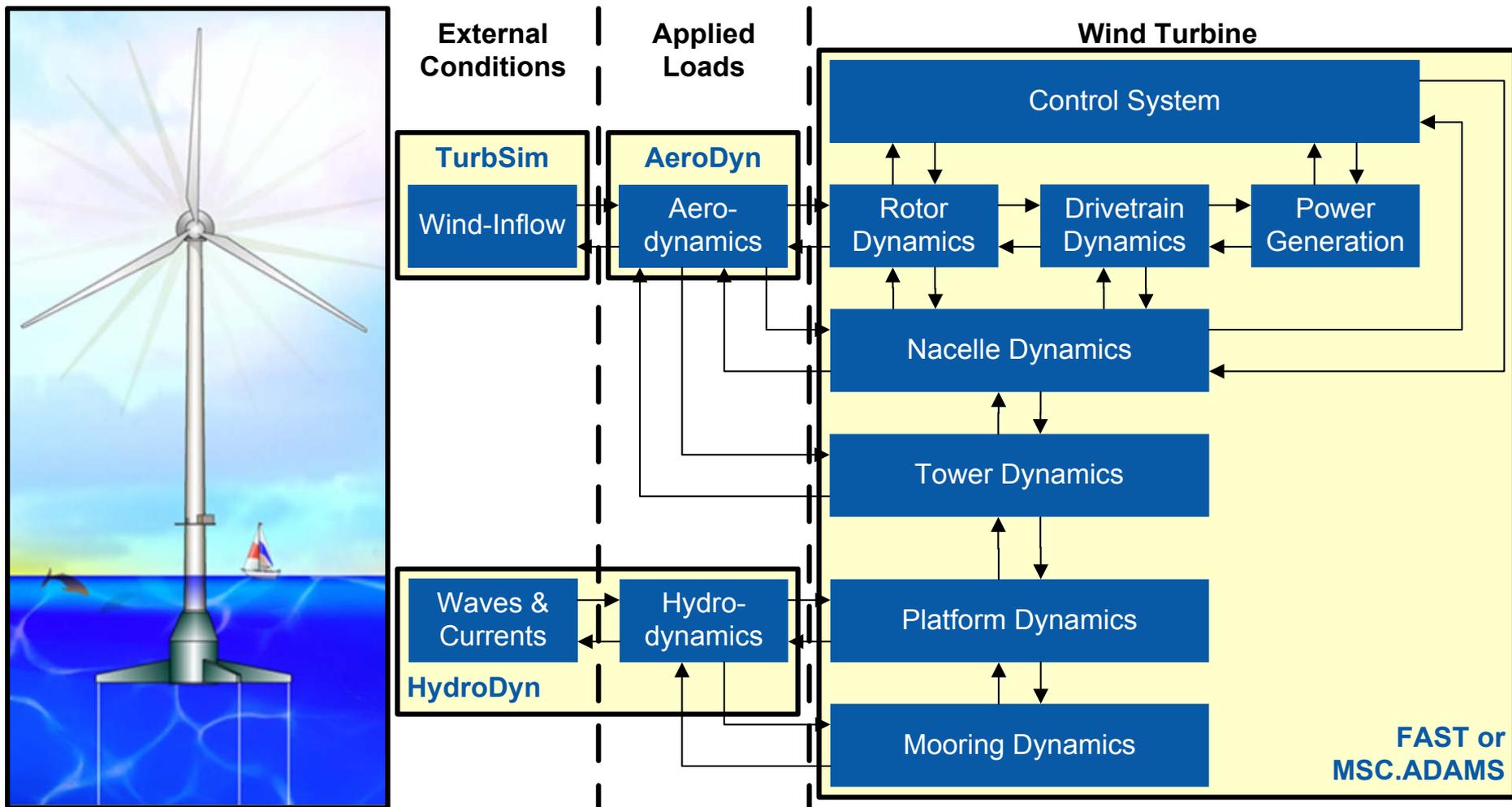
# CAE Tools

## Key NREL Tools in the Design Process



# CAE Tools

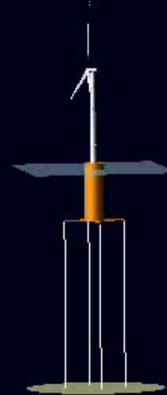
## FAST-AeroDyn-HydroDyn Coupling



# CAE Tools

## Sample MIT/NREL TLP Response

