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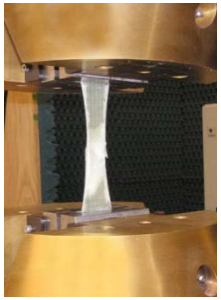

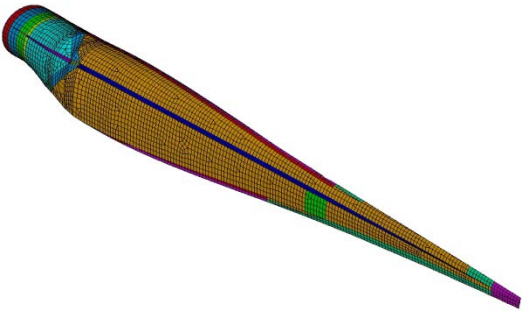

Sandia National Laboratories Wind Turbine Rotor Technology Overview

Brian Naughton, Todd Griffith, Josh Paquette

Sandia National Laboratories

Exceptional service in the national interest

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

SAND Number: 2013-10225P, 2015-3837 C

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Outline

Objective: Provide an overview of Sandia's Wind Energy Technologies Department and identify important research areas and facilitate collaboration.

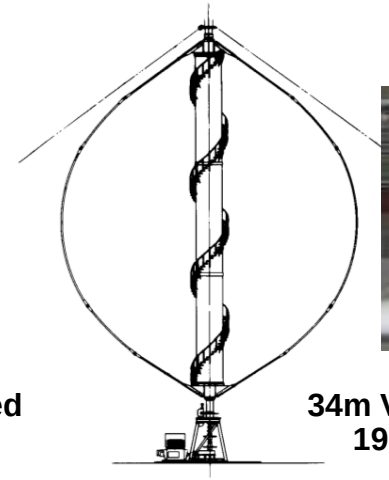
Topics:

- Composite materials testing (coupon & substructure)
- Carbon fiber program with ORNL
- Advanced Manufacturing Initiative (AMI) program
- Composites Inspection
- Effects of manufacturing defects
- Damage progression modeling and analysis
- Lighting damage
- Leading edge erosion
- Large rotors (Sandia 100m blade and ARPA project)
- Blade manufacturing cost model
- Structural Health Monitoring
- Seawater effects on composites (salt-fog testing to simulate offshore environment)
- Blade radar/lightning mitigation ongoing work

