SAND2014-17202PE

Blade Reliability Collaborative Overview

Josh Paquette
Wind Energy Technology Department
Sandia National Laboratories
(505) 844-7766
Joshua.Paquette@sandia.gov

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NNSA Sandia National Laboratories

BRC Mission

Problem:

- **Blade reliability issues related to manufacturing, transportation, installation, and operation can have large effects on COE as blade failures can cause extensive down time and lead to expensive repairs.**

Project Goal:

- **The BRC aims to better understand:**
  - Primary causes of premature blade failure
  - Ability of inspection methods to detect flaws and damage
  - Effects of prominent manufacturing defects on blade materials
  - Adequacy of design tools and certification testing to replicate operational life

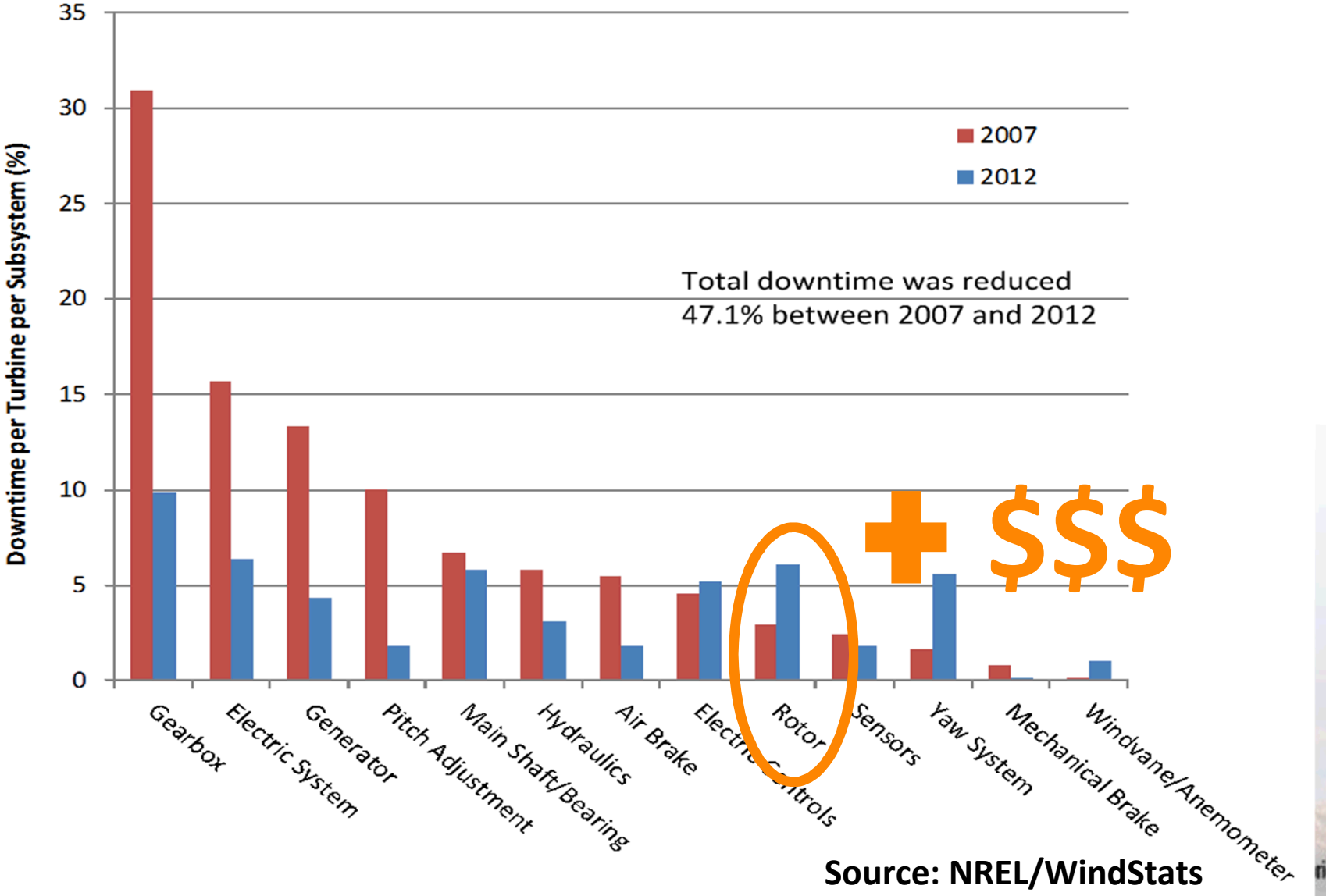
  and

  - Interface with a wide spectrum of industry, lab, and academic partners throughout the project.