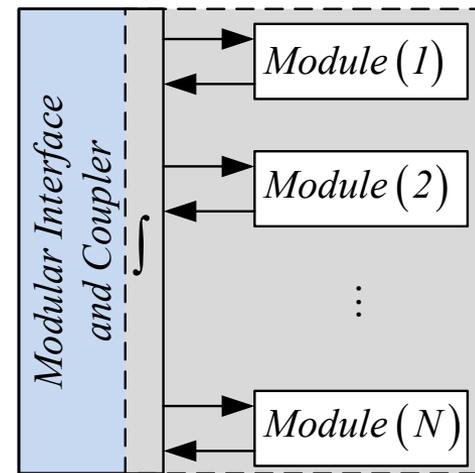
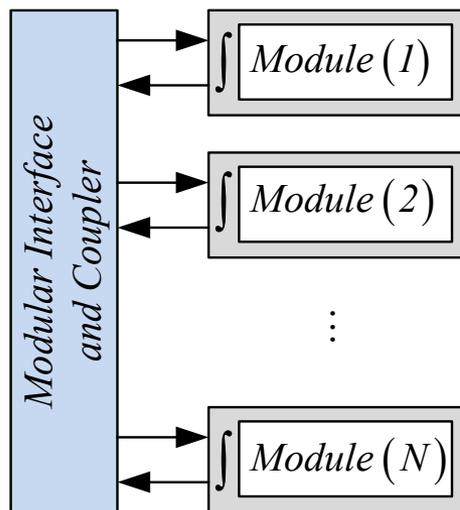
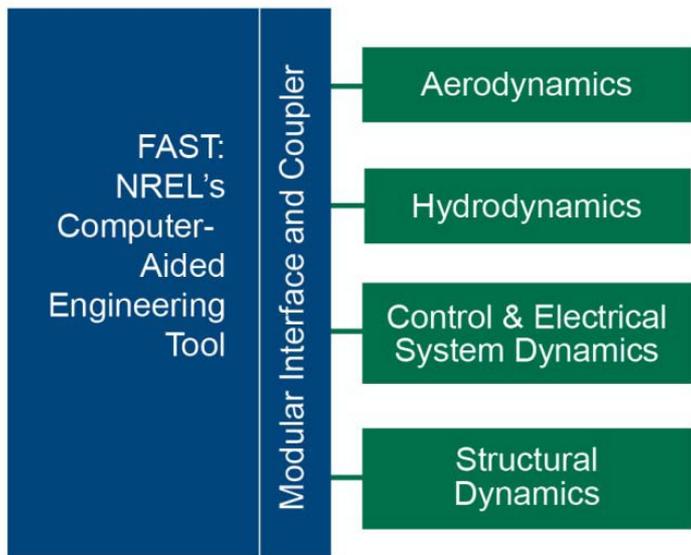
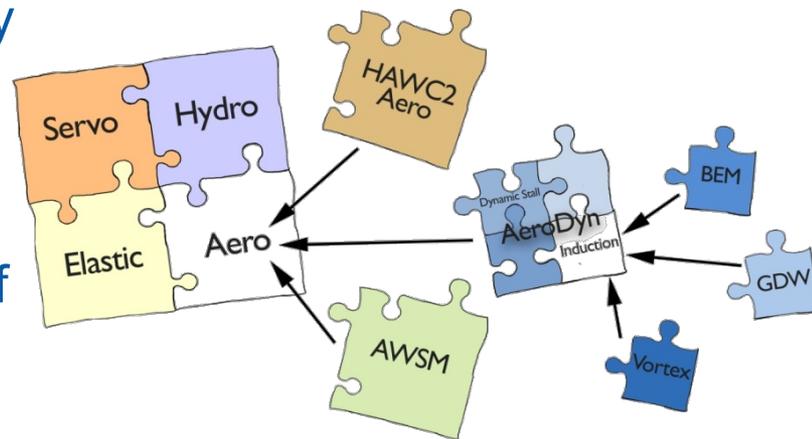
NRELOffshrBslne5MW\_Floating\_TLP\_ADAMS Time= 0.0000 Frame=0001



