Blade Reliability Collaborative Overview

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NNSA National Nuclear Security Administration

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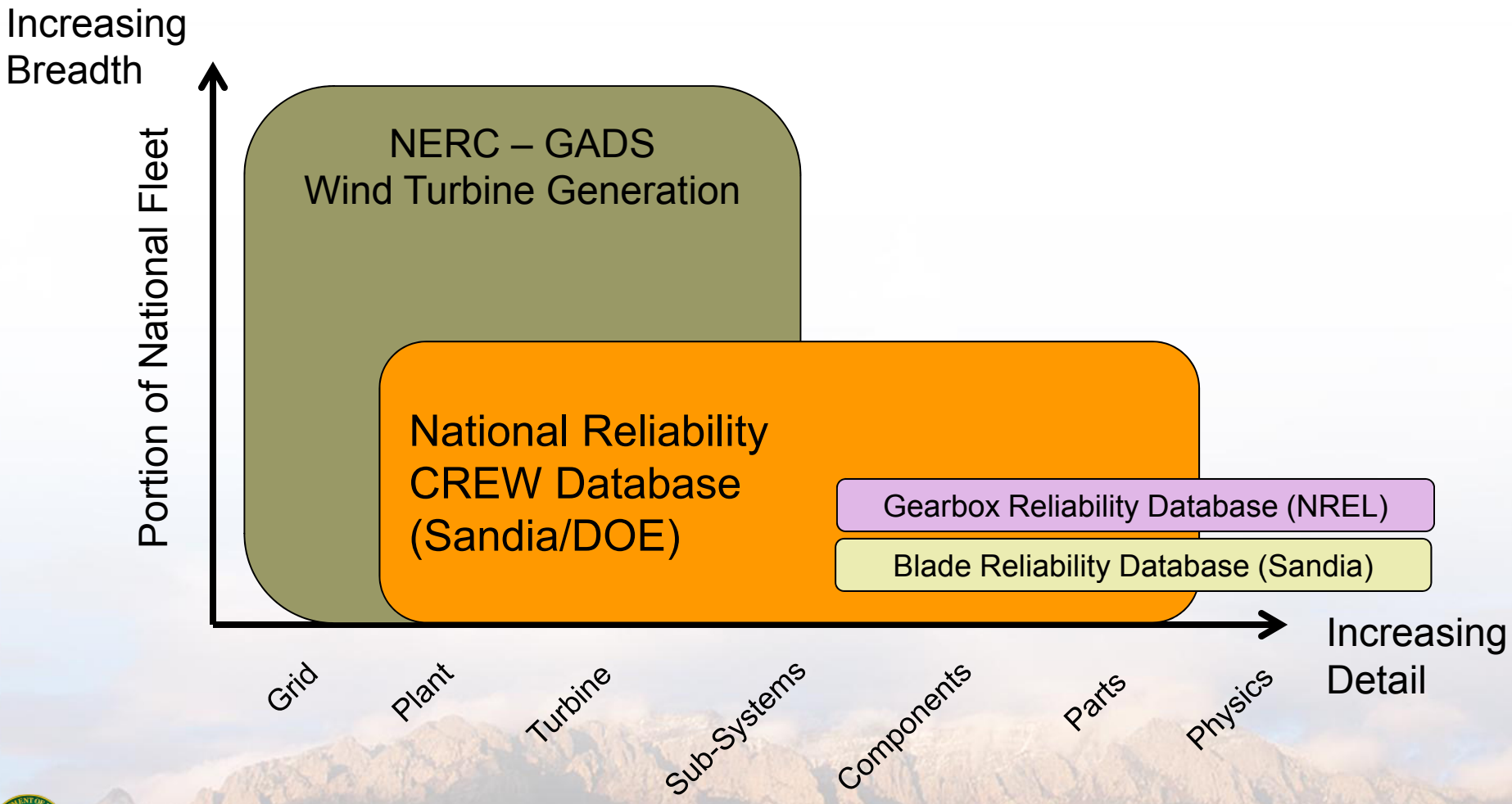
Relationship of Reliability Efforts