SNL Wind Program History

28 Years of wind turbine rotor development

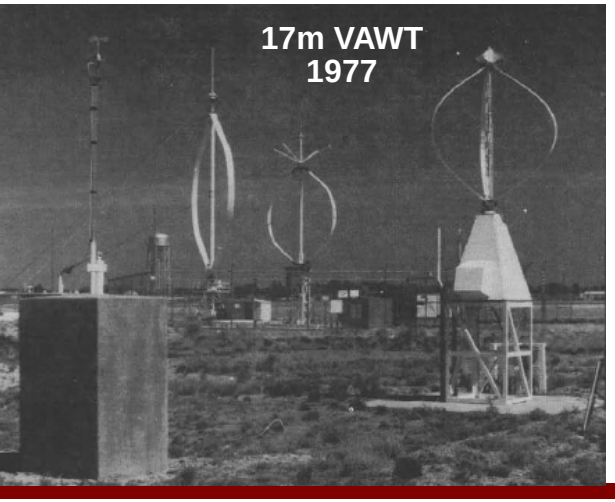
Wind Program Established 1975



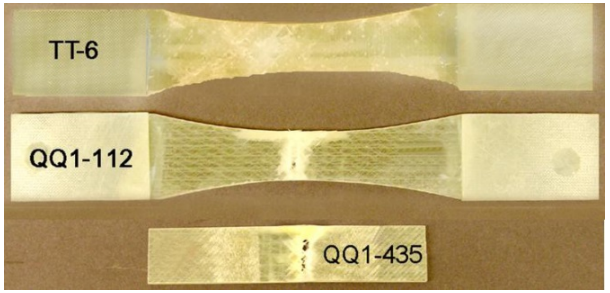
34m VAWT 1984

Blade Program 1994

SWiFT Facility 2013



Composite Materials Database 1988



Advanced Manufacturing Initiative 2008

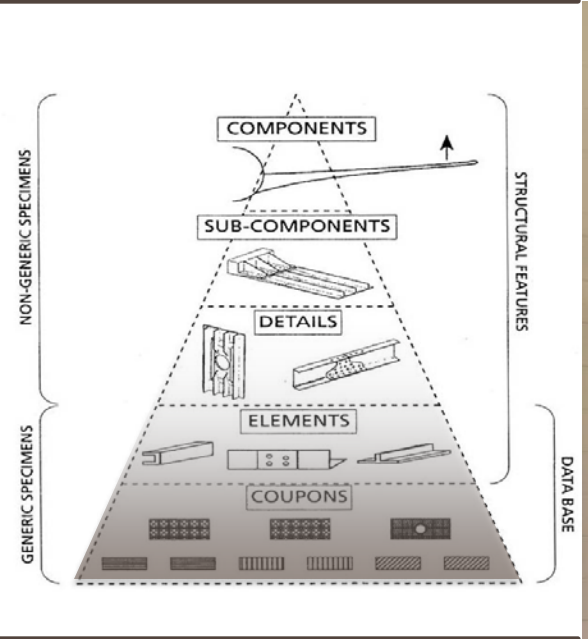
Blade Materials Research – since 1989

- DOE/MSU Fatigue Database
  - Over 500 Materials
  - 16,000+ tests
  - Updates each year wind.sandia.gov
  - Trends analyzed in contractor reports

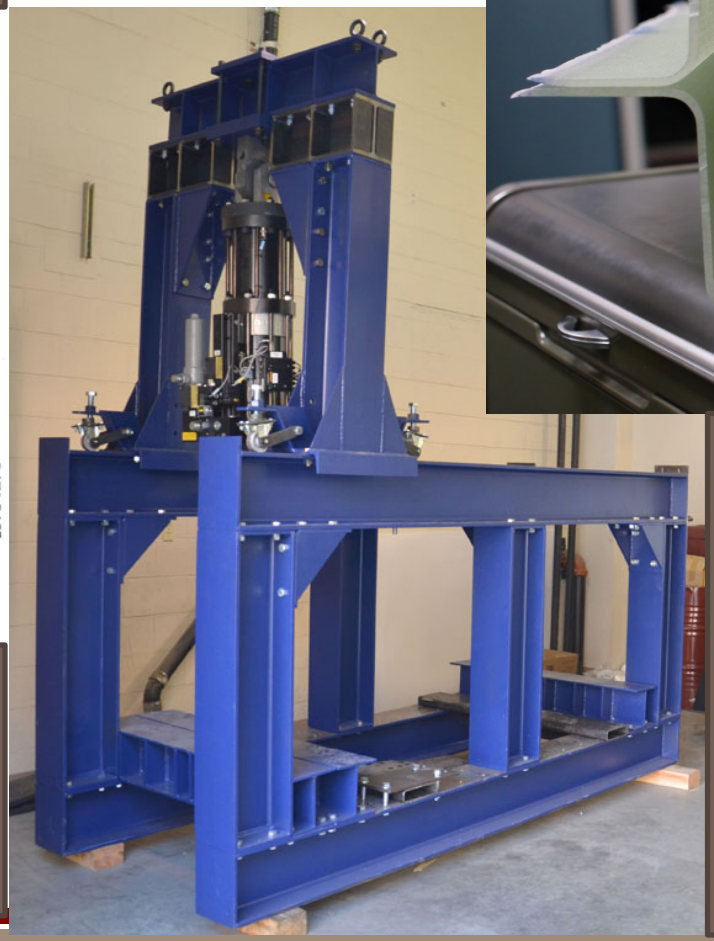
- Emphasis
  - Glass fiber, Carbon fiber and hybrid laminates
  - Spectrum loading
  - Detailed constant life diagrams for current glass and carbon materials
  - Structural details (ply drops, joints)
  - Environmental effects (hot/wet)
  - Processing effects

