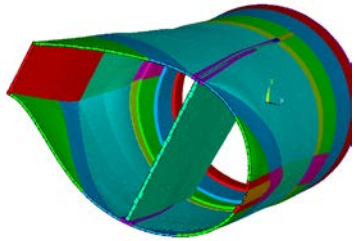
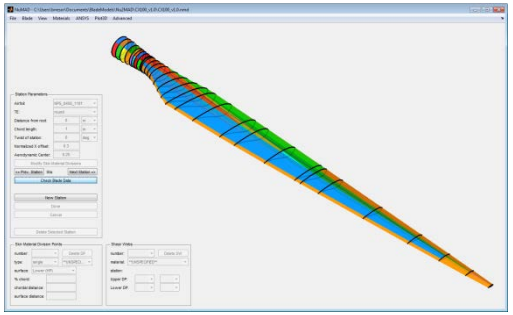
Exceptional service in the national interest

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***

U.S. DEPARTMENT OF ENERGY | NNSA

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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

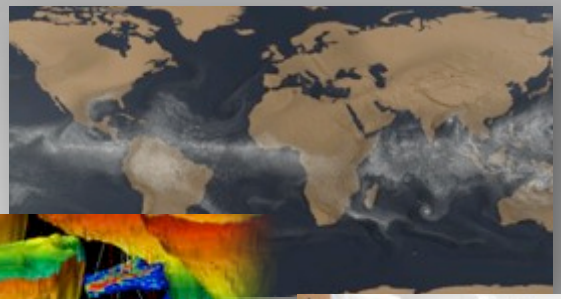
Sandia National Laboratories

Energy Research

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

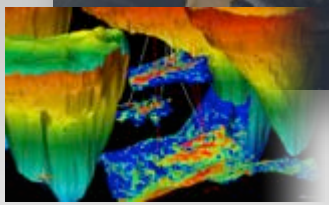
Climate & Environment

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

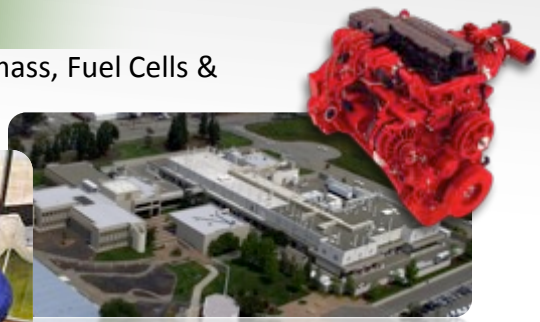


Renewable Systems & Energy Infrastructure

Renewable Energy, Energy Efficiency,
Grid and Storage Systems

Transportation Energy & Systems

Vehicle Technologies, Biomass, Fuel Cells & Hydrogen Technology

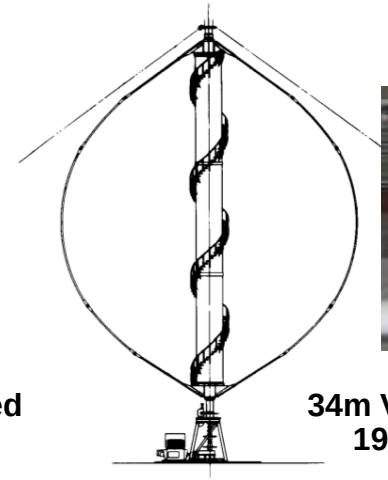


SNL Wind Program History

