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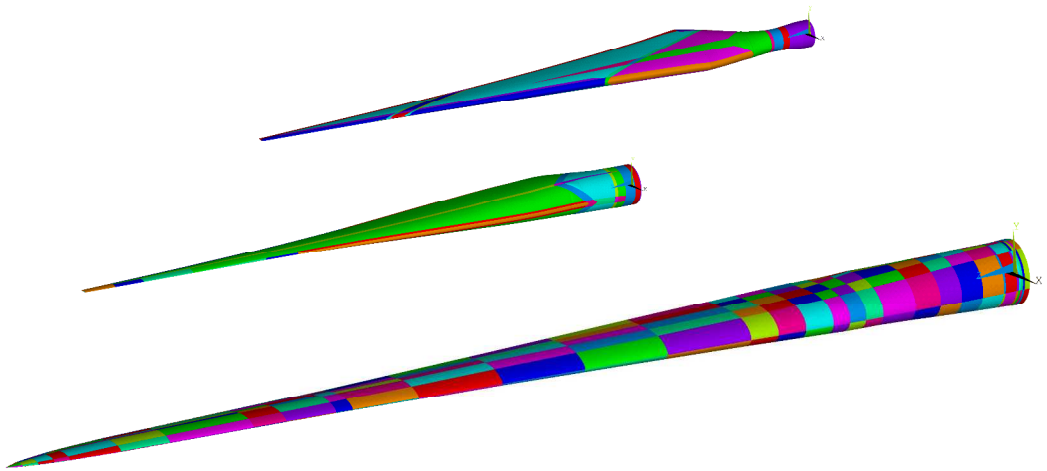

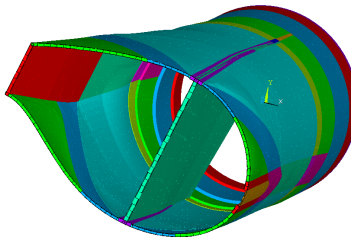

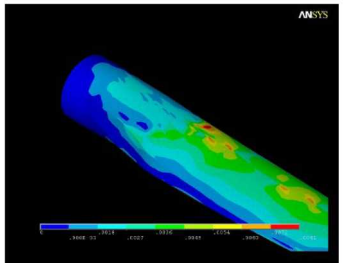

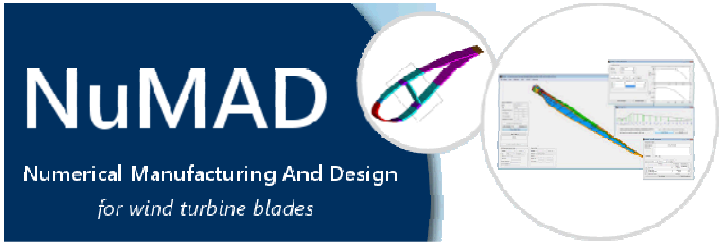

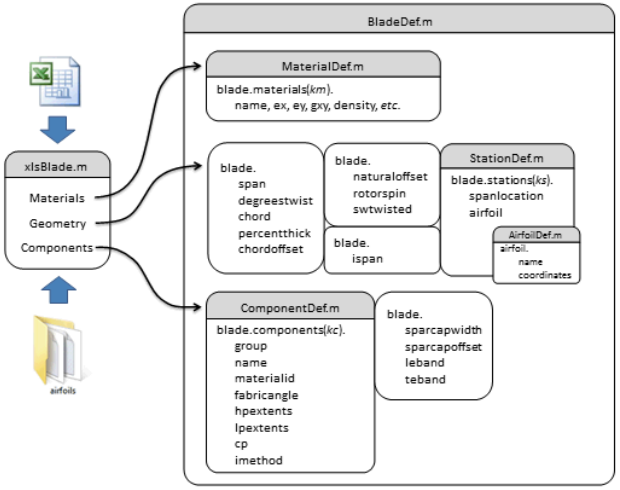

Blade Design Tools and System Analysis

Jonathan Berg

Sandia National Laboratories

jcberg@sandia.gov / 505-284-0905

25 March 2014

Purpose & Objectives

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Problem Statement:

Provide open-source state-of-the-art simulation and analysis tools that researchers need to meet the technical challenges of multi-disciplinary rotor projects.