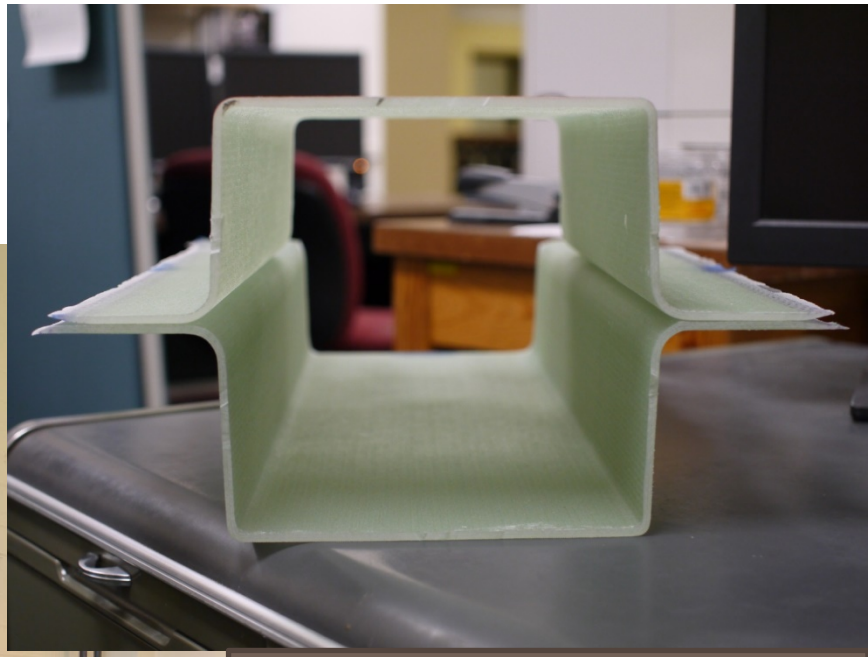
Substructure Testing

Expensive, Proprietary, Fewer tests, more certainty



Cost effective, generic, many tests, statistical





More representative blade structures and loadings can be investigated

Looking ahead

Current research:

Task Areas:

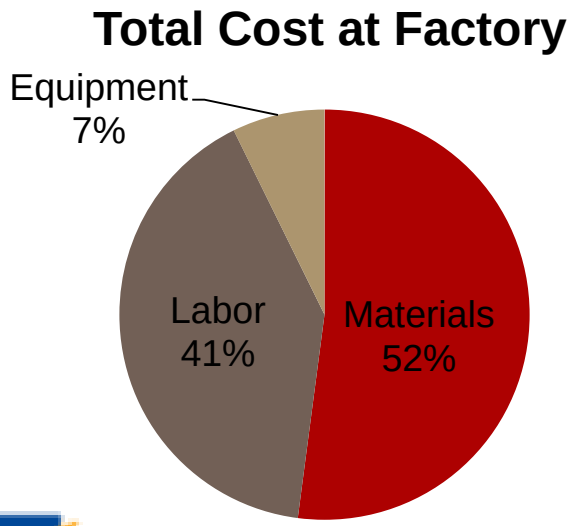
1. Baseline laminates
2. New Materials
3. Adhesives
4. Core materials
5. Substructures

} Blade Materials and Structures

Proposed future research: A 2-year effort to investigate the techno-economic feasibility of low-cost carbon fiber for wind applications.

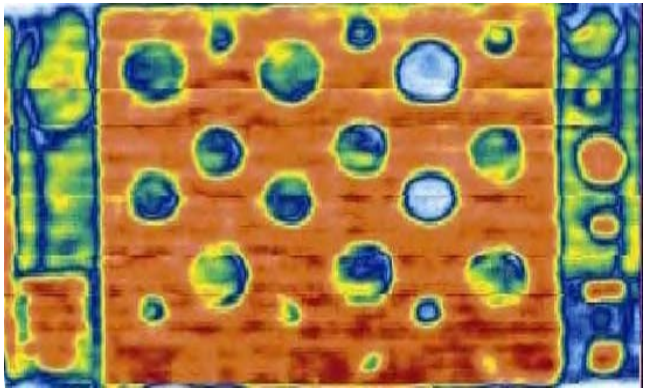
Advanced Manufacturing Initiative

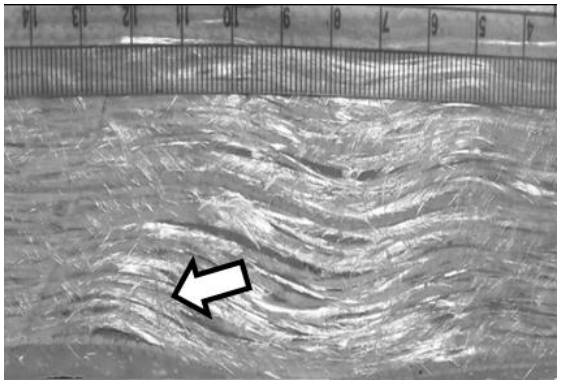
Goal: Increase labor productivity by 35% and reduce cycle time by 35% while maintaining or improving part quality.