Sandia National Laboratories

28 Years of wind turbine rotor development

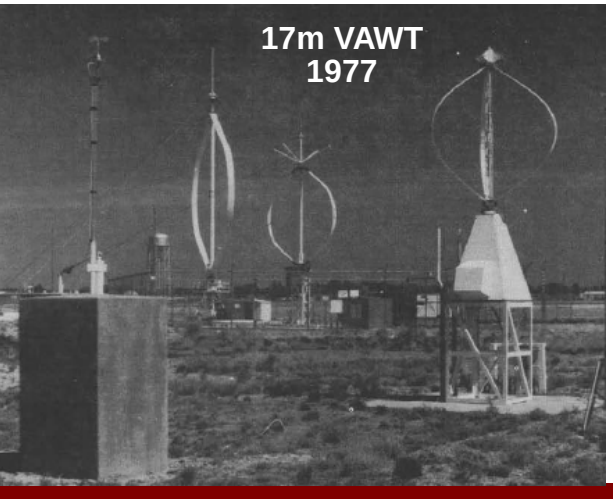
Wind Program Established 1975



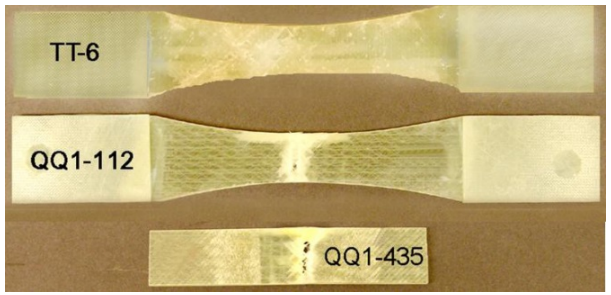
34m VAWT 1984

Blade Program 1994

SWiFT Facility 2013



Composite Materials Database 1988

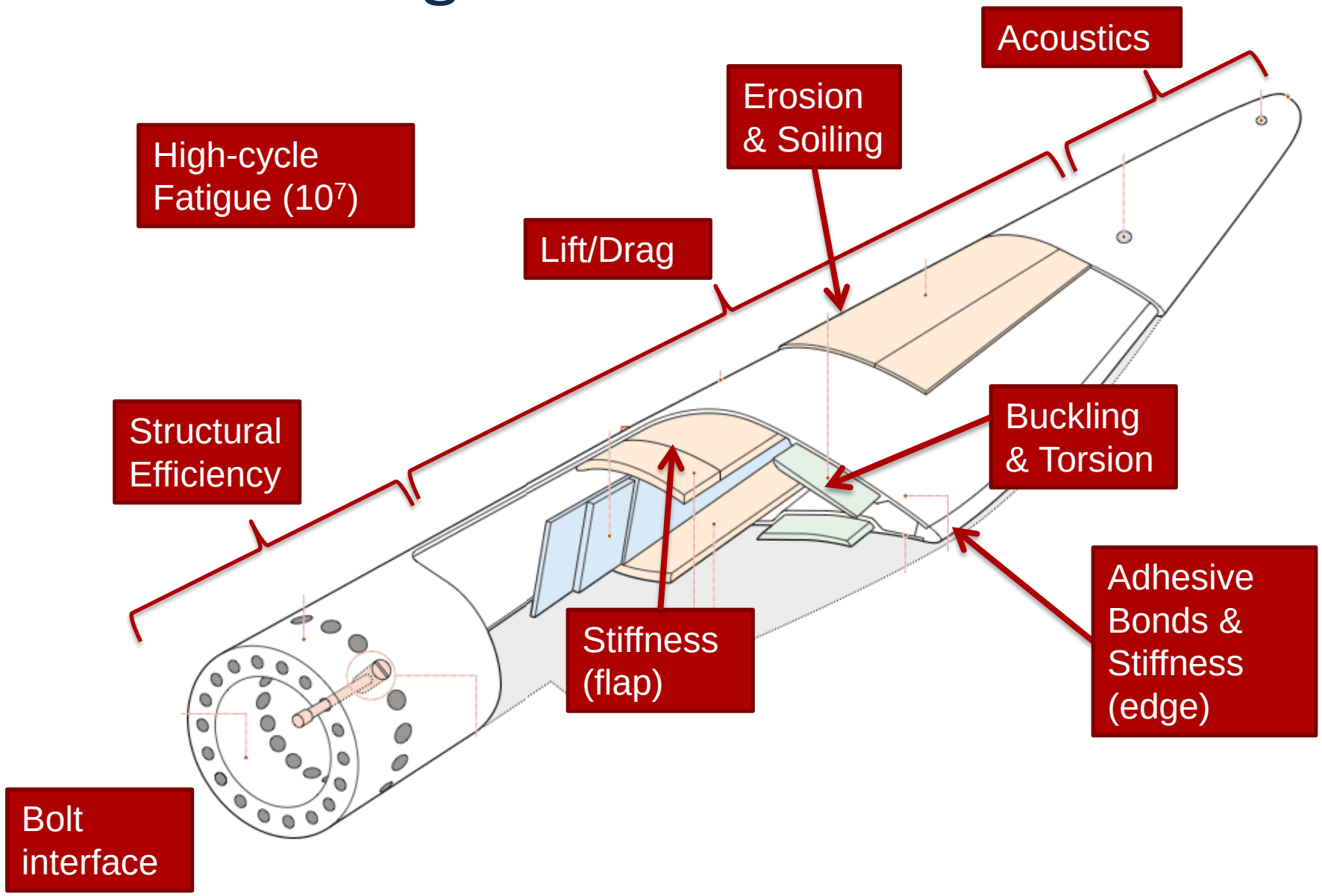


Advanced Manufacturing Initiative 2008

Sandia National Laboratories

Blade Trends

Blade Design Drivers

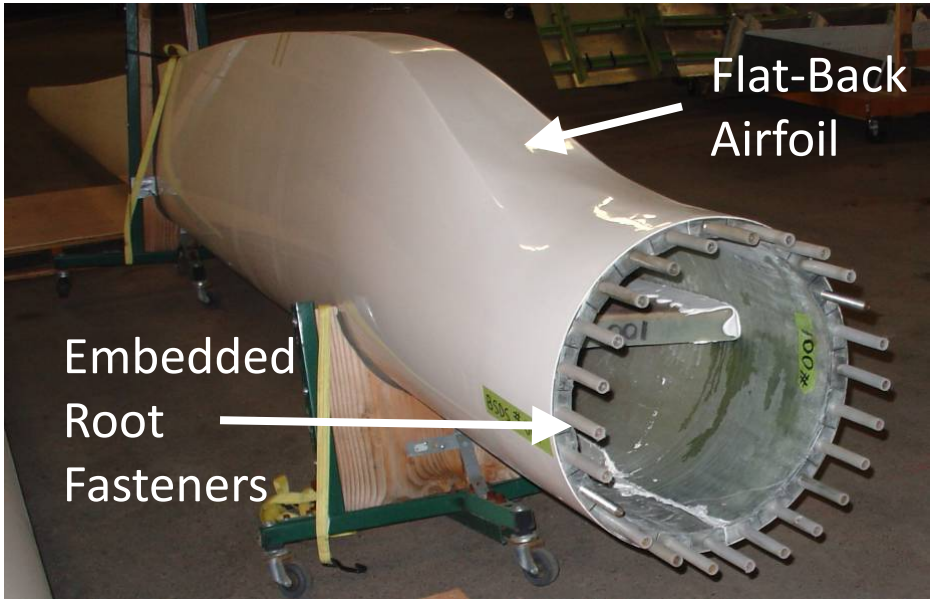


Source: Windpower Monthly July 2012

Sandia Blade Programs

Sandia National Laboratories

Aero-Structural Optimization



Blade System Design Study (BSDS) Blade

- Impact: Common in current production blades

Passive Load Alleviation

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

Sweep Twist Adaptive Rotor (STAR) Blade

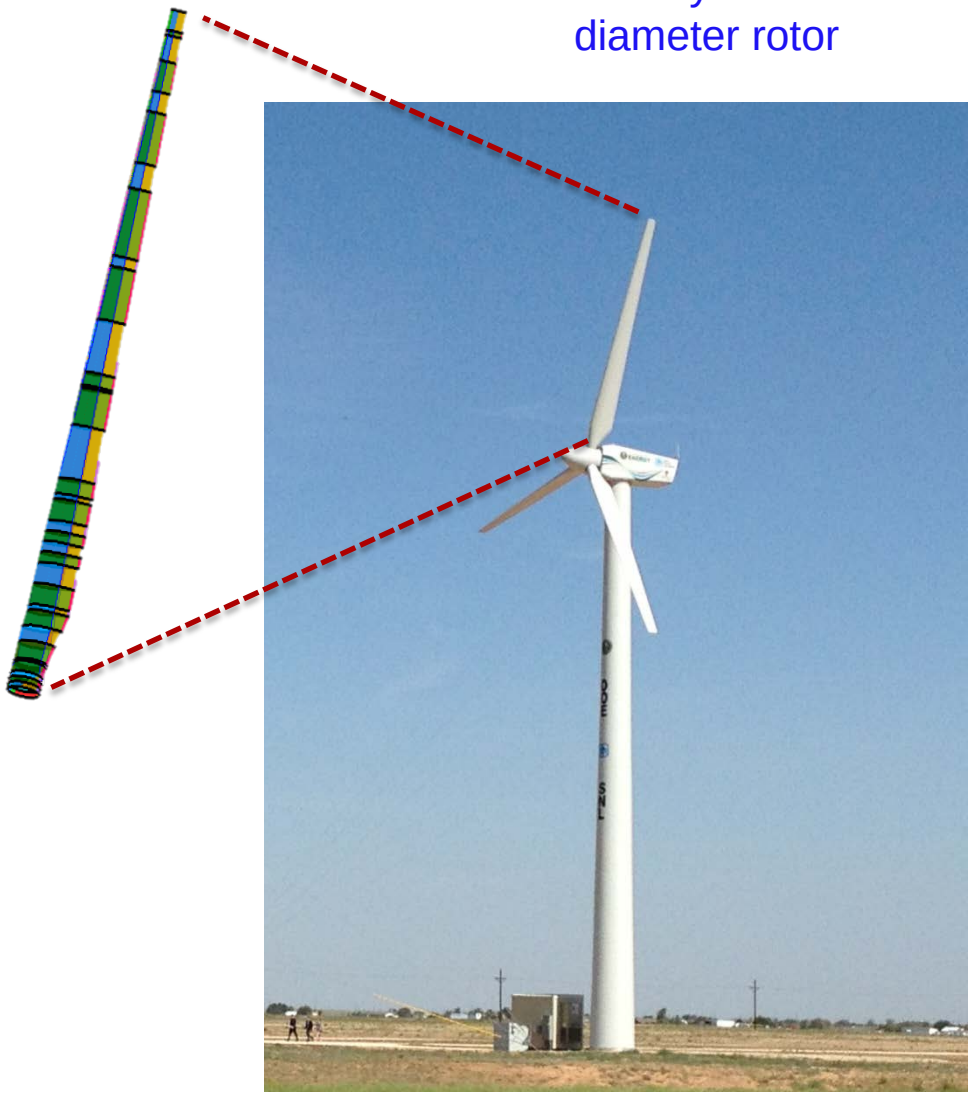