# CAE Tools

## Main Focus: Modularization & Coupled Simulation

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

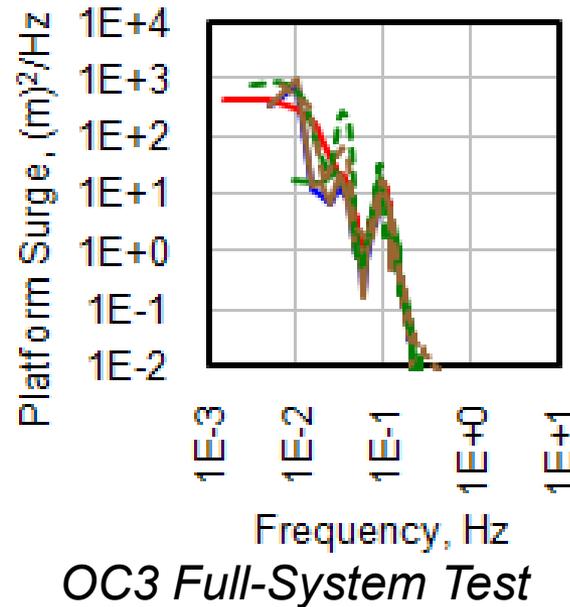


Loose- (left) and tight- (right) coupling schemes

# CAE Tools

## Model Verification (Code-to-Code)

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

