Exceptional service in the national interest

Sandia National Laboratories

Sandia Blade Design Tools: NuMAD Overview
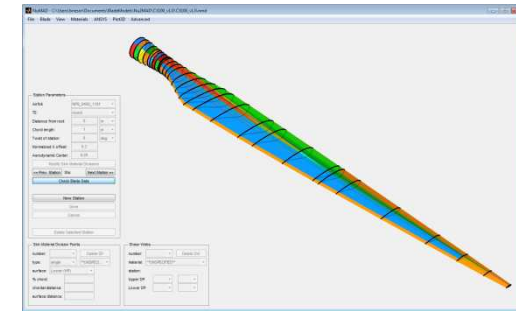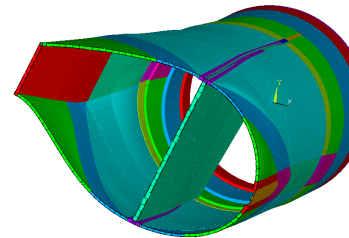
October 28, 2015

SMART Wind Composites Virtual Meeting: Blade Design

Presenter: D. Todd Griffith, PhD   dgriffi@sandia.gov

Outline

- Background
  - Sandia National Laboratories
  - Sandia's Wind Energy Department
- Blade Trends
- Introduction to NuMAD (version 2.0)
  - Sandia's Matlab-based blade design tool
  - Features and capabilities
- Supporting capabilities to NuMAD
  - MSU Wind Composite Materials Property Database
  - Sandia Blade Manufacturing Cost Model
  - Sandia VAWT Codes

Energy & Climate PMU

Energy Research

ARPAe, BES Chem Sciences, ASCR, CINT, Geo Bio Science, BES Material Science

Climate & Environment

Measurement & Modeling, Carbon Management, Water & Environment, and Biofuels

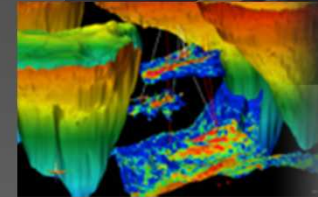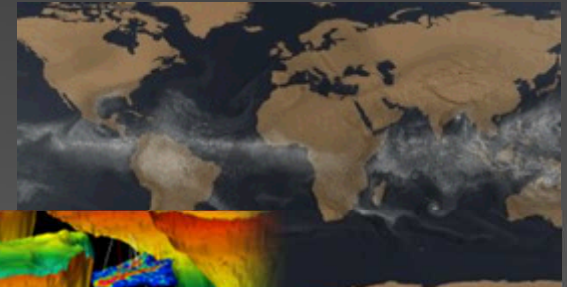**Nuclear Energy & Fuel Cycle**

Commercial Nuclear Power & Fuel, Nuclear Energy Safety & Security, DOE Managed Nuclear Waste Disposal

Renewable Systems & Energy Infrastructure

Renewable Energy, Energy Efficiency, Grid and Storage Systems
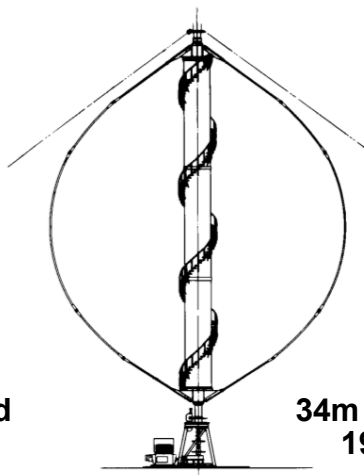
Transportation Energy & Systems

Vehicle Technologies, Biomass, Fuel Cells & Hydrogen Technology

SNL Wind Program History

28 Years of wind turbine rotor development

Wind Program Established 1975
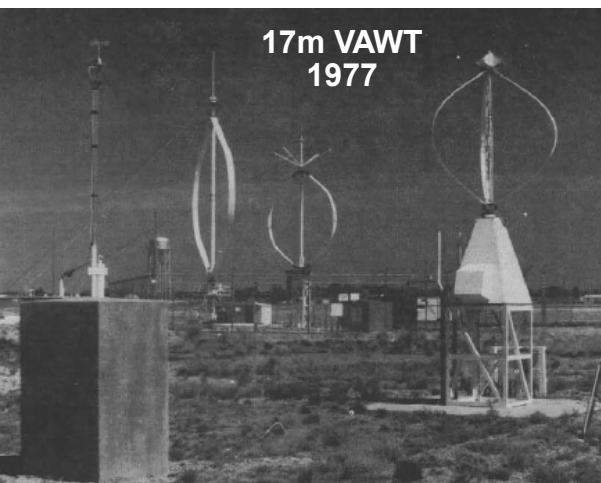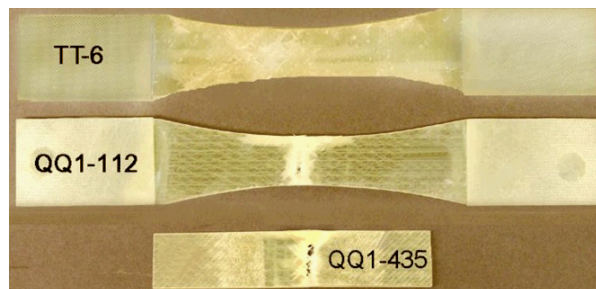
34m VAWT 1984