Blade Reliability Collaborative

Improve the reliability of blades through field investigations, inspection technology, evaluating effects of defects, and improved design, analysis and certification

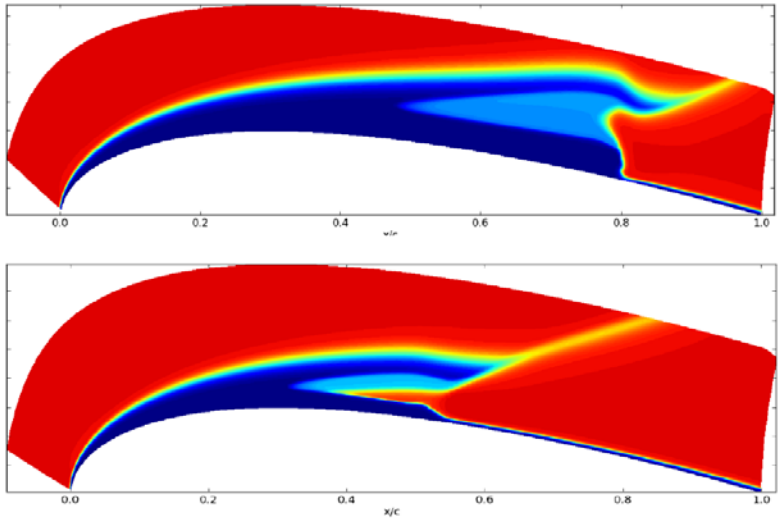




Many industry participants

Leading-Edge Erosion:

Characterization
Measurement
Modeling



No Roughness

k_s = 350 μm

Oran W. Nicks Low Speed Wind Tunnel

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SNL/GE Wind Energy Discussion

1. Large rotors (Sandia 100m blade and ARPA project)
2. Blade manufacturing cost model
3. Structural Health Monitoring & Prognostics Management
4. Seawater effects on composites (salt-fog testing to simulate offshore environment)
5. Blade radar/lightning mitigation

POC: D. Todd Griffith, dgriffi@sandia.gov

Document Number:
SAND2015-9795 PE

U.S. DEPARTMENT OF ENERGY

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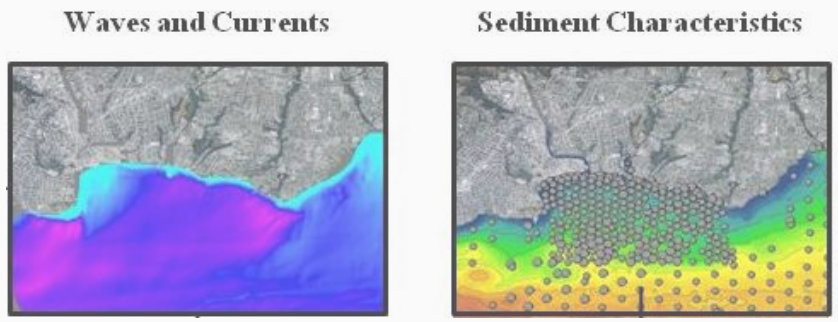
Offshore Wind @ Sandia

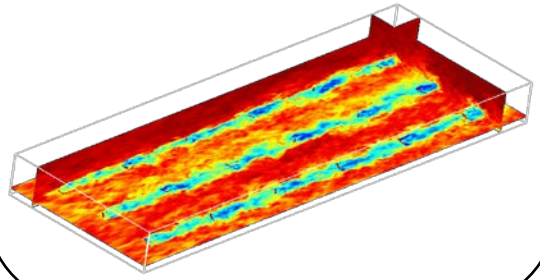
- **Vision**: Promote & accelerate the commercial OW industry and **reduce costs** through **technical innovation:**
  - Siting/Permitting: Sediment Transport & Radar
  - Large offshore HAWT rotors
  - Deepwater VAWT system
  - Structural health and prognostics management
  - Offshore wind farm modeling