Impact of Project:

- Enable Sandia projects to have access to cutting edge simulation capabilities
- Inform and enable the entire research community in cutting edge methodologies and algorithms for effective simulation and analysis

This project aligns with the following DOE Program objectives and priorities

- **Optimize Wind Plant Performance:** Reduce Wind Plant Levelized Cost of Energy (LCOE)
- **Accelerate Technology Transfer:** Lead the way for new high-tech U.S. industries
- **Modeling & Analysis:** Conduct wind techno-economic and life-cycle assessments to help program focus its technology development priorities and identify key drivers and hurdles for wind energy technology commercialization

Technical Approach

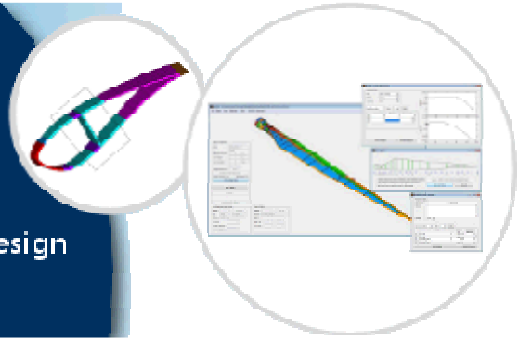
- Complementary and Efficient
  - Utilize a hybrid of existing external design codes and in-house developments
  - Complement the NREL NWTC Design Codes and commercially available codes with software toolboxes to increase our efficiency
  - Create new capabilities only when needed capabilities do not exist
- Modular and Object-Oriented
  - Enable highly effective and flexible **parametric systems analyses** by creating capabilities that can be connected and utilized as needed to fit the problem
  - "Object-oriented" is more than a buzzword; this programming convention **logically breaks down problems** and **manages how data and methods interact**