In summary:

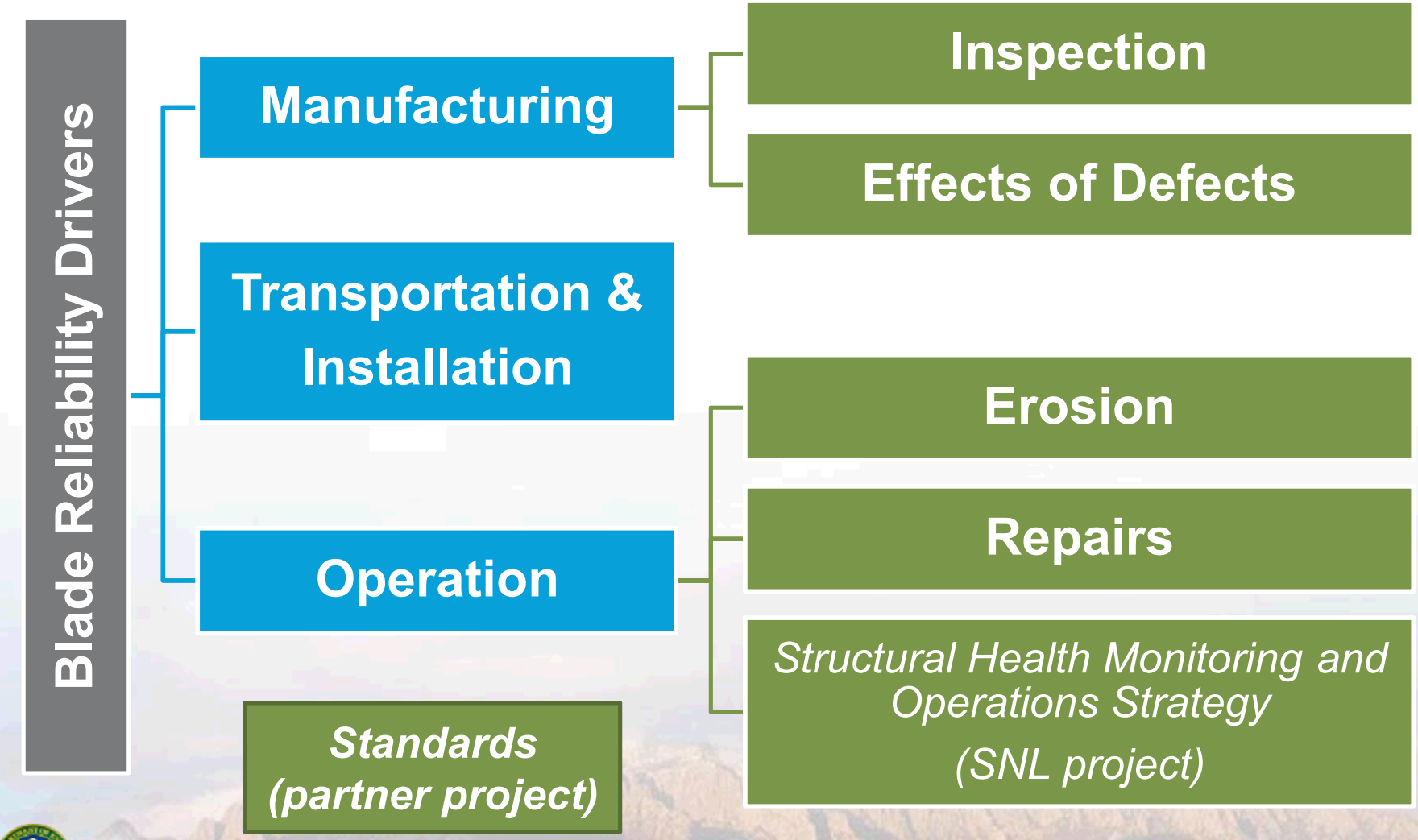
- Improve the reliability of blades such that service lifetimes can achieve the 20-30 year targets that are expected by wind plant operators and financiers.