Blade Program 1994

SWiFT Facility 2013
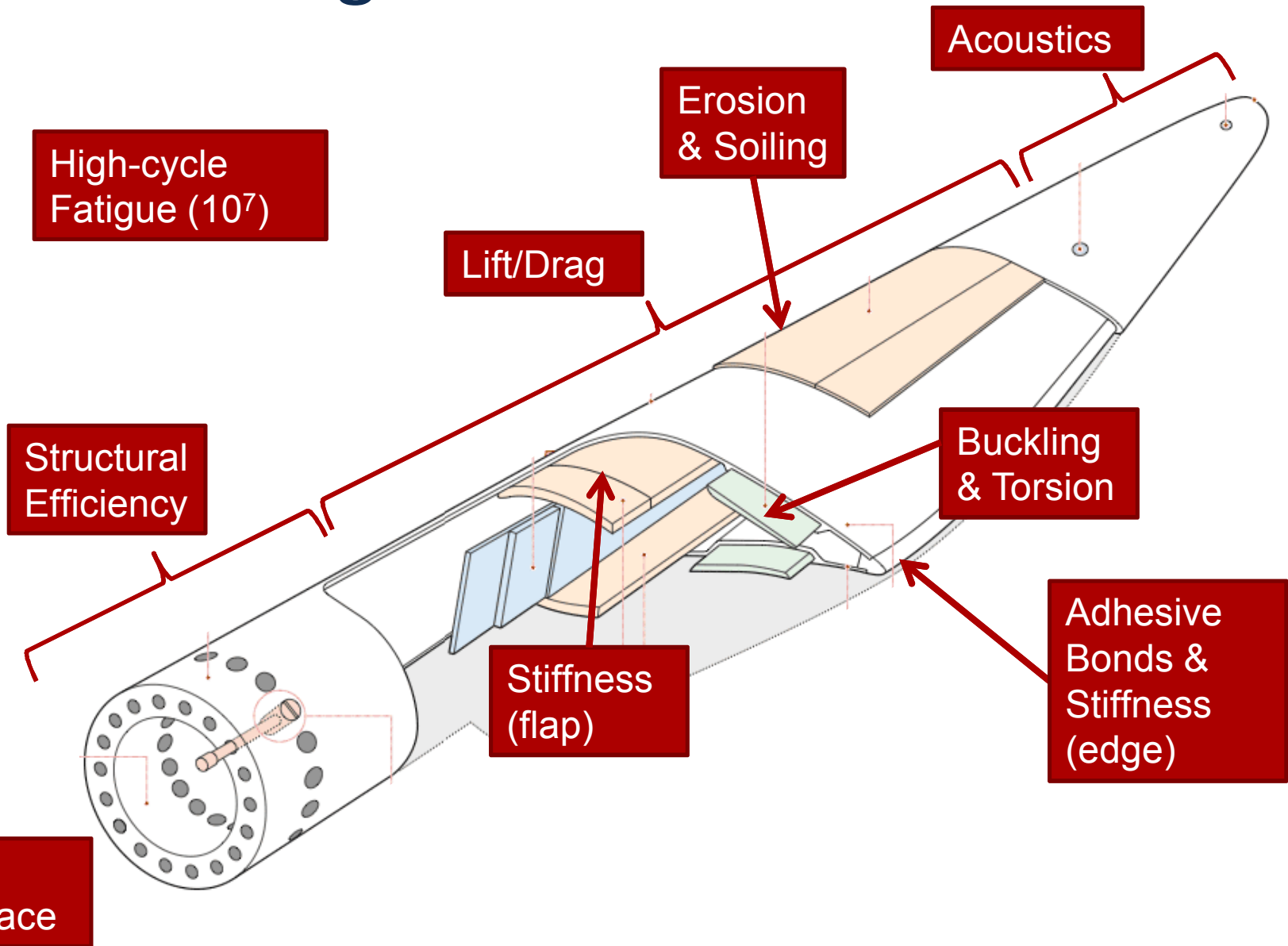
17m VAWT 1977

Composite Materials Database 1988

Advanced Manufacturing Initiative 2008

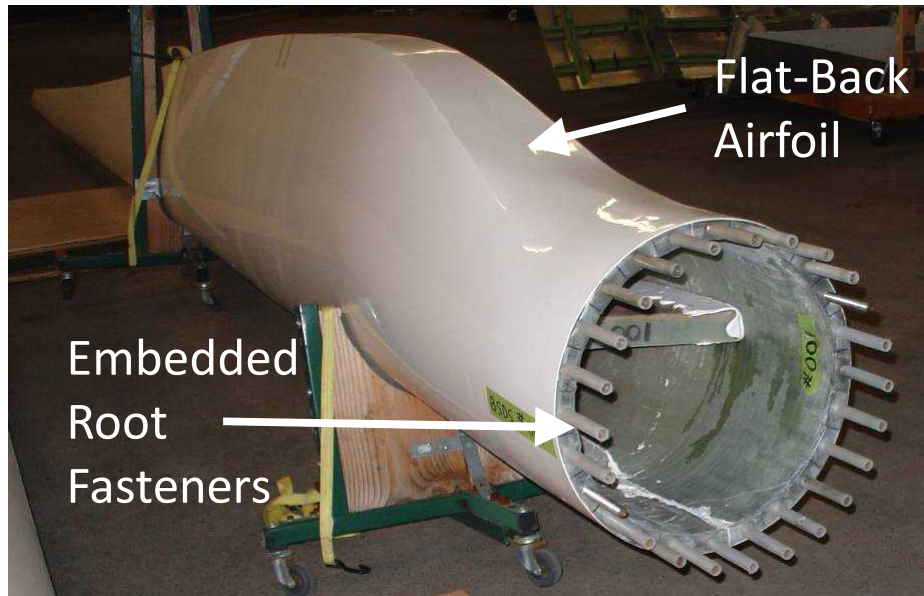TT-6

QQ1-112

QQ1-435

Blade Trends

Blade Design Drivers

Acoustics

Erosion & Soiling

High-cycle Fatigue (10^7)

Lift/Drag

Structural Efficiency

Buckling & Torsion

Stiffness (flap)

Adhesive Bonds & Stiffness (edge)

Bolt interface

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Sandia Blade Programs

Aero-Structural Optimization

Flat-Back Airfoil

Embedded Root Fasteners

Blade System Design Study (BSDS) Blade

- Impact: Common in current production blades

Passive Load Alleviation

Off-axis Carbon Skin

Twist-Bend Coupled Experimental 100kW (TX-100) Blade Skin Blade Skin

Sweep Twist Adaptive Rotor (STAR) Blade

- Industry impact: Several current production and concept blades use this technology

# National Rotor Testbed (Current)

Nominally 27 meter diameter rotor

- Design and manufacture sub-scale rotors for the SWiFT turbines to emulate a modern, megawatt scale rotor.