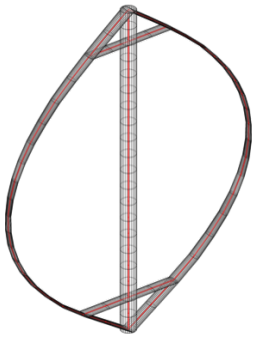


Offshore Siting Analysis

Sensing, Structural Health, and Prognostics

High-resolution Offshore Wind Farm Modeling





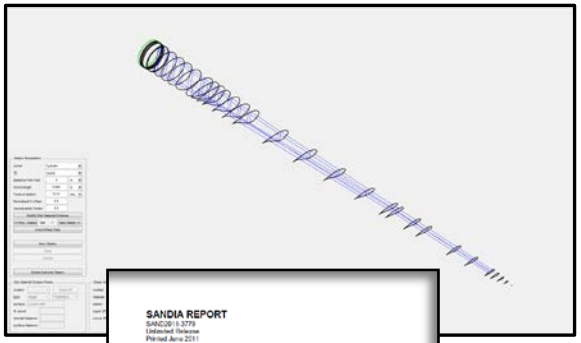
Deepwater Offshore VAWT

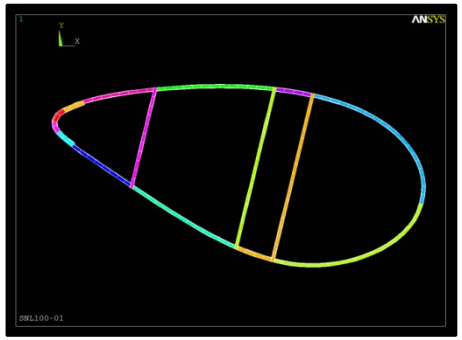
Large Offshore Rotors

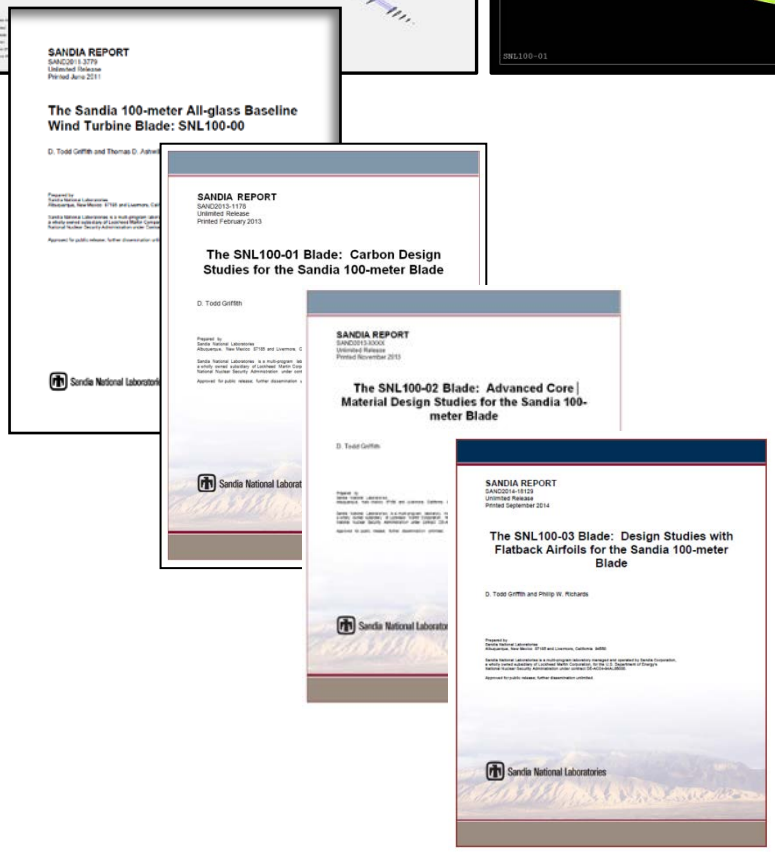
Large Offshore Rotor Development (100-meter Blade Project)