Why Blades?



Source: NREL/WindStats

BRC (and related) Areas of Research



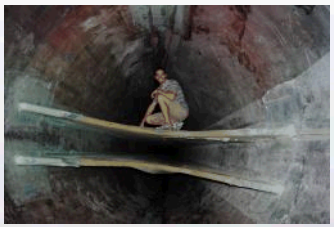
Standards

Mfg. Process
How are they created?

Repair
Can you fix them/resulting-damage?

Flaws/ Damage

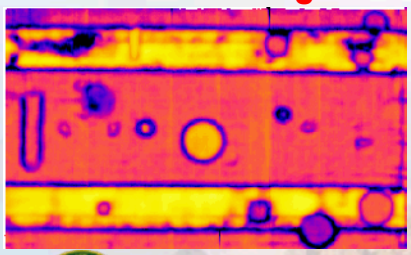
Inspection
How do you find them?



Effects of Defects
What do they do?

Technology Improvement

UT Flaw Image



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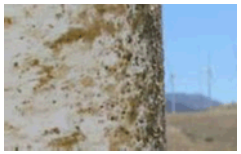
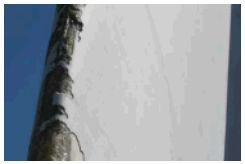
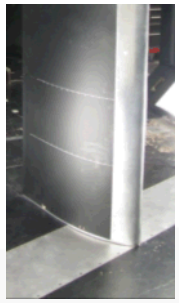




Mechanisms
What causes it?

Standards

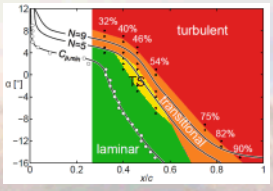
Technology Improvement



Erosion

Treatment
How to deal with it?

Aerodynamics
How is performance affected?



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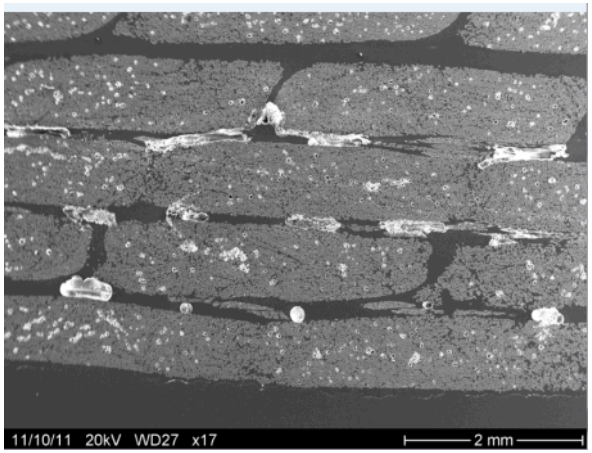
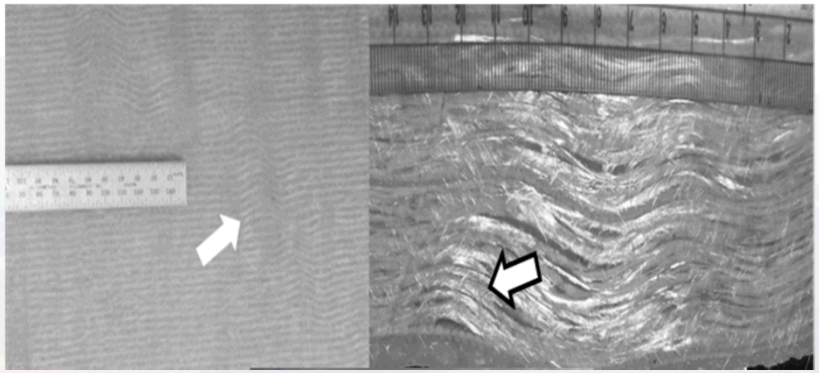
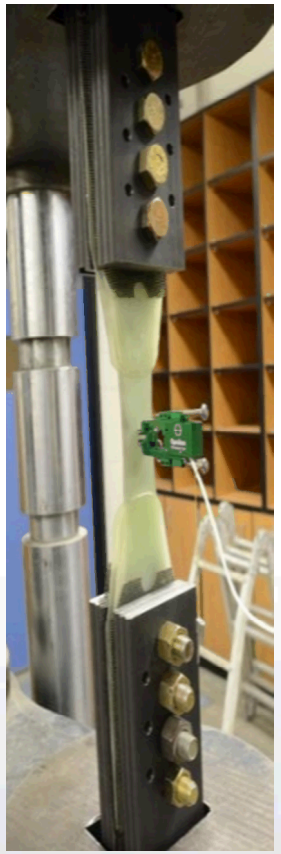
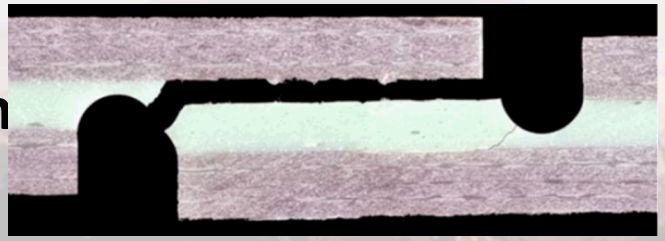
Effects of Defects