NuMAD Blade Design Tool

NuMAD

Numerical Manufacturing And Design

for wind turbine blades

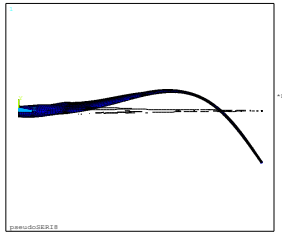


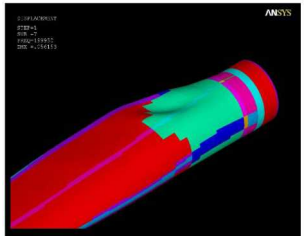
ANSYS

ANSYS Analysis

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

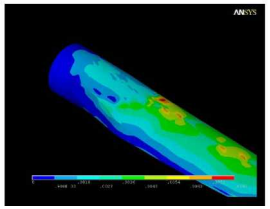
Modal





Buckling

Stress & Strain



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

Accomplishments and Progress

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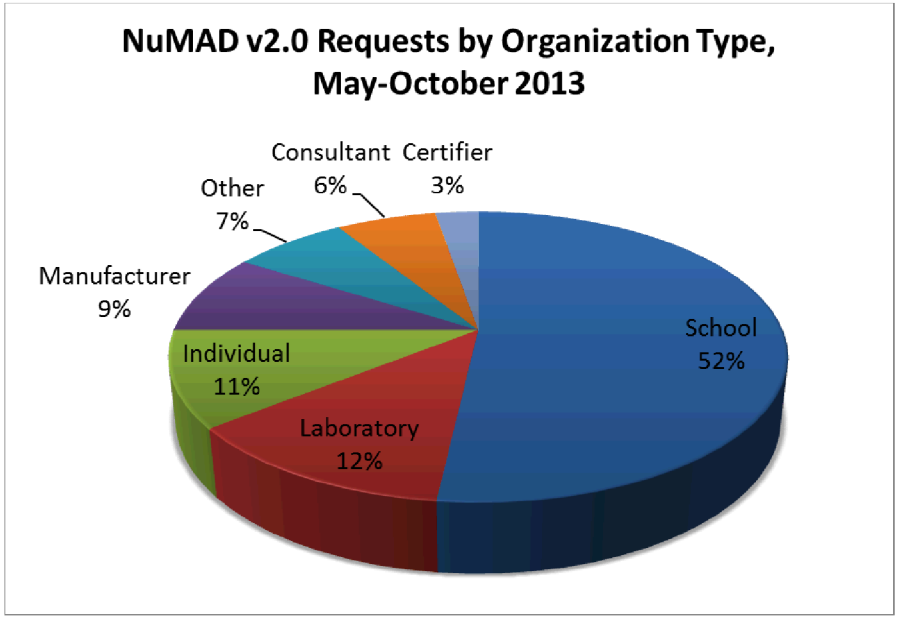
- Publicly Released NuMAD v2.0
  - Sandia's NuMAD tool began a complete overhaul in 2010.
  - It has been used internally since then with huge success.
  - It was released publicly in April 2013.
- Download Statistics
  - Requested by 112 users during 6 month timeframe (May-October)
  - 52% of requests 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

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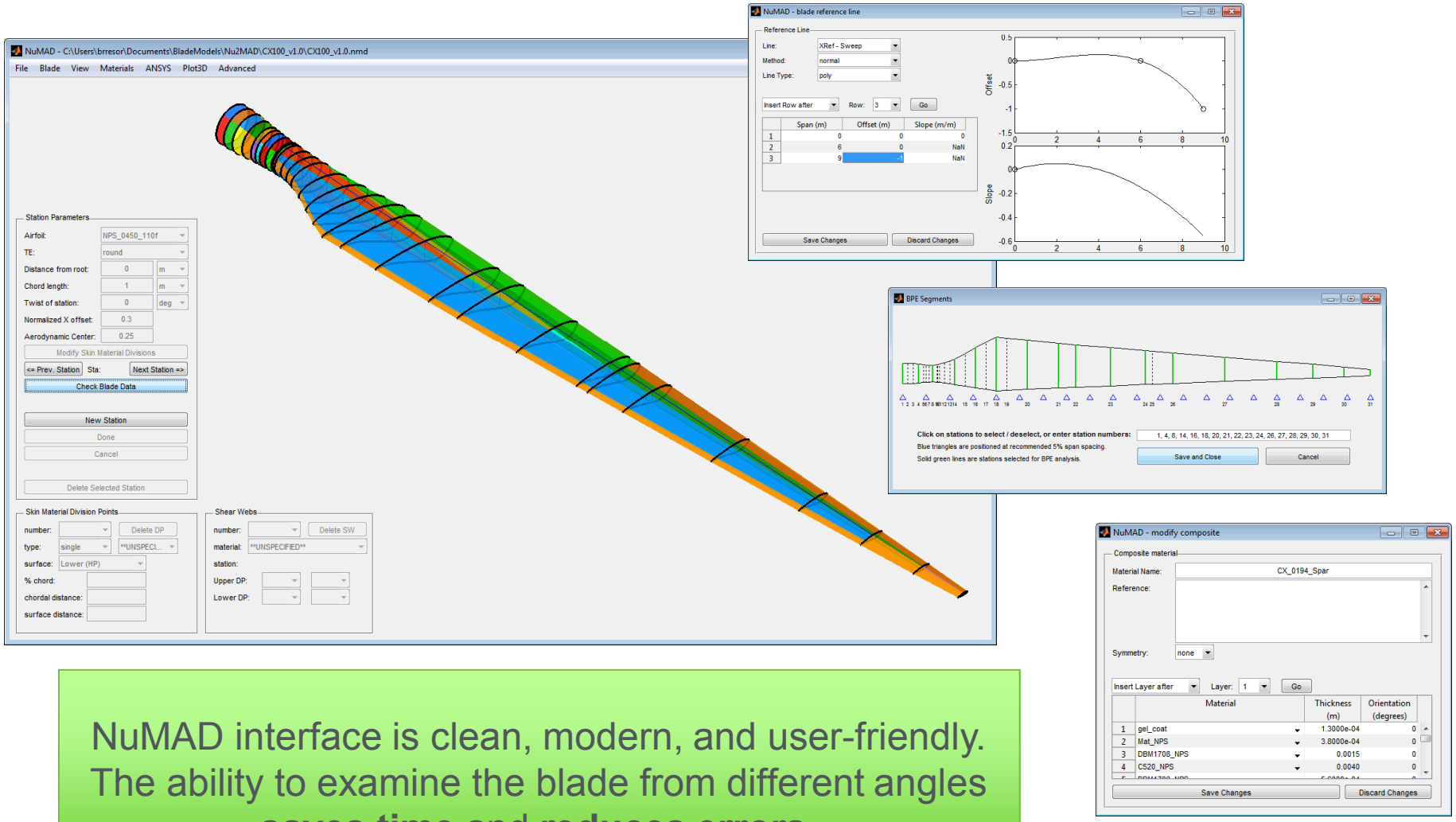