- **Summary**
  - Large blade design studies
  - **Public domain blade project**
  - **Reference Models**
- **Objectives & Results**
  - Identify trends and challenges
    - High weight and cost
    - Transportation
    - Shell/panel buckling
    - Gravitational Fatigue loading
    - Flutter
- **Products (public)**
  - 100-m blade and 13.2 MW turbine reference models
  - **Blade Manufacturing Cost Model**

http://largeoffshorerotor.sandia.gov

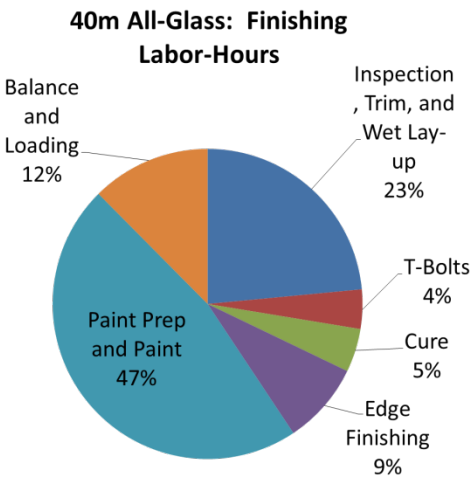


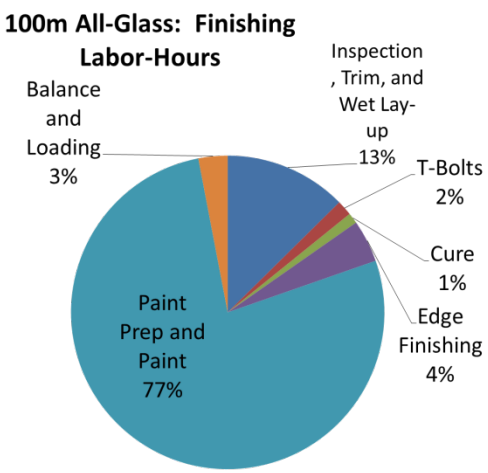




Sandia Blade Manufacturing Cost Model (version 1.0)

- 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.

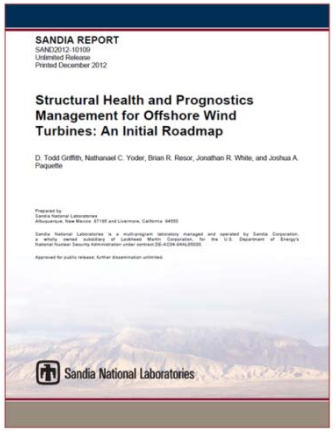
Link to project website: Publications at bottom of page

Structural Health and Prognostics Management

- **Summary/LCOE Impact**
  - **Mitigate rising costs for offshore O&M** (estimated to be 2-5 times of land-based)
  - **Maximize energy capture** by increasing availability
- **Focus Areas**

  Simulation of Damage:
  1. Identify best operating signatures (sensors) : Damage Detection
  2. Analyze effects of damage (state of health and remaining life): Prognostics
- **Key Blade Downtime Issues**
  - Rotor imbalance
  - Trailing edge disbonds
  - Leading edge cracks
  - Edge-wise vibration
  - Erosion
  - Lightning
  - Icing

Initial Roadmap Report

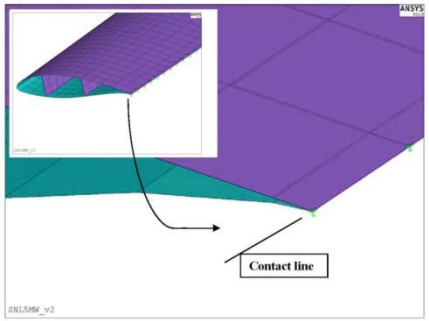


SANDIA REPORT
SAND2012-10109
Unlimited Release
Printed December 2012

Structural Health and Prognostics Management for Offshore Wind Turbines: An Initial Roadmap

D. Todd Griffith, Nathanael C. Yoder, Brian R. Resor, Jonathan R. White, and Joshua A. Paquette

Sandia National Laboratories



Greater motivation offshore with accessibility issues.
Reduce O&M costs and Maximize Energy Capture

Seawater effects on composites
(salt-fog testing to simulate offshore environment)

http://arc.aiaa.org/doi/abs/10.2514/6.2012-1575

Miller, Mandell, Samborsky, Hernandez-Sanchez, & Griffith, “Performance of Composite Materials Subjected to Salt Water Environments”, AIAA Paper 2012-1575.