- Industry impact: Several current production and concept blades use this technology

National Rotor Testbed (Current)

Sandia National Laboratories

- 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

Nominally 27 meter diameter rotor



Blade Design Tools & System Modeling

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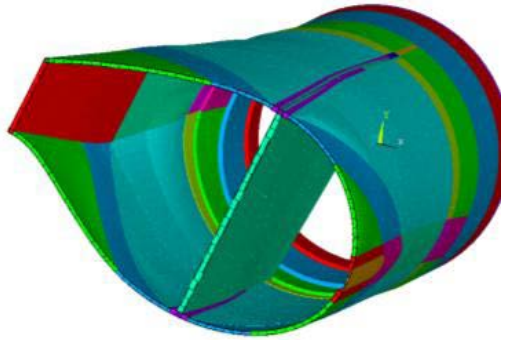
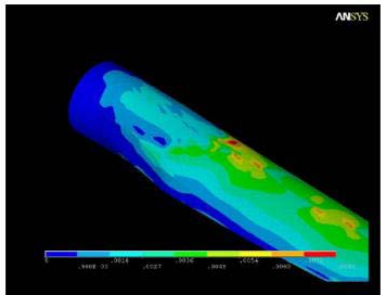
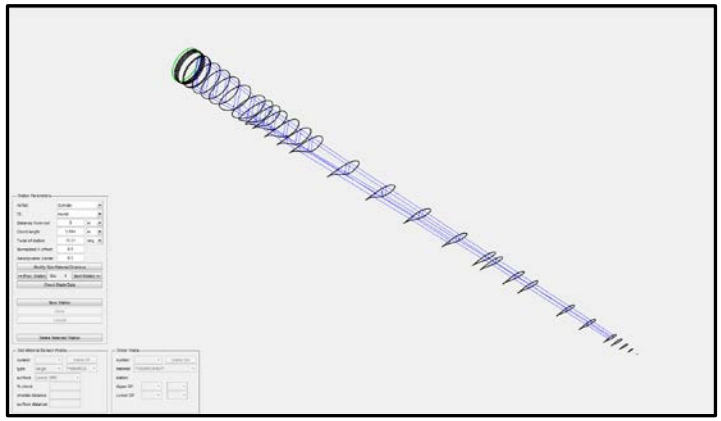
- Design codes to analyze:
  - Structures
  - Aerodynamics
  - Control
  - Aero-servo-elastic stability
  - Manufacturing costs







Sandia National Laboratories

Introduction to NuMAD v2.0

"Numerical Manufacturing And Design"

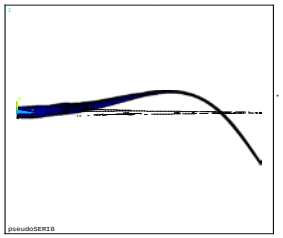
NuMAD Blade Design Tool

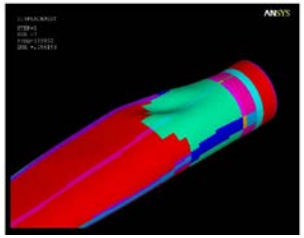
- Information manager for blade geometry, materials, and layup.
- Enables many types of analysis, including Finite Element Analysis in ANSYS