- Enables low-cost field testing of new rotor technologies.

- Public rotor design
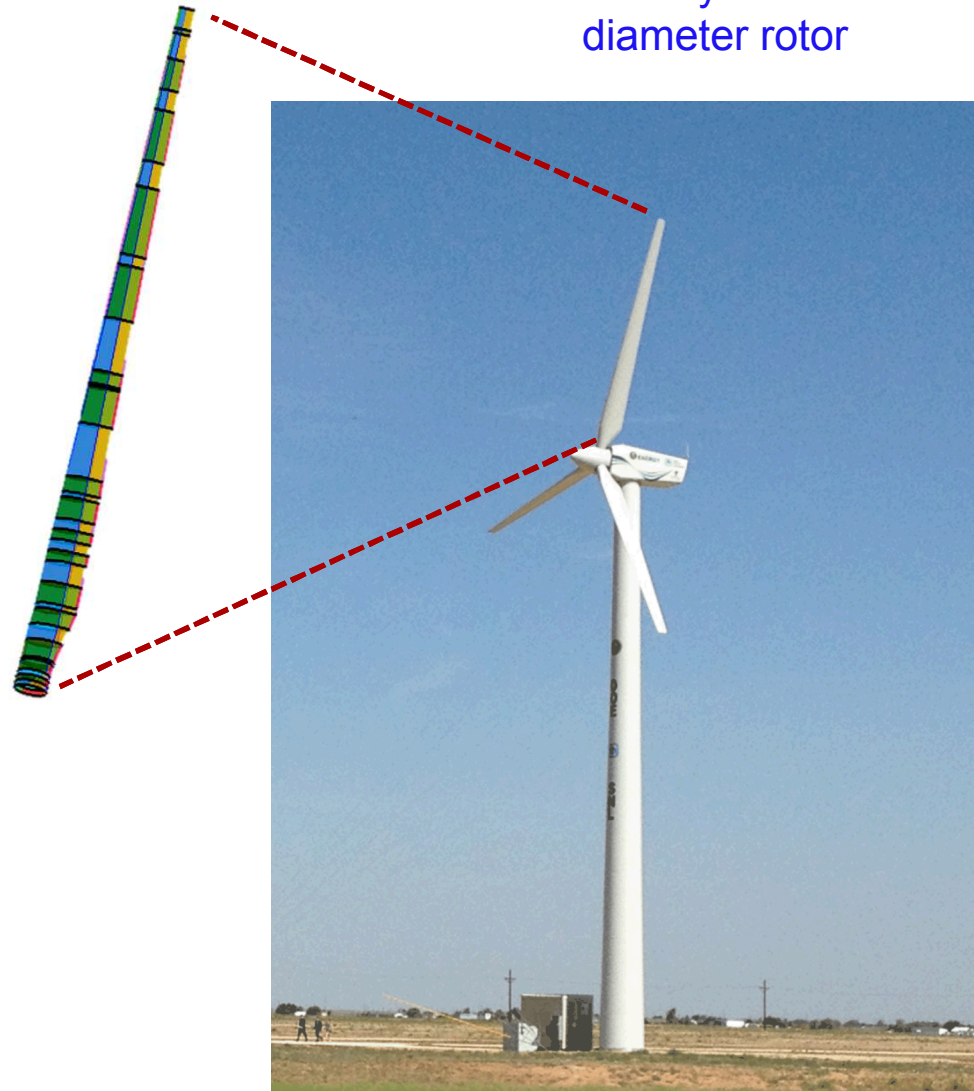
Blade Design Tools & System Modeling

- Design codes to analyze:
  - Structures
  - Aerodynamics
  - Control
  - Aero-servo-elastic stability
  - Manufacturing costs
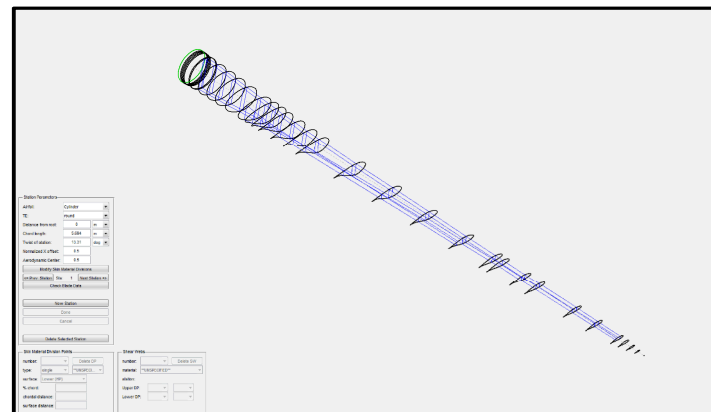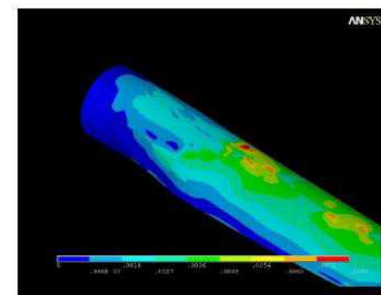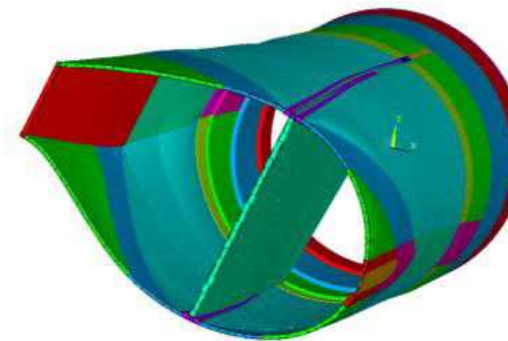
Introduction to NuMAD v2.0

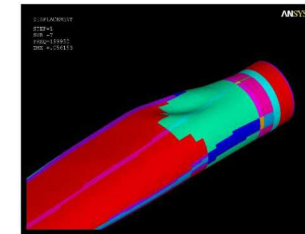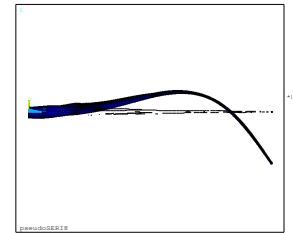## "Numerical Manufacturing And Design"

NuMAD Blade Design Tool
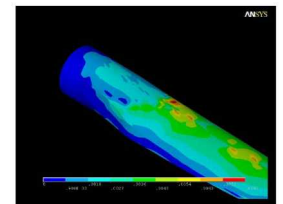

ANSYS Analysis

- Information manager for blade geometry, materials, and layup.