NuMAD interface is clean, modern, and user-friendly. The ability to examine the blade from different angles **saves time** and **reduces errors**.

Accomplishments (FY12)

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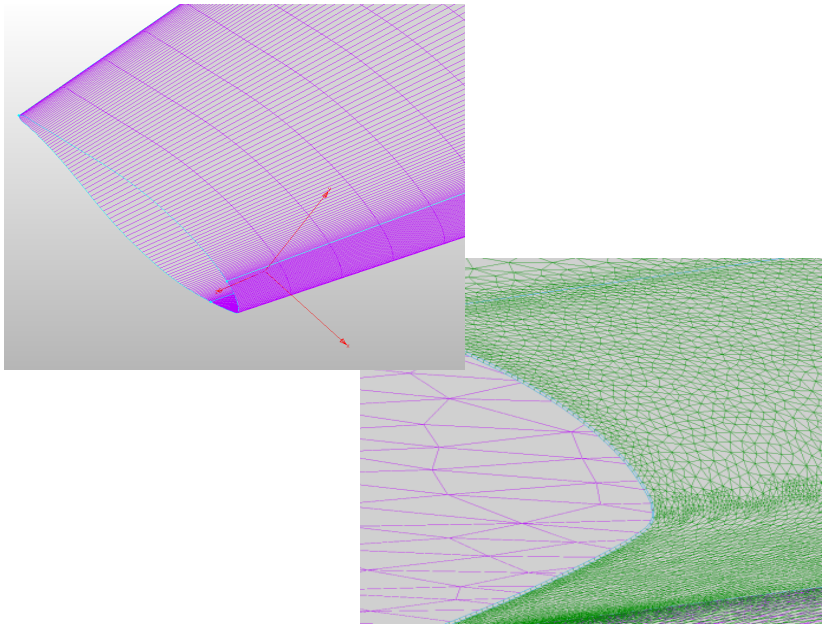
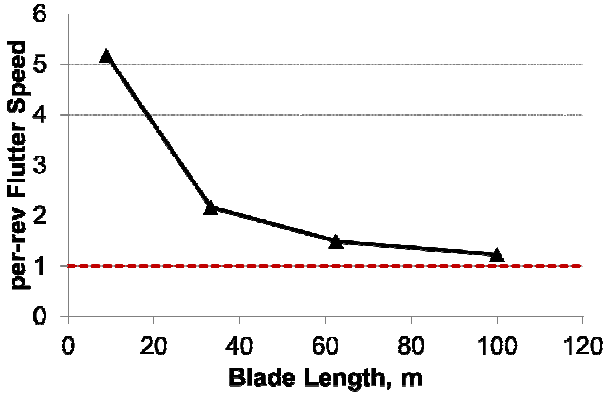
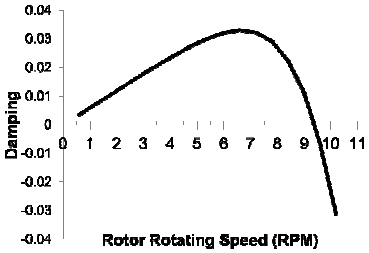
- Output from NuMAD for CFD mesh generation
  - Suggested by user feedback
  - Enables CFD and structural analyses to originate from the same blade definition
- Implement an improved classical flutter analysis tool
  - Capability is directly integrated within NuMAD
  - Enables "quick check" of wind blade flutter margins
  - Applicable to very large blades