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

ANSYS Analysis

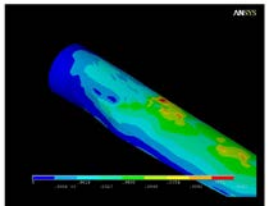
Modal





Buckling

Stress & Strain



Blade Design Cycle

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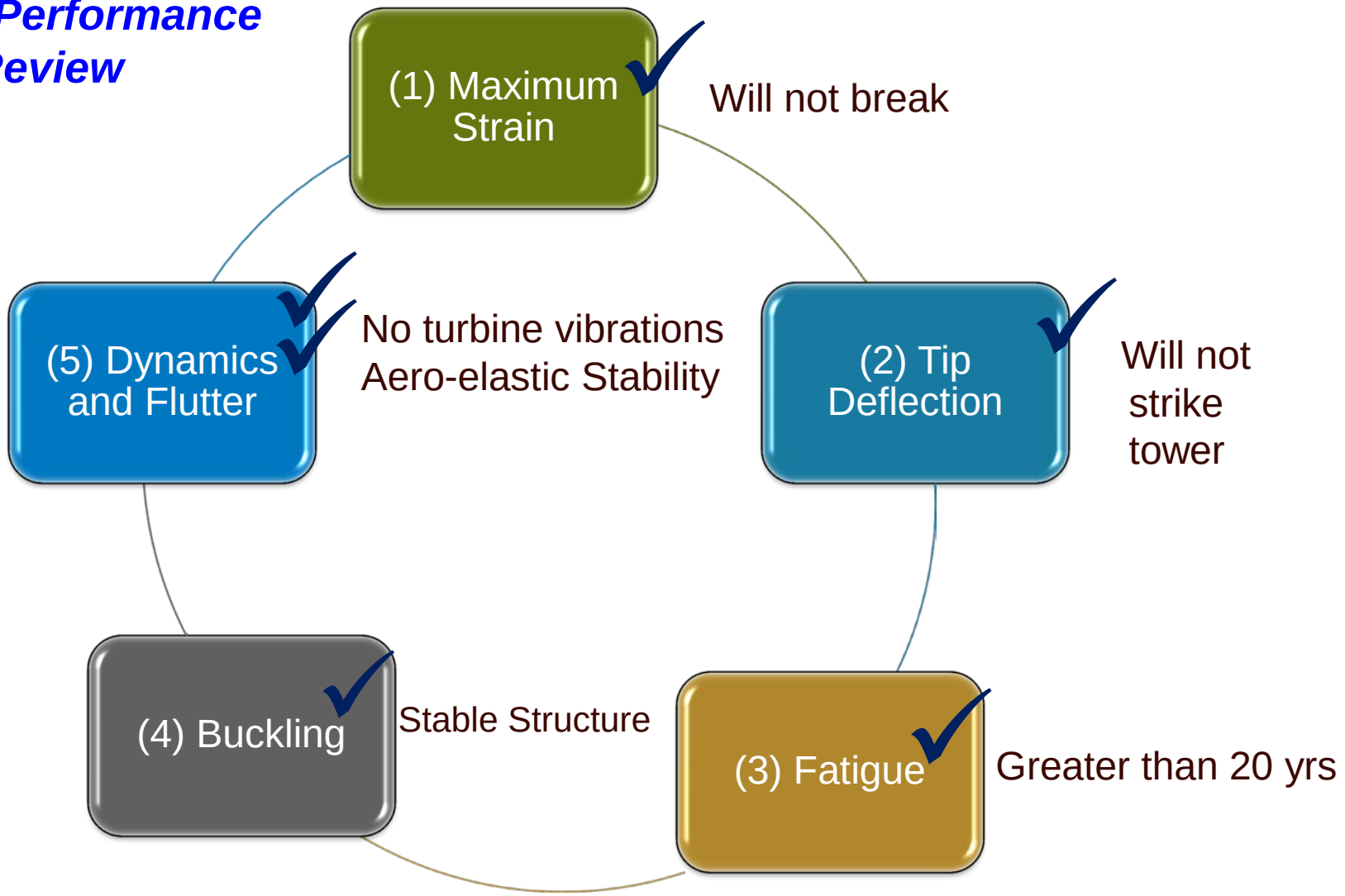
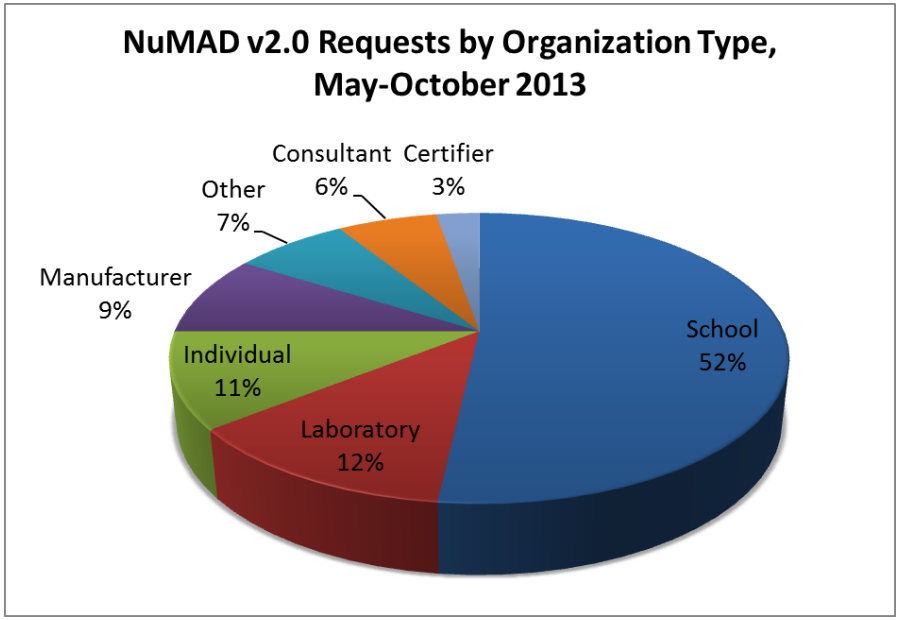
Repeat design loop until all design requirements are satisfied.