- Enables many types of analysis, including Finite Element Analysis in ANSYS
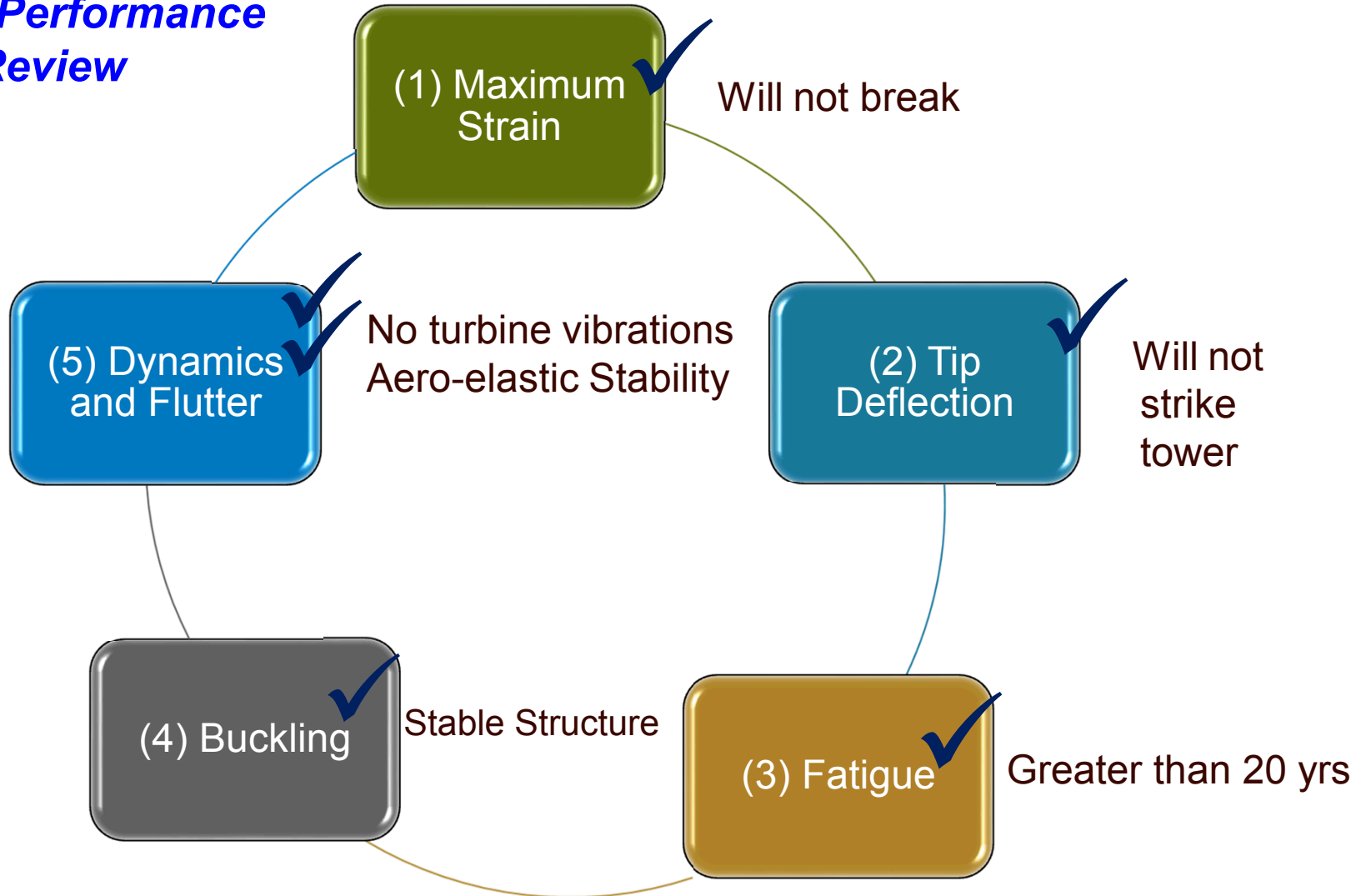
Modal

Buckling

Stress & Strain

NuMAD is an example of complementing existing codes with needed capabilities.

Blade Design Cycle

Design Performance Review

Repeat design loop until all design requirements are satisfied.

(1) Maximum Strain ✔ — Will not break

(2) Tip Deflection ✔ — Will not strike tower

(3) Fatigue ✔ — Greater than 20 yrs

(4) Buckling ✔ — Stable Structure

(5) Dynamics and Flutter ✔ — No turbine vibrations Aero-elastic Stability
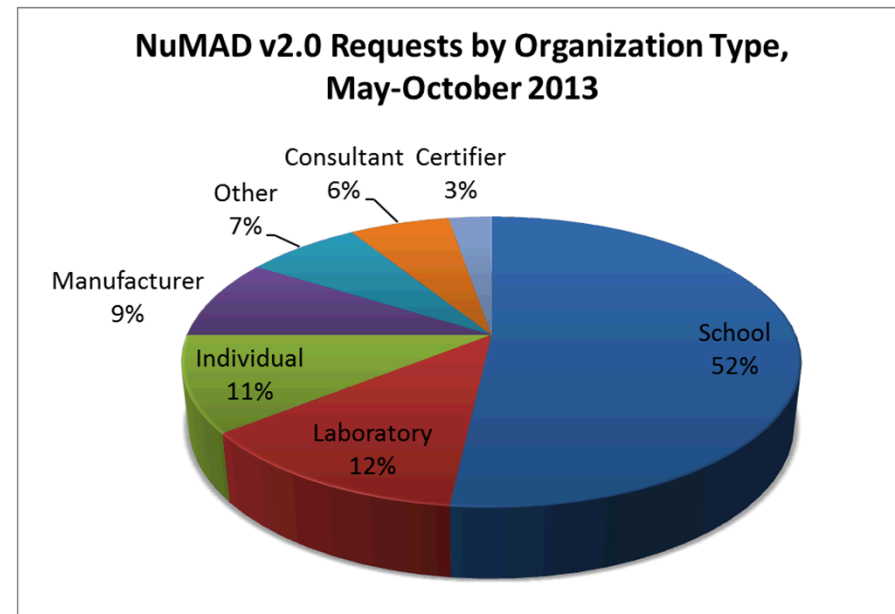
Sandia National Laboratories