Lightning & Radar Mitigation in Wind Turbine Blades

- Lightning strikes more than 2% of the US wind turbine fleet annually
  - Repairs for strikes generally exceed $30,000 per blade
  - Fatal strikes are fewer, but can cost over $450,000 per event
  - Total estimated cost to US wind industry: nearly $98M per year
- **The radar return of the metal down-conducting lightning cable is relatively strong compared to the other parts of the structure**
- The lightning cable can therefore greatly effect the radar returns from wind turbine blades
- **Sandia is leading an effort to mitigate the radar return and ensure lightning protection.**
  - **Opportunity for industry input: Sandia is initiating a survey to align the work with industry needs**

Typical lightning protection cable

1. Large rotors (Sandia 100m blade and ARPA project)

2. Blade manufacturing cost model

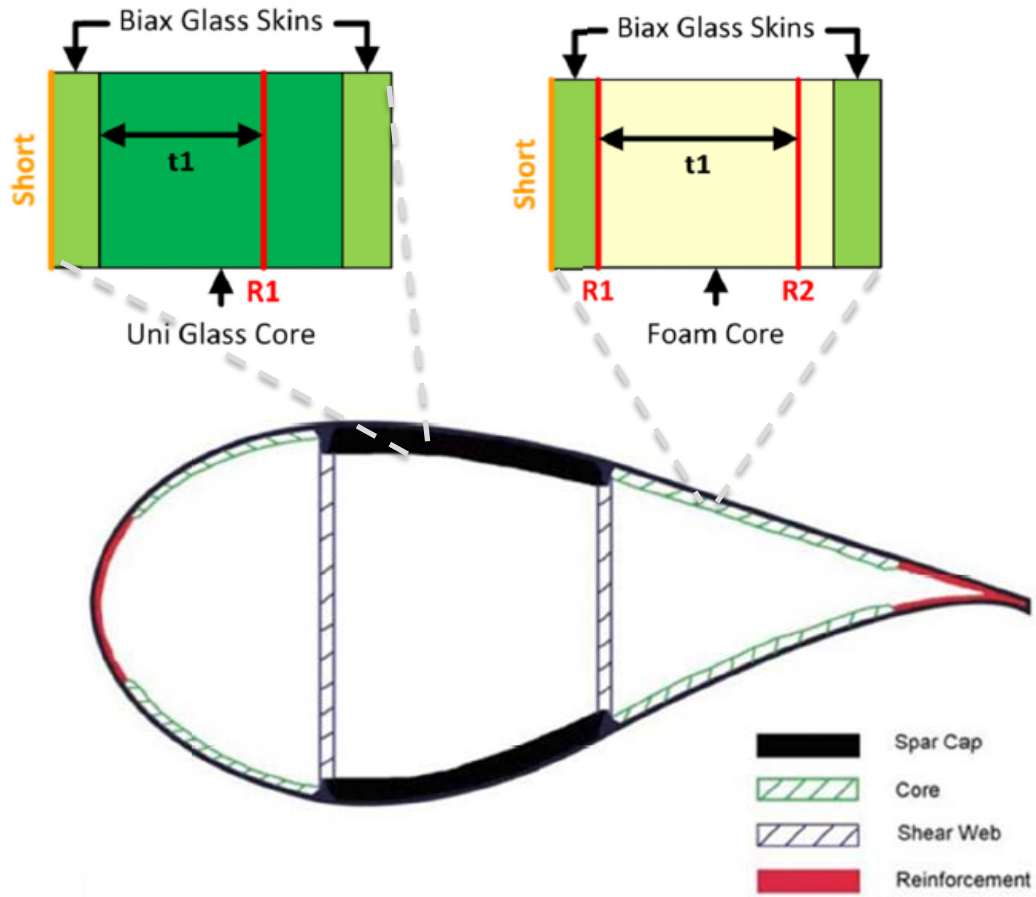
3. Structural Health Monitoring & Prognostics Management