Design Performance Review



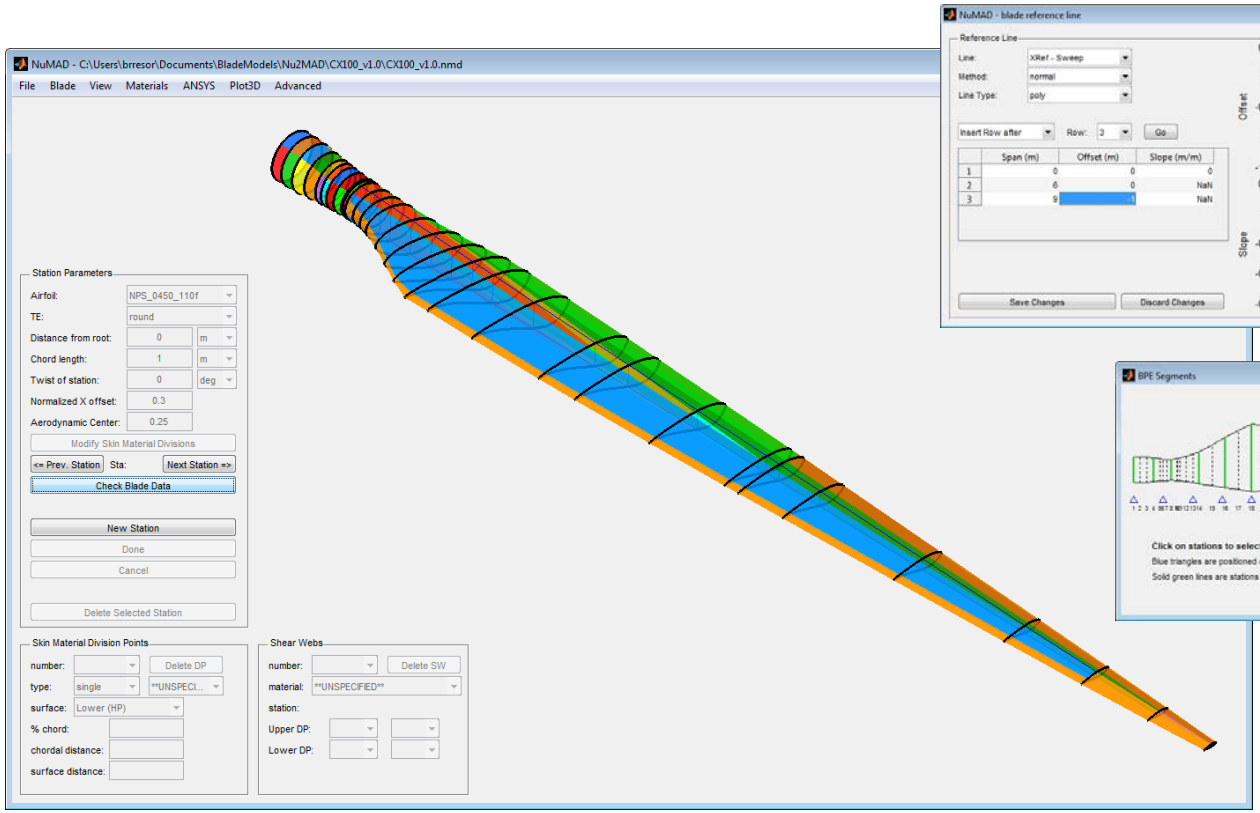
Usage in the Wind Community

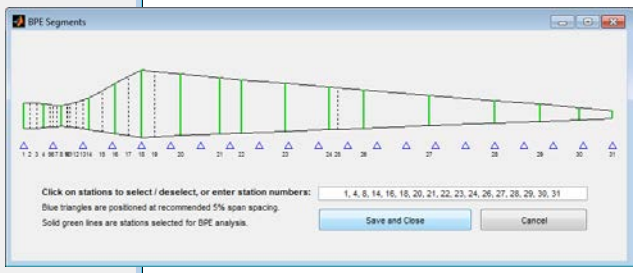
- Publicly Released NuMAD v2.0
  - Sandia's NuMAD tool began a complete overhaul in 2010.
  - It has been used internally since then with huge success.
  - It was released publicly in April 2013.
- Download Statistics
  - Requested by 112 users during 6 month timeframe (May-October)
  - 52% of requests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

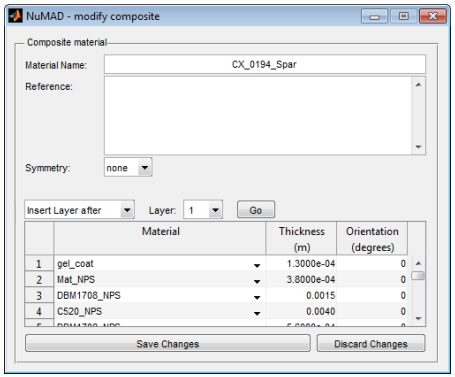


NuMAD was developed to meet the need for an **open-source** and **efficient tool** to create **high fidelity blade models**