Usage in the Wind Community

- Publicly Released NuMAD v2.0
  - Sandia's NuMAD tool began a complete overhaul in 2010.
  - It has been used internally since then with huge success.
 - It was released publicly in April 2013.
- Download Statistics
  - Requested by 112 users during 6 month timeframe (May-October)
  - 52% of requests from Academia
  - 12% of requests from Laboratories
  - Remaining 36% split between Individuals, Manufacturers, Consultants, Certifiers, and Other

NuMAD v2.0 Requests by Organization Type, May-October 2013

- Consultant 6%
- Certifier 3%
- Other 7%
- Manufacturer 9%
- Individual 11%
- Laboratory 12%
- School 52%

NuMAD was developed to meet the need for an **open-source** and **efficient tool** to create **high fidelity blade models**

NuMAD v2.0 Interface
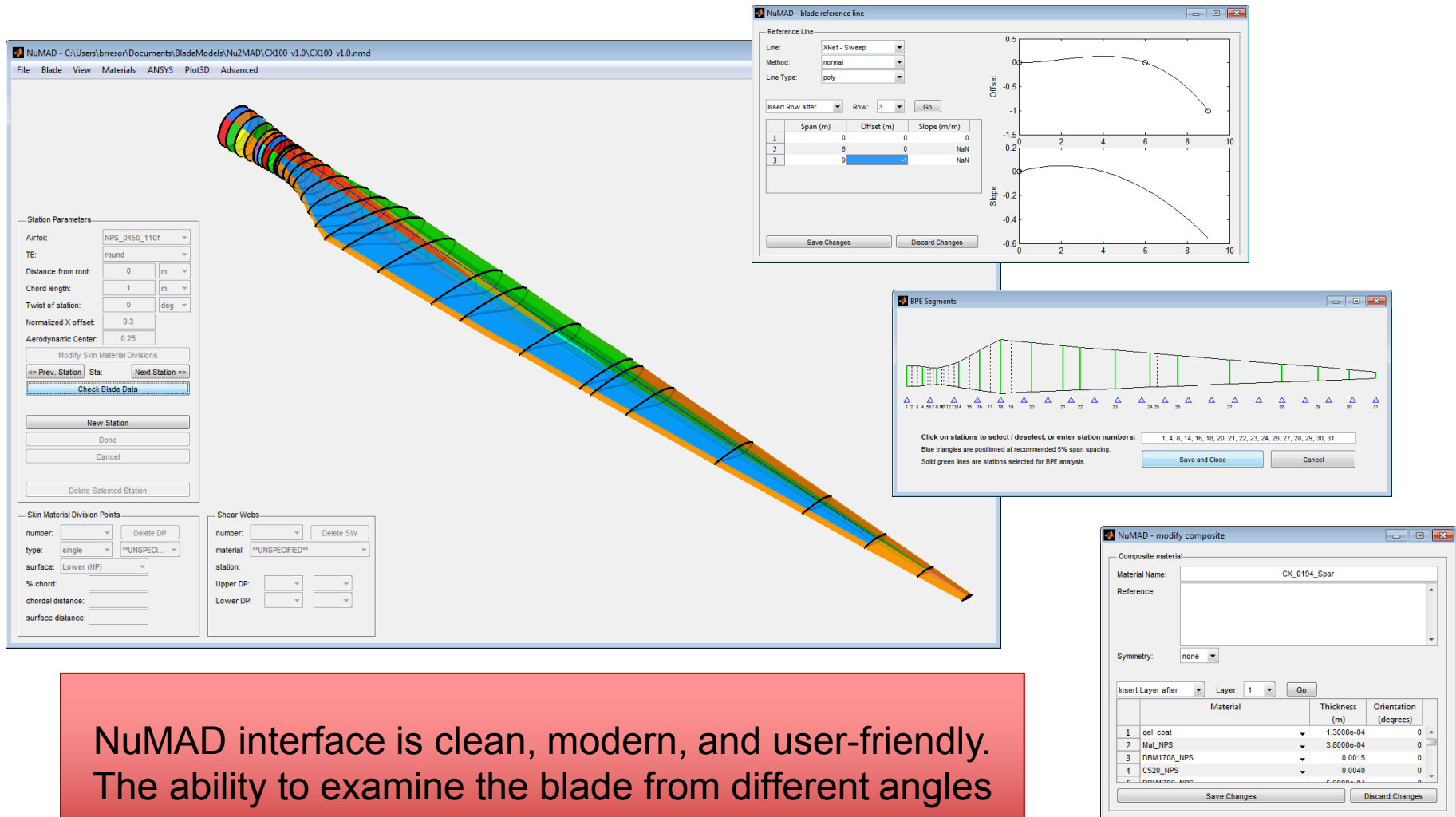
NuMAD interface is clean, modern, and user-friendly. The ability to examine the blade from different angles **saves time** and **reduces errors**.