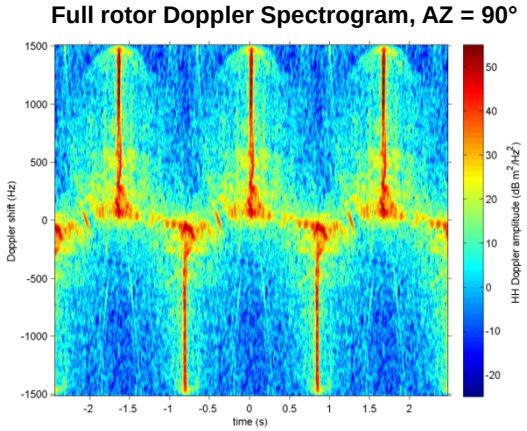
4. Seawater effects on composites (salt-fog testing to simulate offshore environment)

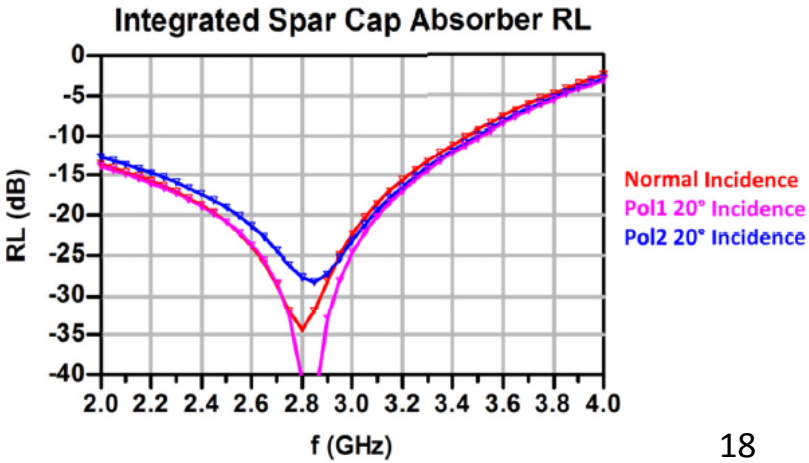
5. Blade radar/lightning mitigation

Radar friendly blade

Develop a low-cost material treatment compatible with current manufacturing processes that can reduce the RCS by 20 dB

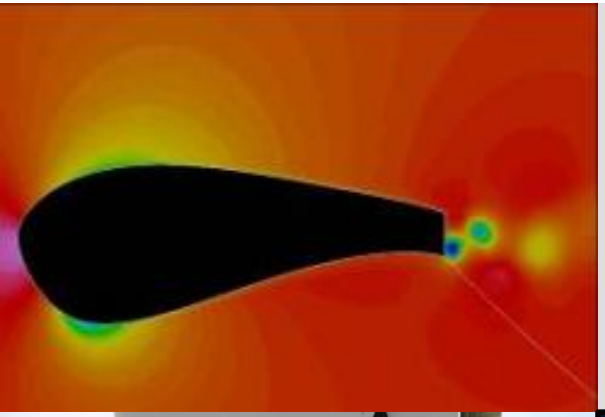


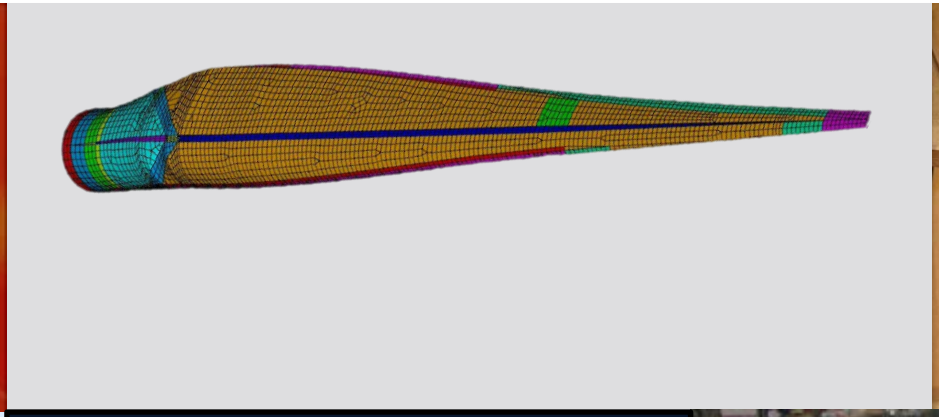




Source: Sandia National Laboratories

Rotor Technology Integrators





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