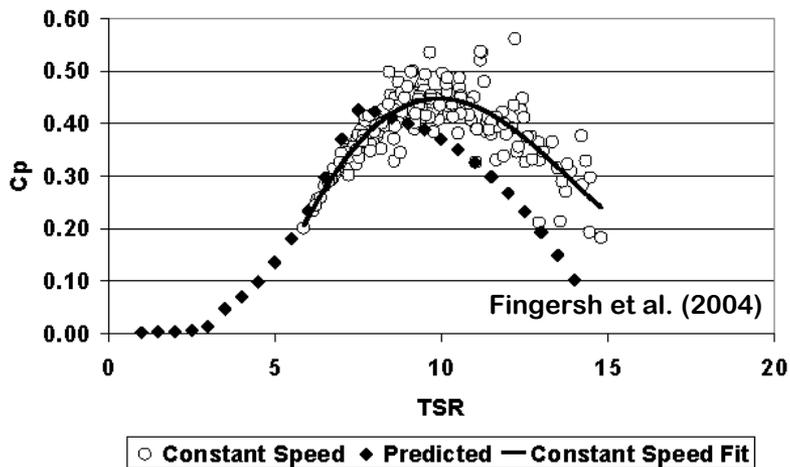


**GL Certificate Approving  
FAST & ADAMS with AeroDyn**

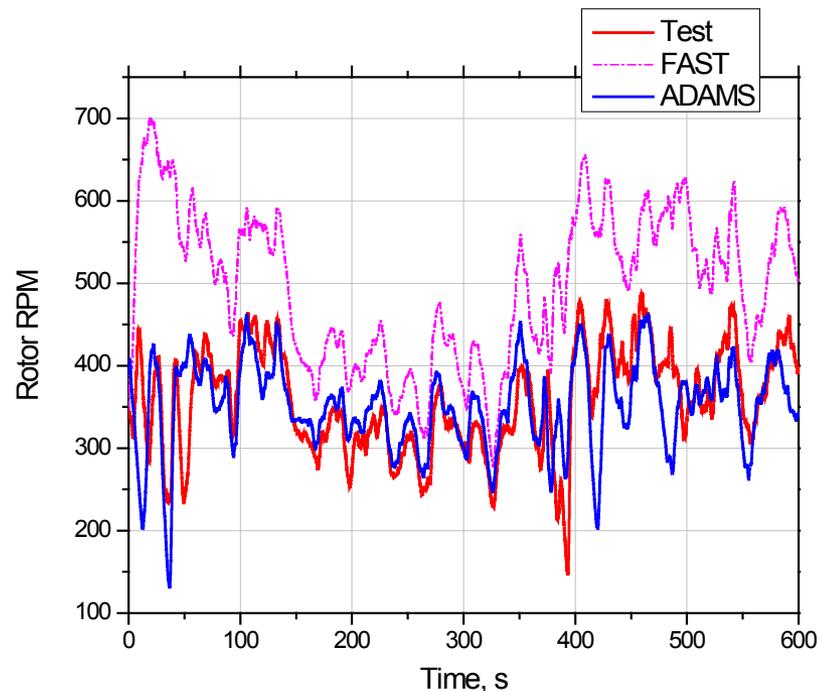
# CAE Tools

## 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*

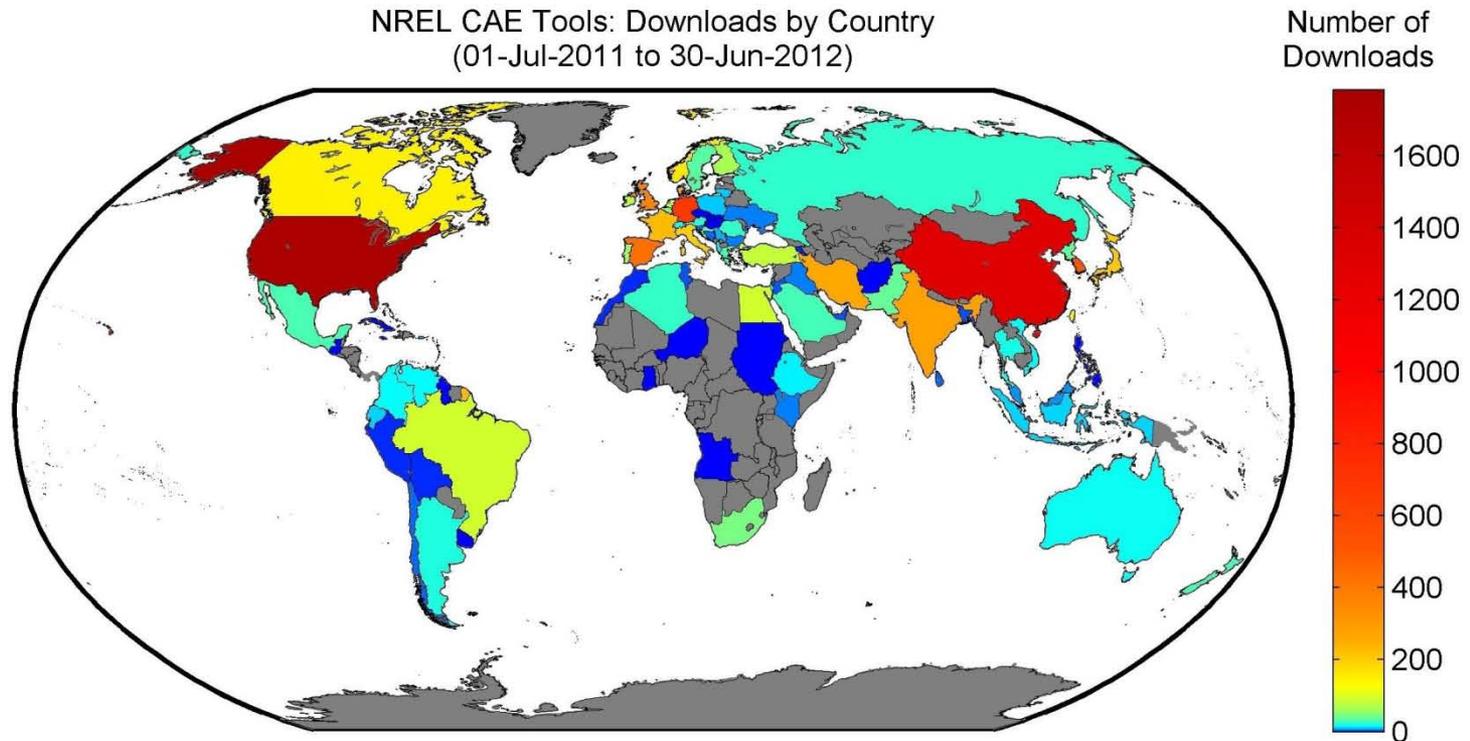


*SWRT in high winds – **ADAMS** has Blade Torsion, **FAST** doesn't*