Additional Features/Capabilities (1)

- **Output from NuMAD for CFD mesh generation**
  - **Enables CFD and structural analyses to originate from the same blade definition**
- **Implemented an improved classical flutter analysis tool**
  - **Capability is directly integrated within NuMAD**
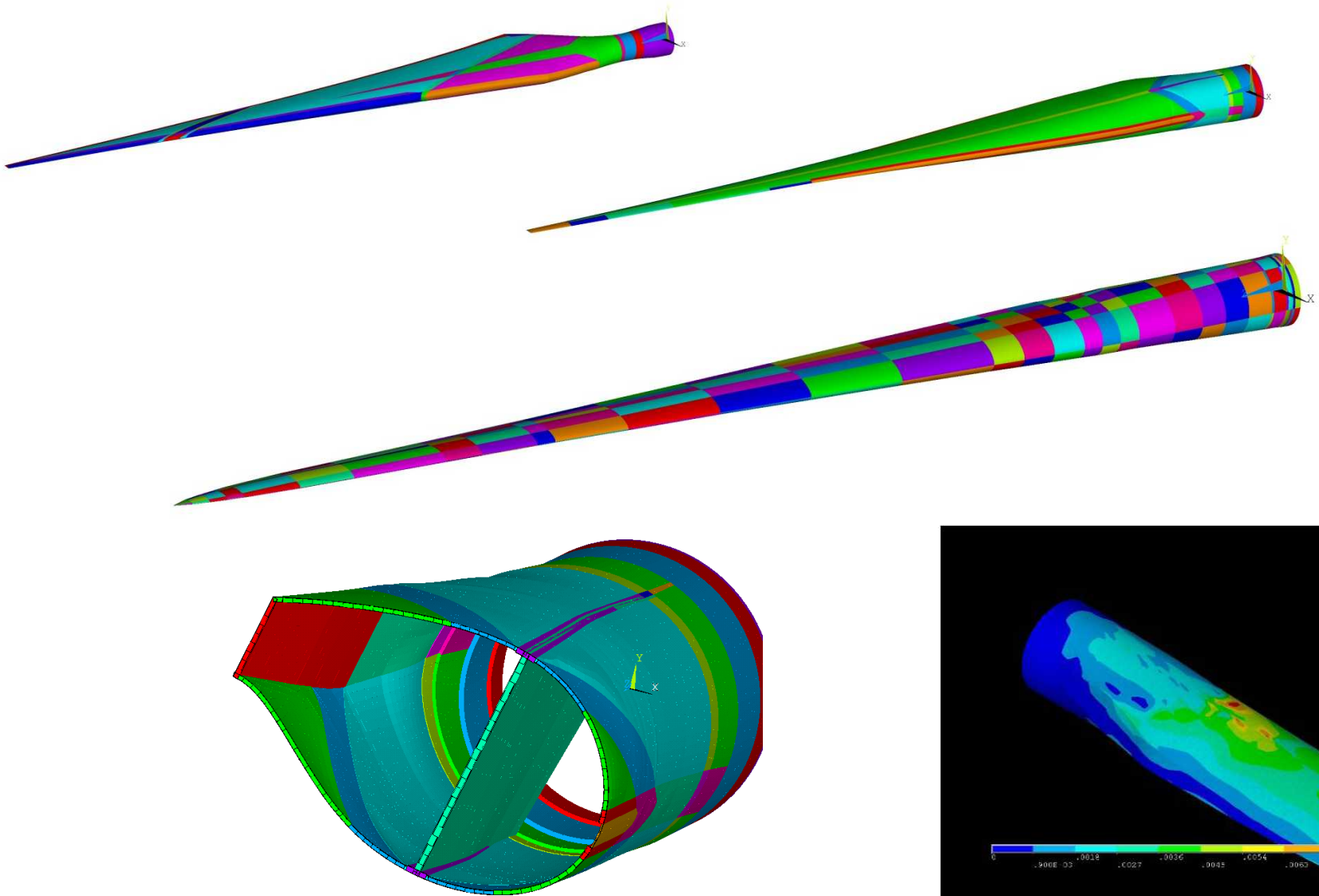 - **Enables "quick check" of wind blade flutter margins**
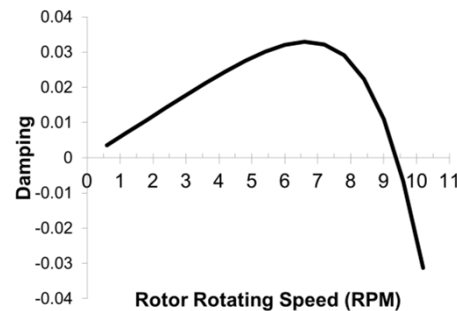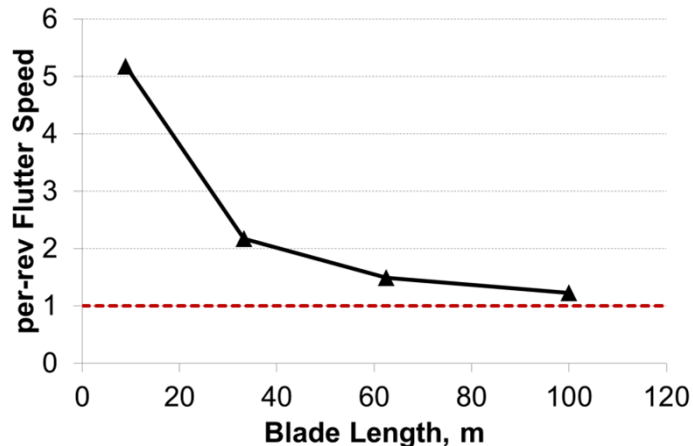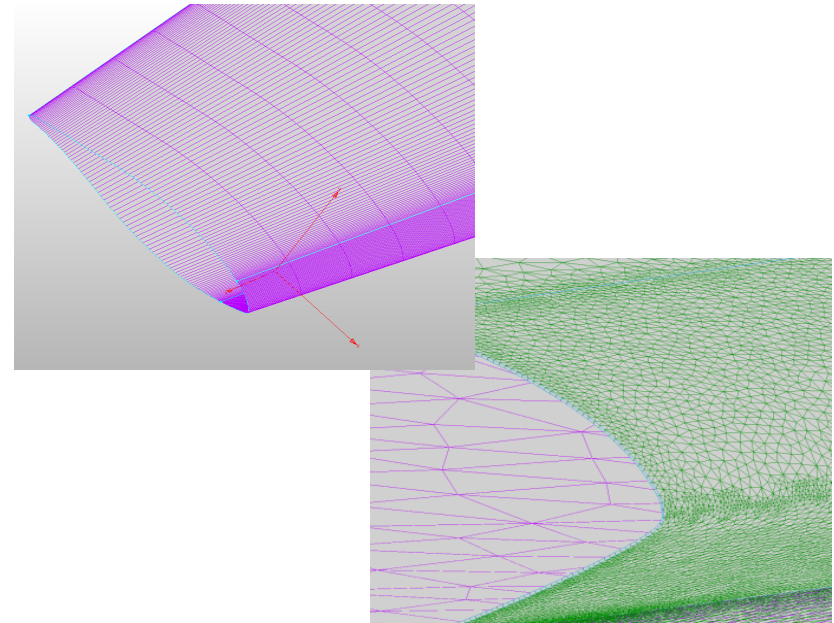
Additional Features/Capabilities (2)