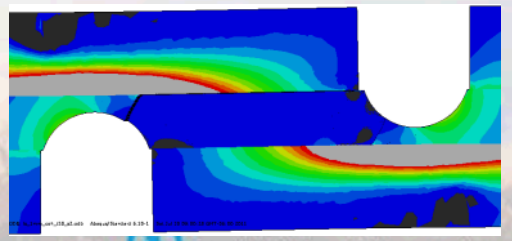
- Tested coupon samples containing prominent types of blade flaws
- Developed probabilistic flaw and damage model for blade design
- Created/validated new cohesive zone modeling procedure to analyze fiber waviness and adhesive crack growth





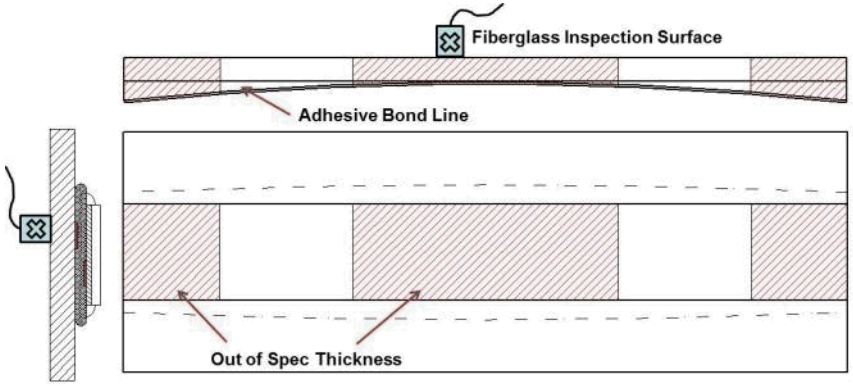


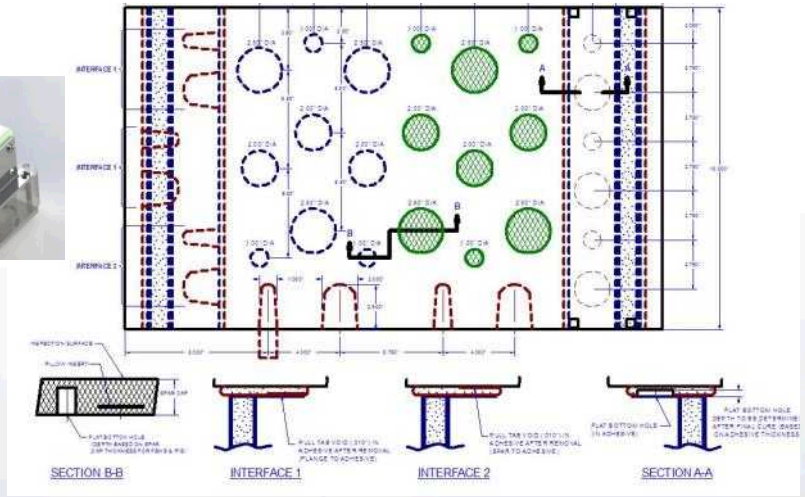




Non-Destructive Inspection

- Developed initial set of wind-blade-specific panels with flaws and tested with over 20 equipment developers
- Completed inspection of sub-scale validation blade with 5 equipment manufacturers
- Developed improved hardware for ultrasonic inspection, allowing for sensitive inspection of thick composites
- Developed methods to detect flaws in both th spar cap and bond line and methods to quantify bond line thickness
- Designed/fabricated fiberglass and carbon NDI Reference Standards for setting up and verifying the proper function of inspection equipment
- Completed manufacturing plant visits to assess applicability of lab-based inspection methods