# Users & Support

## Users of NREL-Developed Tools

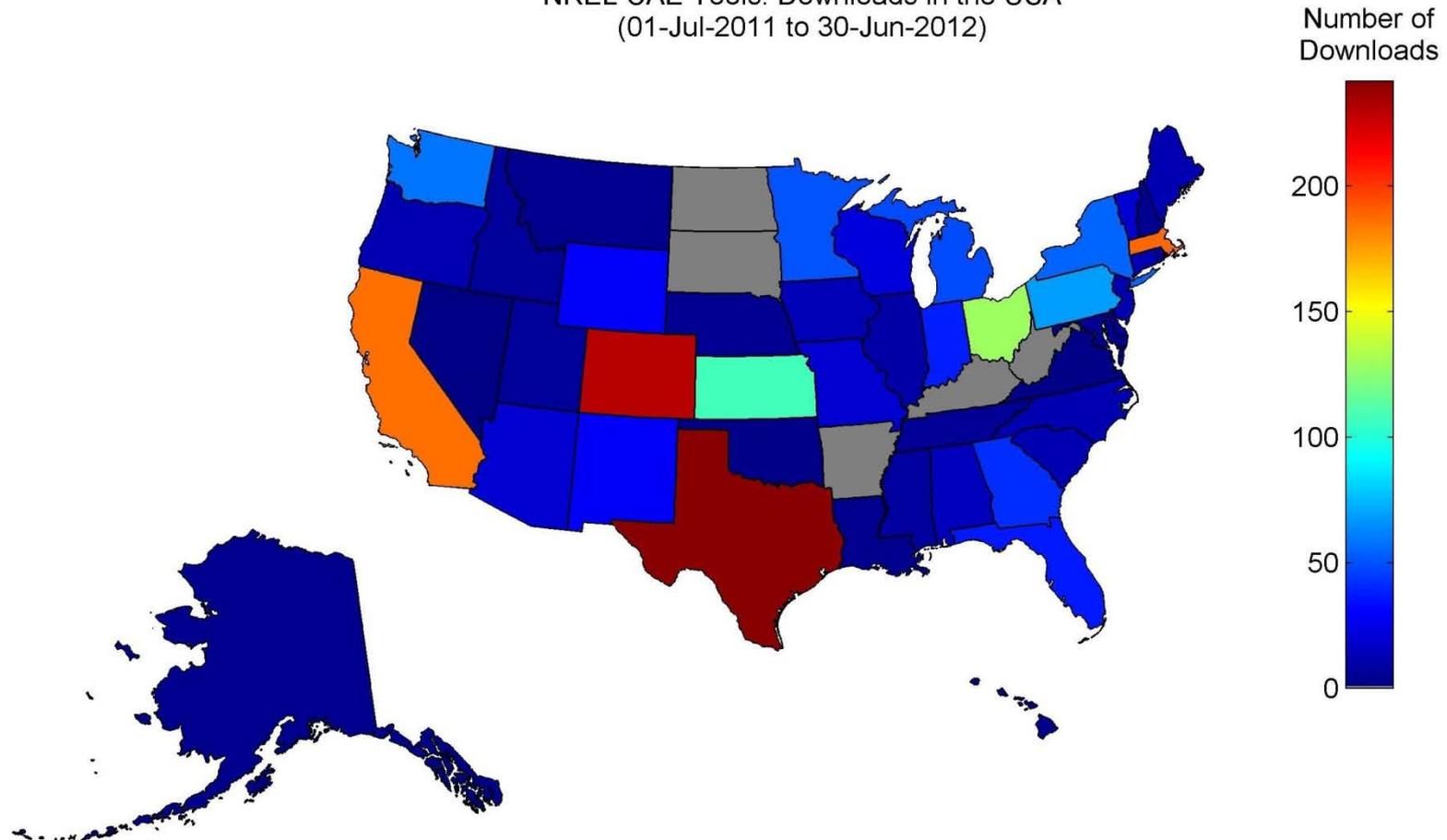
- Used worldwide by wind turbine manufacturers, consultants, certifiers, researchers, & educators
- In last 12 months, there have been 8,947 unique downloads by 3,296 users from 1,071 organizations in 93 countries