- Developed new object-oriented approach to represent blade information

- Developed a combined aero-structural optimization framework
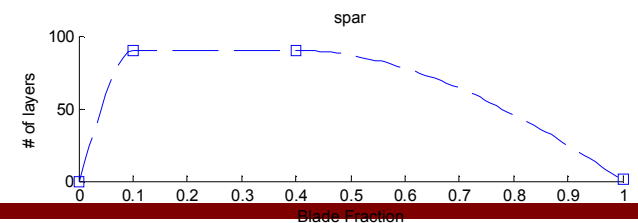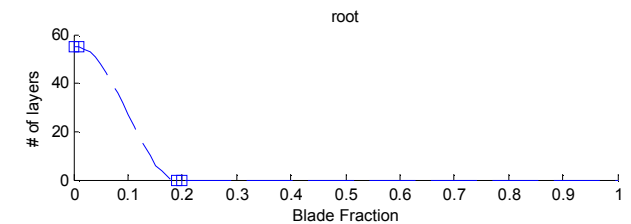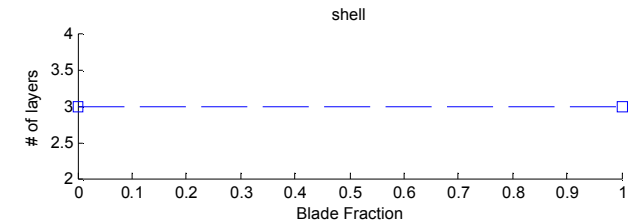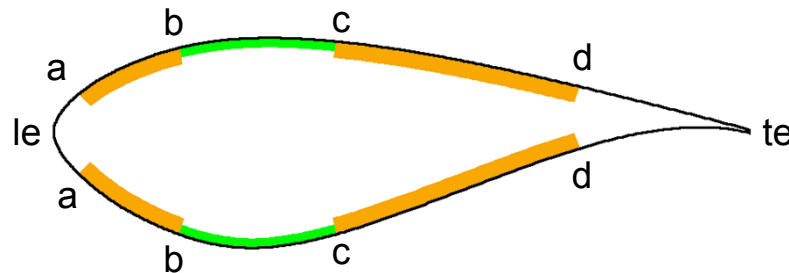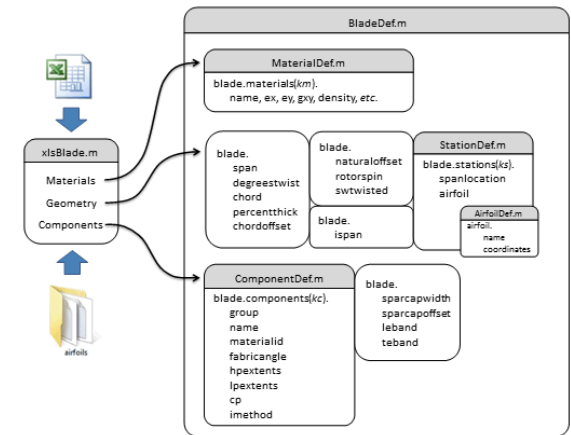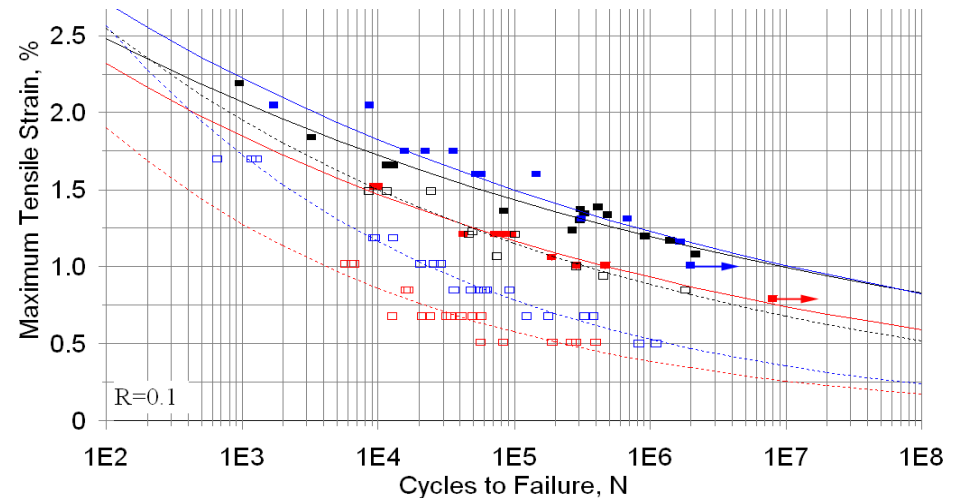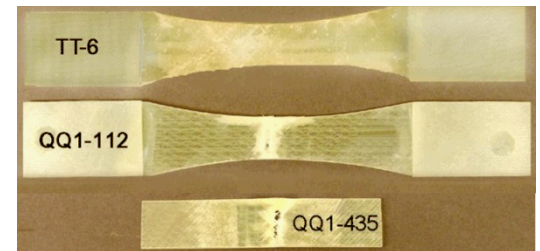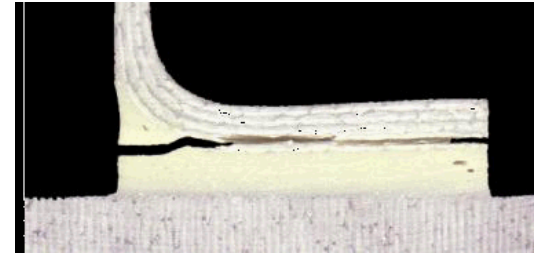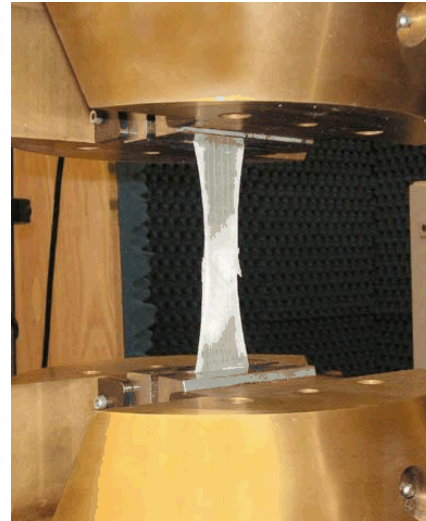
Example Applications of NuMAD