NuMAD v2.0 Interface



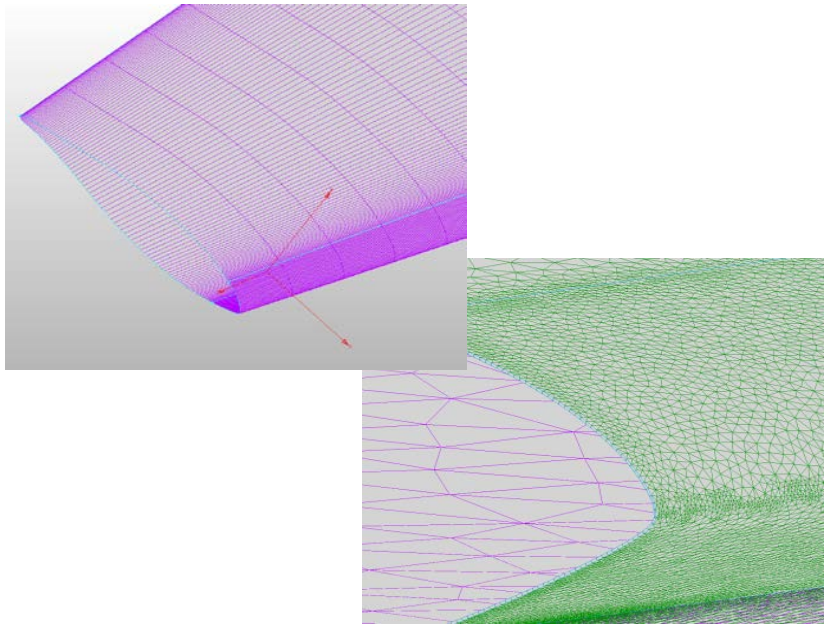


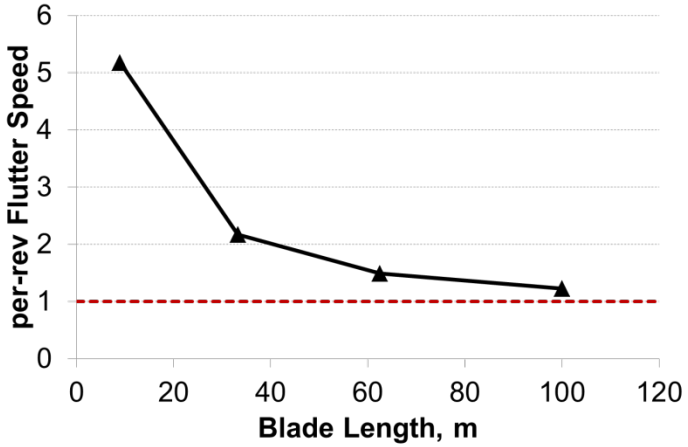


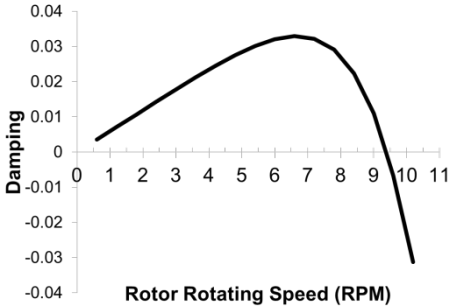
NuMAD interface is clean, modern, and user-friendly. The ability to examine the blade from different angles **saves time** and **reduces errors**.

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

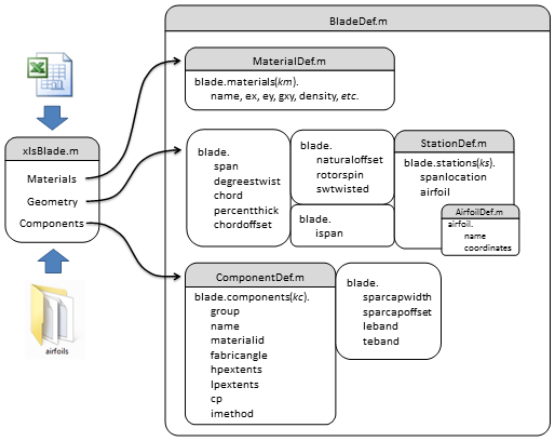


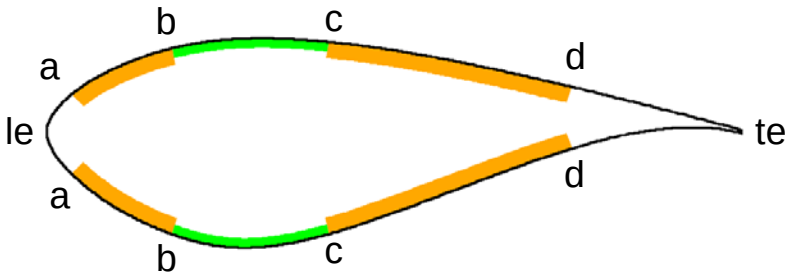


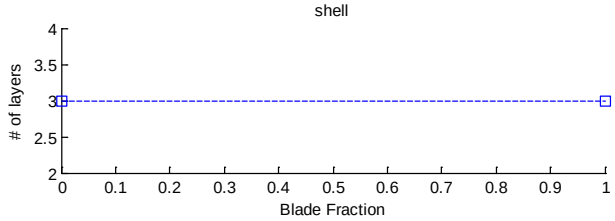


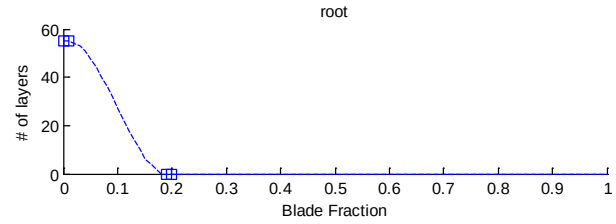
Additional Features/Capabilities (2)

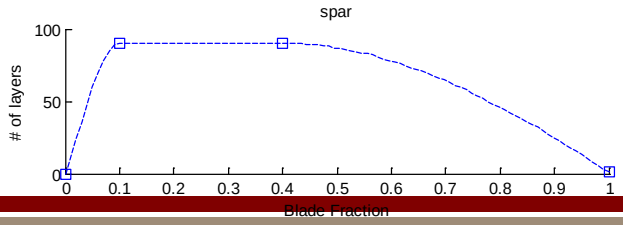
- Developed new object-oriented approach to represent blade information
- Developed a combined aero-structural optimization framework