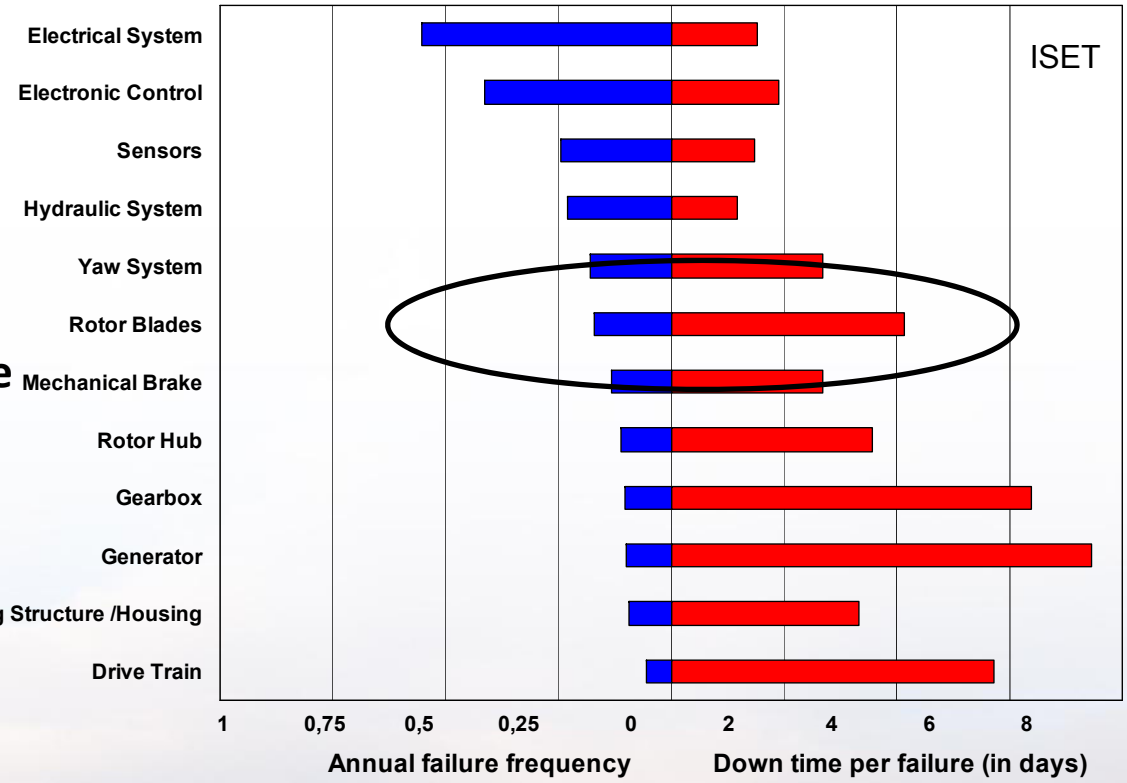
Blade Reliability

Motivation

"80% of the blades that require repair have never been flown."

Gary Kanaby, Knight & Carver Wind Blade Division.

- **Blades are being delivered to the site in a condition that often requires additional treatment of quality issues before they can be installed**
- **Rare installations need to have all the blades replaced after the discovery of a batch problem**
- **Blade failure can cause extensive down time and lead to expensive repairs.**
- ***Blade reliability issues need early attention because of the lost production and cost of significant failures***



Historical European Experience (Paul Kühn, ISET)

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Preliminary Survey of Operators 2008

- **Five Plants – over 400 turbines**
- **Mostly 3+ years old**
- **About 80 blade replacements (40 at one plant)**
- **Replacement times range from 2 weeks to 2 months**
- **Blade Issues Cited:**
  - Manufacturing Issues – waviness and overlaid laminates
  - Bad bonds, Delamination, and Voids
  - Leading Edge Erosion
  - Trailing Edge Splits
  - Lightning – Comments:
    - At one plant - Every blade has been struck at least once
    - Many repairs and replacements
    - Scorching and splits

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Major Issues for Improved Blade Reliability

"Delphi" Expert's Group Assessment of Issues

- **Experts from Industry, consulting, academia, and national labs convened to identify critical issues**
- **Collected expert knowledge as a basis for planning to address blade reliability needs**

1. **Infusion Quality**
2. **Bonding Quality**
3. **Inspection Capability**
4. **Environmental Protection**
5. **Multiple Assembly Plants or Assembly Lines**
6. **Certification, Tracking and Feedback**

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Major Activities

Blade Reliability Collaborative

Survey & Root Cause Analysis	Conduct root cause analysis of field-failures and document the issues
Inspection Validation	Create the ability for manufacturers to determine the quality of their product before it leaves the factory
Effects of Defects	Determine how critical manufacturing flaws are progressing to failures under typical loading
Analysis Evaluation	Assess the ability of design analysis tools to find and characterize potential failure modes in both fatigue and strength
Certification Testing	Evaluate the ability of certification testing to uncover potential reliability issues and find innovative ways for testing to provide better insight

All BRC results will be public

Survey and Root Cause Analysis

Activity Leader: Tom Ashwill

What is causing early field failures and unreliability?