# Users & Support

## Users of NREL-Developed Tools (cont)

NREL CAE Tools: Downloads in the USA  
(01-Jul-2011 to 30-Jun-2012)



# Users & Support

## Successful Applications (Only Subset Shown)



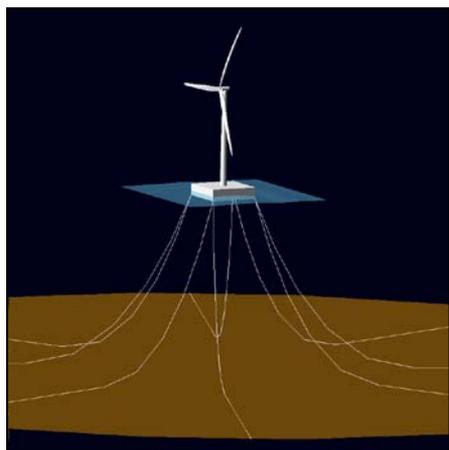
*Southwest  
Windpower  
Skystream*



*CART2*



*Clipper 2.5-MW  
Liberty*



*NREL 5-MW Turbine on ITI Energy Barge*



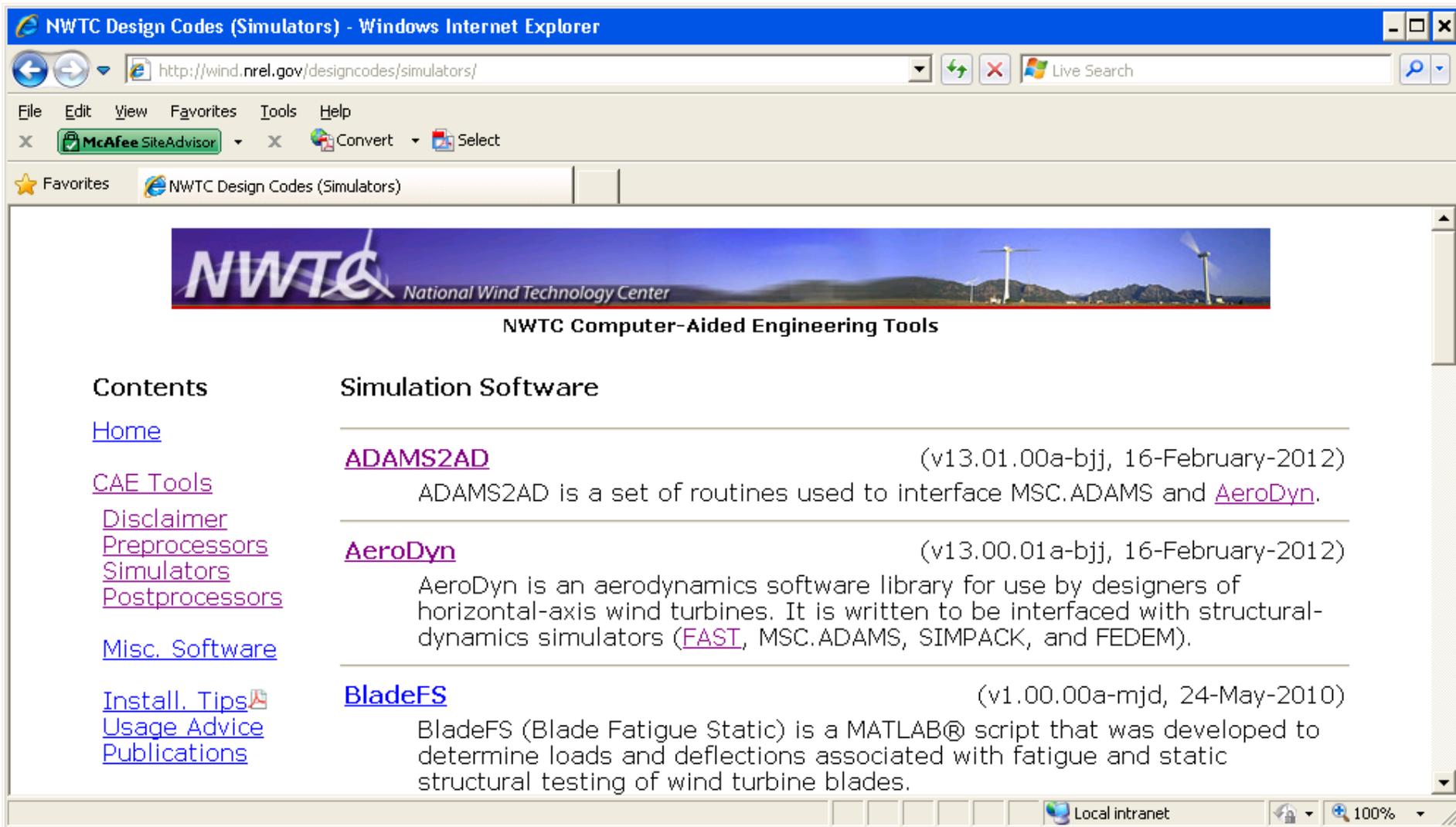
*NorthWind 100*



*GE 1.5 MW*

# Users & Support

## NWTC CAE Tools Website



The screenshot shows a Windows Internet Explorer browser window displaying the NWTC Design Codes (Simulators) website. The address bar shows the URL <http://wind.nrel.gov/designcodes/simulators/>. The website features a banner for the National Wind Technology Center (NWTC) and a section titled "NWTC Computer-Aided Engineering Tools".

**Contents**

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- [Usage Advice](#)
- [Publications](#)

**Simulation Software**

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**ADAMS2AD** (v13.01.00a-bjj, 16-February-2012)  
ADAMS2AD is a set of routines used to interface MSC.ADAMS and [AeroDyn](#).

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**AeroDyn** (v13.00.01 a-bjj, 16-February-2012)  
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 ([FAST](#), MSC.ADAMS, SIMPACK, and FEDEM).

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**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.