Example Applications of NuMAD

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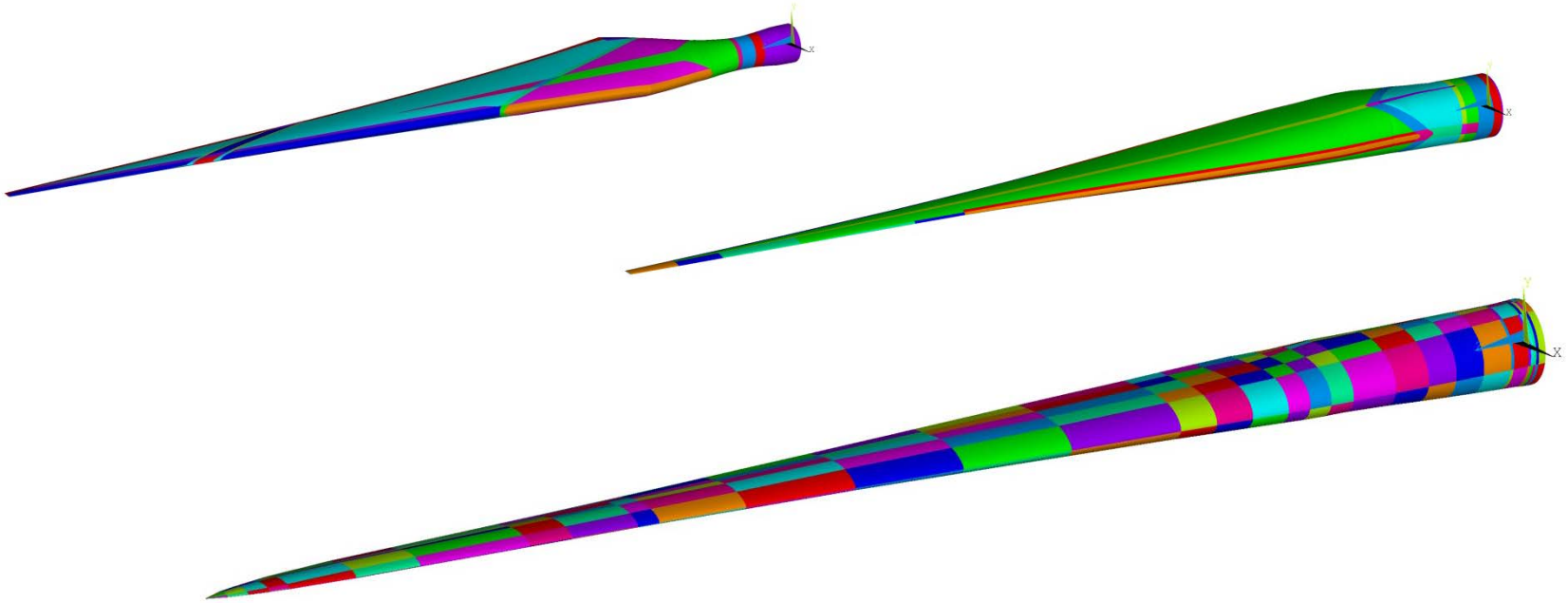

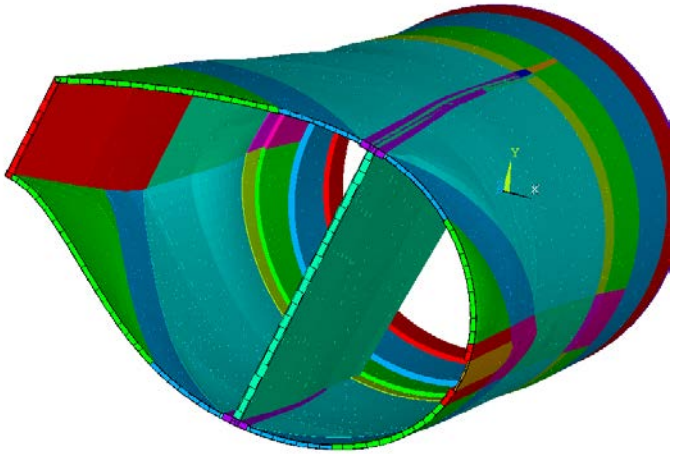

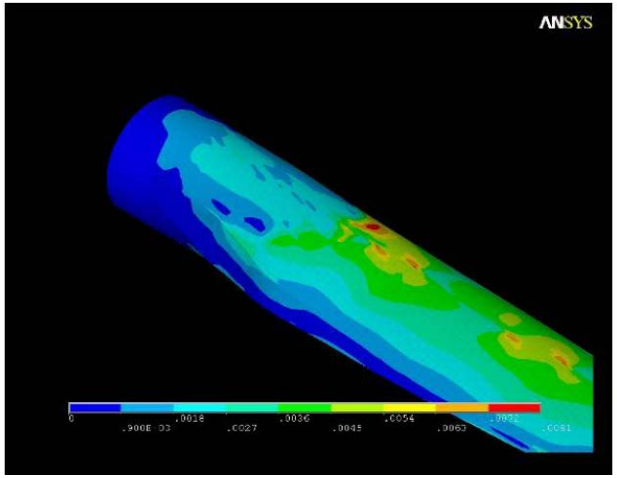

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Supporting Capabilities to the NuMAD toolbox

Composite Materials Database

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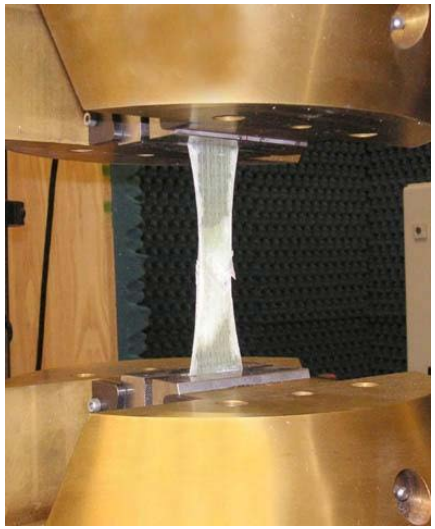
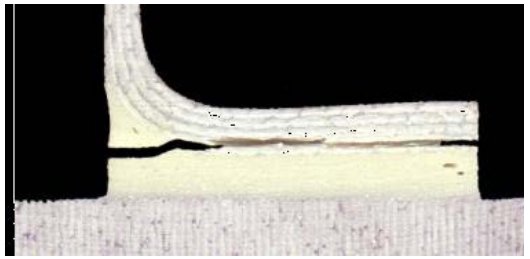
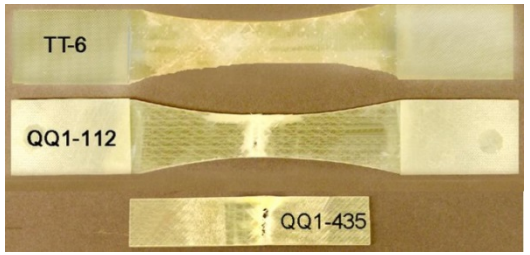
Characterize static and fatigue properties of blade materials from suppliers (resins, fabrics, adhesives, cores), and laminates and structural details from blade manufacturers.