Accomplishments (FY13)

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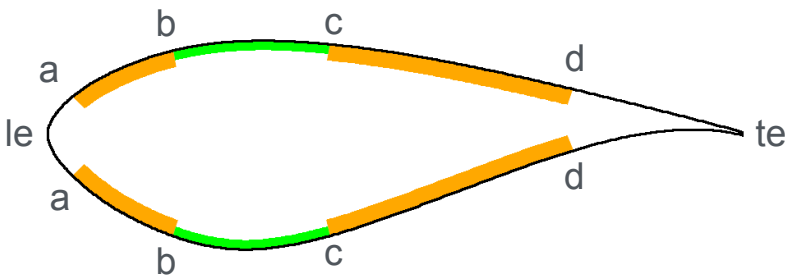
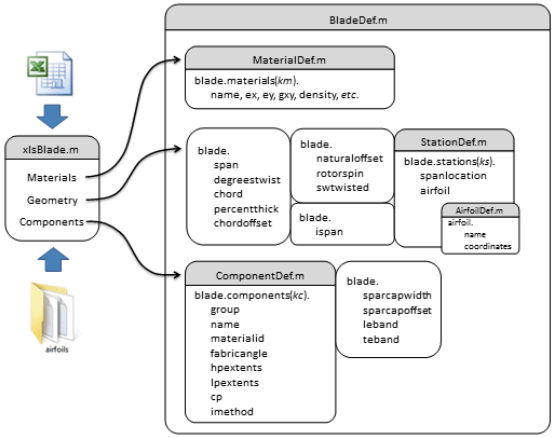
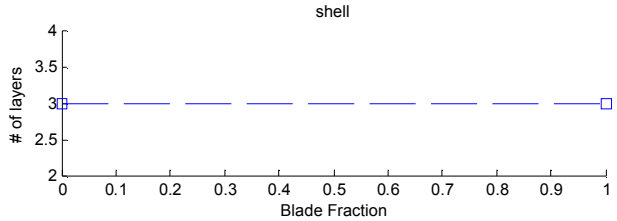
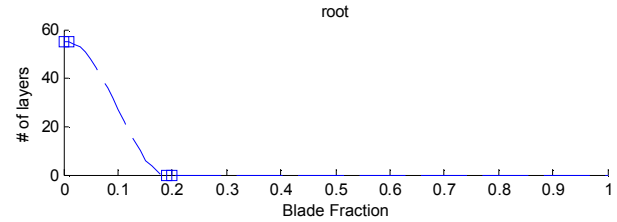
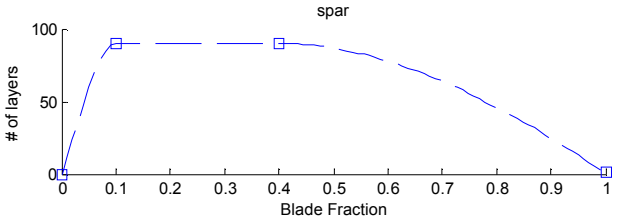
- FY13 activities funded by individual projects (rather than making Design Tools development a separate project)
- Needs of the National Rotor Testbed drove the following accomplishments
  - Developed new object-oriented approach to represent blade information
  - Developed a combined aero-structural optimization framework