# Users & Support

## NWTC Forum

The screenshot shows a Windows Internet Explorer browser window displaying the NWTC Forum. The address bar shows the URL <https://wind.nrel.gov/forum/wind/>. The page header includes the NWTC logo and the text "NREL's National Wind Technology Center". A search bar is located in the top right corner. Below the header, there is a "Board index" link and a "User Control Panel" link. The current date and time are displayed as "Wed Jul 25, 2012 6:27 am". The last visit was on "Tue Jul 24, 2012 2:18 pm". The page also features links for "View unanswered posts", "View new posts", "View active topics", and "Mark forums read". A table titled "WIND EXTERNAL" lists forum topics with columns for "TOPICS", "POSTS", and "LAST POST".

|  | TOPICS | POSTS | LAST POST                                    |
|--|--------|-------|--|
| <b>Access Requests (READ THIS FIRST BEFORE CREATING AN ACCOUNT)</b><br>Information on accessing our forums.  | 1      | 2     | by Marshall.Buhl<br>Thu Jul 05, 2012 8:25 am |
| <b>Computer-Aided Engineering Software Tools</b><br>Provide feedback, request enhancements, and get help with wind-turbine computer-aided engineering tools. | 353    | 1630  | by Rebecca.Sykes<br>Wed Jul 25, 2012 4:12 am |
| <b>Rotor Aerodynamics</b><br>Discuss the theory and modeling of rotor aerodynamics.  | 25     | 126   | by Marshall.Buhl<br>Thu Jul 05, 2012 9:56 am |

# *Questions?*



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