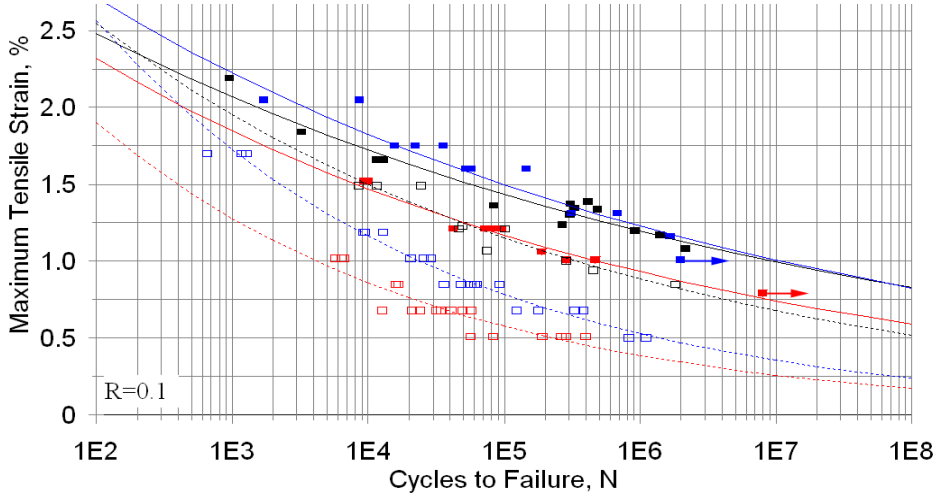
Results published in Composite Materials Database since 1989

MONTANA STATE UNIVERSITY



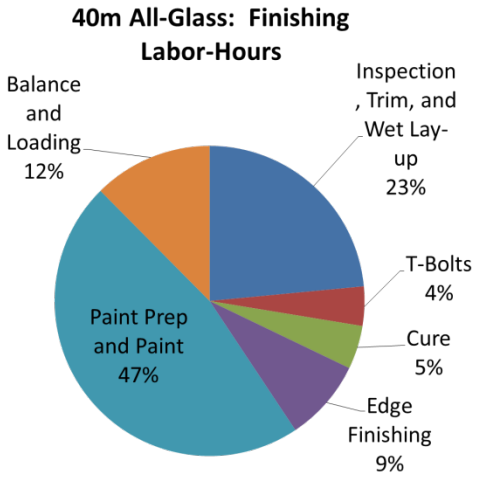


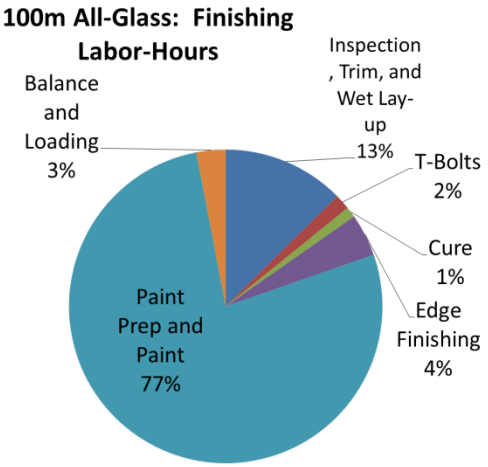




Sandia Blade Manufacturing Cost Model (version 1.0)

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

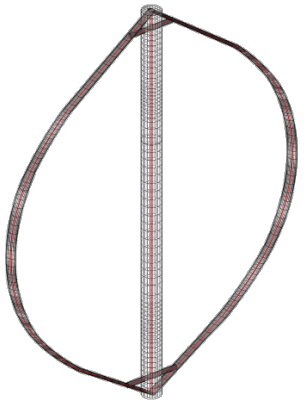


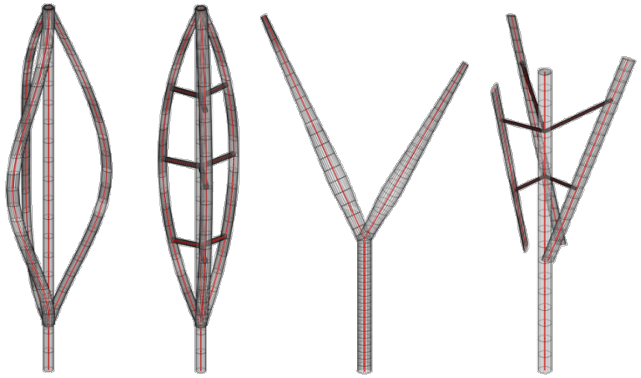


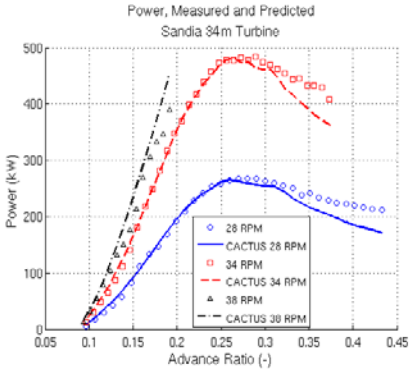
One example: An analysis of labor costs shows the growth in labor hours for area-driven manufacturing tasks such as paint prep and paint as blades grow longer.

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?

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