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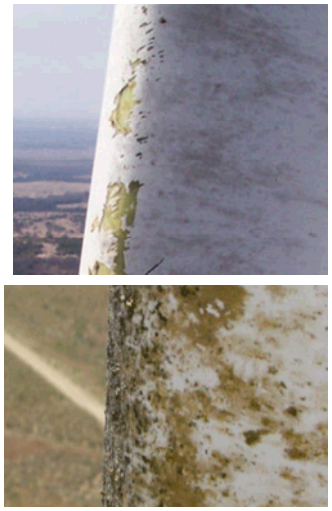
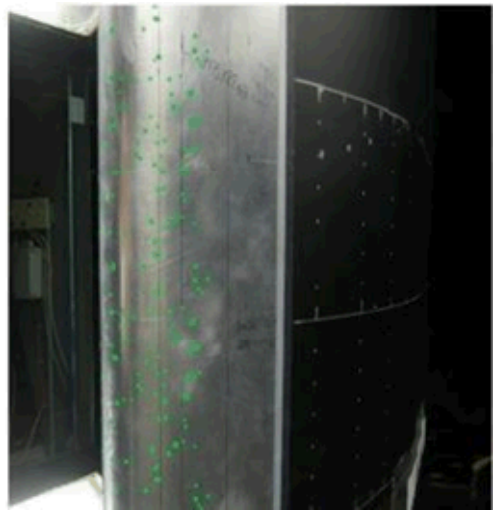
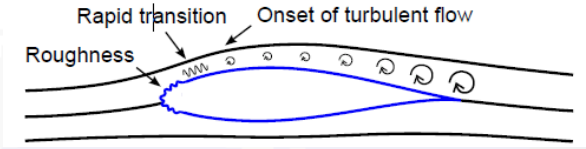
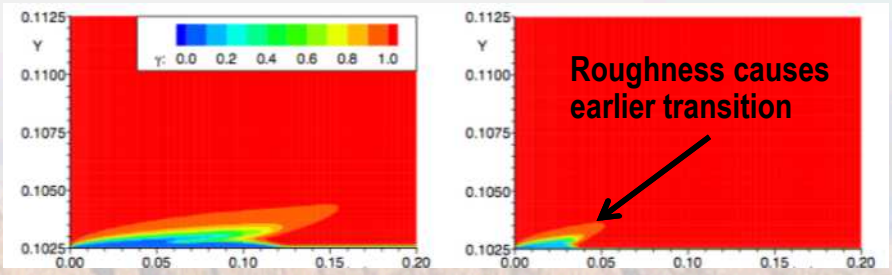
Leading Edge Erosion

- Gathered detailed LE erosion measurements from utility scale wind farm
- Built and tested LE erosion wind tunnel models
- Created CFD model of leading edge erosion
- Tight interaction between modelers and experimentalists
- Detailed calibration and validation of model









Current and Future Work

- **Non-Destructive Inspection**
  - Probability of detection (POD) experiment on wind blade laminate specimens
  - Targeted manufacturing floor inspection technology study
  - Targeted field inspection technology study
- **Effects of Defects**
  - Adhesive bond failure mechanisms
  - Fatigue testing of flawed laminates
  - Probabilistic design of blades with flaws
  - Damage progression in thick laminates and blade sub-structures
  - Damage initiation/progression in sandwich structures
  - Damage arresting laminates
- **Leading Edge Erosion**
  - Development of engineering-level model of erosion effect on aerodynamics
  - Mechanical testing of erosion specimens
  - Erosion mitigation cost model
- **Composite Repairs**
  - Review of state of industry
  - Inspection and testing of repairs
- **Lightning**
  - Mechanical testing of “prepared” coupons
  - Development of improved lightning strike arrest system

Discussion Questions

- **What current blade issues do owners, operators, and service companies struggle with?**
- **What current blade issues are OEM's struggling with?**
- **What can DOE and National Labs do to help solve these problem?**
- **What problems are 5, 10, 15 years out that we need to get ahead of?**