Supporting Capabilities to the NuMAD toolbox
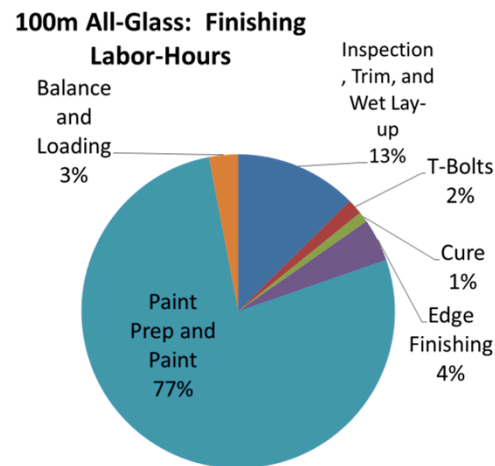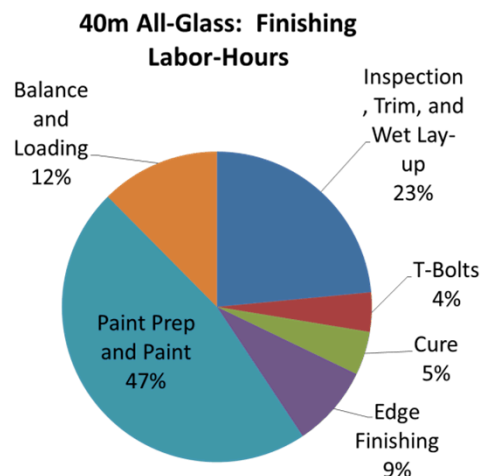
Composite Materials Database

Characterize static and fatigue properties of blade materials from suppliers (resins, fabrics, adhesives, cores), and laminates and structural details from blade manufacturers.

Results published in Composite Materials Database since 1989

Sandia Blade Manufacturing Cost Model (version 1.0)

- Components of the Model:
  - (1) Materials, (2) Labor, (3) Capital Equipment
  - Detailed Labor Breakdown by major operation
  - Reports: SAND2013-2733 & SAND2013-2734

40m All-Glass: Finishing Labor-Hours

- Balance and Loading 12%
- Inspection, Trim, and Wet Lay-up 23%
- T-Bolts 4%
- Cure 5%
- Edge Finishing 9%
- Paint Prep and Paint 47%

100m All-Glass: Finishing Labor-Hours

- Balance and Loading 3%
- Inspection, Trim, and Wet Lay-up 13%
- T-Bolts 2%
- Cure 1%
- Edge Finishing 4%
- Paint Prep and Paint 77%

One example: An analysis of labor costs shows the growth in labor hours for area-driven manufacturing tasks such as paint prep and paint as blades grow longer.

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Sandia VAWT Codes List

- **Geometry/Modeling & Post-processing**
  - VAWTGen Code
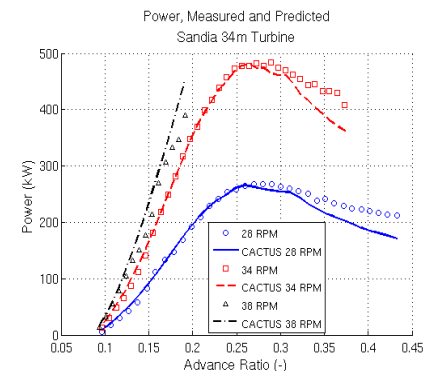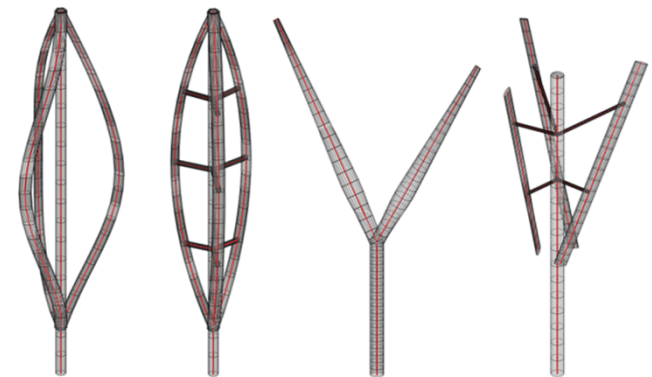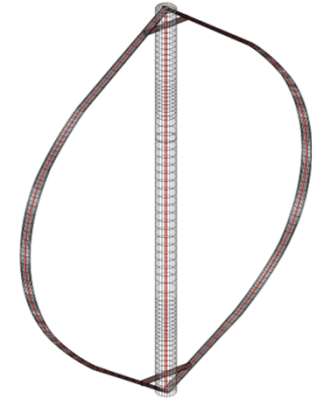
- **Aerodynamics**
  - CACTUS code

- **Structural Dynamics**
  - OWENS code
  - Features: Modal, Transient, Static

- **Hydrodynamics**
  - WaveEC2Wire code
  - Notes: Coupled with OWENS

Questions?