Summary of Accomplishments/Results

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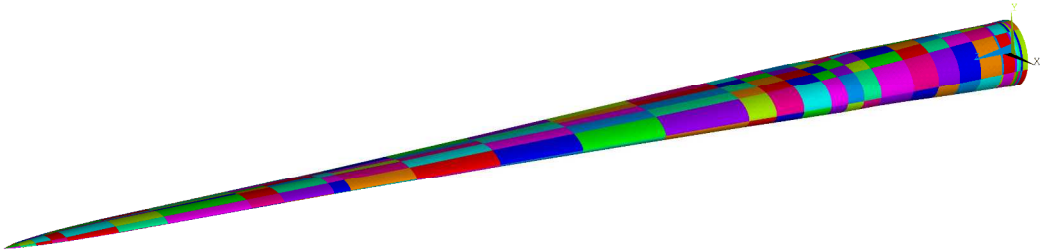
- Significant NuMAD development
- Enabled internal projects
  - Large Offshore Rotor (100m blade)
  - Offshore Structural Health studies
  - Blade Reliability Collaborative
  - National Rotor Testbed
  - System Benefits of Increasing Tip Speed
- Released reference model for 5MW / 61.5m wind turbine blade
  - Calculated detailed layup properties for “NREL offshore 5-MW baseline wind turbine”
  - Provides a common reference for blade design studies and tool development



Project Plan & Schedule

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Summary	
WBS Number or Agreement Number	WE 3.4.1
Project Number	21112
Agreement Number	22527

Legend	
	Work completed
	Active Task
	Milestones & Deliverables (Original Plan)
	Milestones & Deliverables (Actual)

	FY2012				FY2013				FY2014			
Task / Event	Q1 (Octt-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Octt-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Octt-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Project Name: Blade Design Tools & System Analysis												
Q1 Milestone: Evaluate 9m blade model (BPE module) against static load test.												
Q2 Milestone: Create NuMAD output that facilitates CFD mesh generation.												
Q3 Milestone: Integrate material failure model capabilities in NuMAD.												
Q4 Milestone: Release NuMAD v2.0												
Current work and future research												

Comments

- NuMAD v2.0 files were packaged and ready for release by Q4 milestone date, but copyright assertion process was delayed by circumstances outside our control.

Project Budget

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Budget History					
FY2012		FY2013		FY2014	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$400K	--	$0	--	$0	--

- $7k of FY11 funding was carried over into FY12
- FY12 spending finished at 97% expenditure; Remainder carried over to the National Rotor Testbed project
- Starting in FY13, Sandia Blade Design Tool efforts are funded by the projects which they support, such as the National Rotor Testbed

Communications and Technology Transfer:

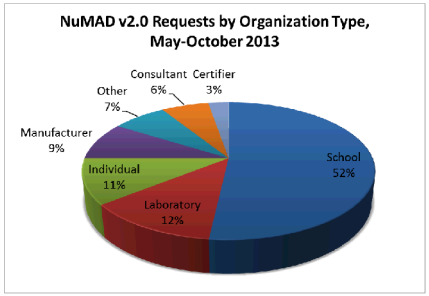
NuMAD v2.0 freely available under open-source license at wind.sandia.gov

Publication, presentation, tutorial/workshop

- Conducted a NuMAD workshop to get user feedback on beta version prior to the SNL Wind Blade Workshop on May 29, 2012
- Resor, B. R. "Definition of a 5MW/61.5m Wind Turbine Blade Reference Model," Sandia National Laboratories: SAND2013-2569, 2013.
- Resor, B. R. Owens, B. C. & Griffith, D. T. "Aeroelastic Instability of Very Large Wind Turbine Blades." (Scientific Poster) Proceedings of the European Wind Energy Association Annual Conference, 2012.

Partners, Subcontractors, and Collaborators:

- Supports multiple Sandia projects
- Growing external user community



Next Steps and Future Research

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FY14/Current research:

Continued development of multi-objective optimization framework for innovative blade design, with emphasis on verified algorithms and using High Performance Computing resources.

Collaboration with NREL on current work related to Systems Engineering framework, blade cost models, and blade design optimization.

NRT, Large Offshore Rotor, Tip Speed Study, Low-cost Carbon Fiber

Proposed future research:

Future developments will be driven by individual projects with common themes:

- Higher fidelity
- Multi-disciplinary (including cost modeling)
- More confidence to guide decisions for lowering COE