Field experience & Manufacturing Output

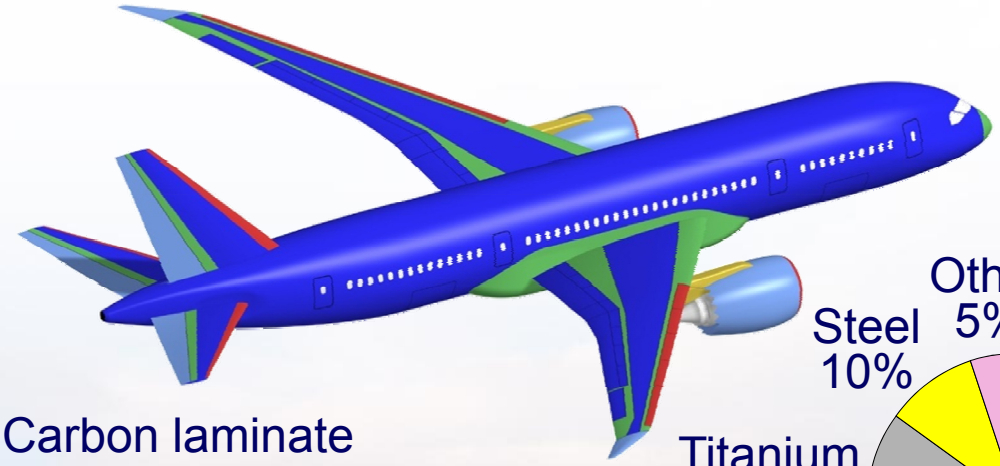
Inspection is the link between the two

- Operator surveys
- Blade repair data
- Field failure assessments and root cause analysis
- Manufacturer inputs
- Quantify the impact of lightning damage
- Create a blade failure mode database

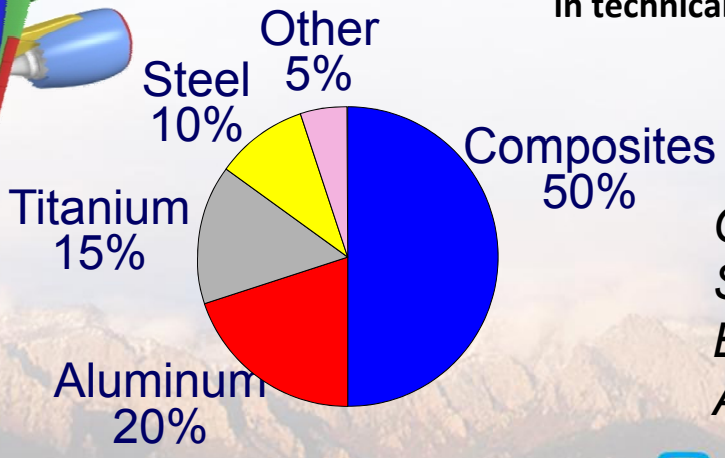
Inspection Validation

Activity Leader: Dennis Roach

- Find aging parts and characterize flaws
- Manufacture known flaws
- Bring in vendors to Validate their capabilities
- Sandia's Aviation Assurance NDT Validation Center (AANC)



- Carbon laminate
- Carbon sandwich
- Fiberglass
- Aluminum
- Aluminum/steel/titanium pylons



Composite Structures on Boeing 787 Aircraft

- **The Boeing 787 is 50% composite material in structural elements**
- **Composite Inspection is growing in technical sophistication**

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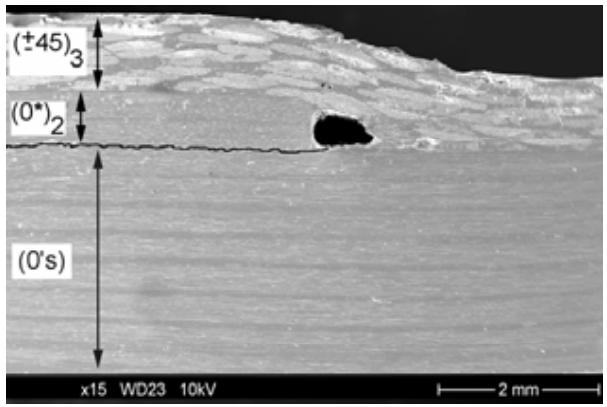
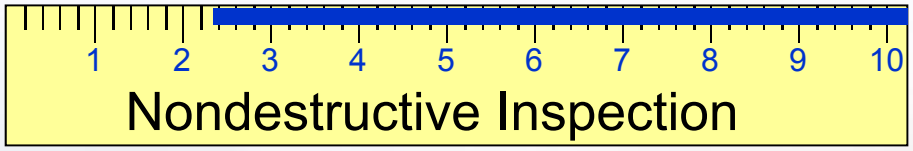
Effects of Defects

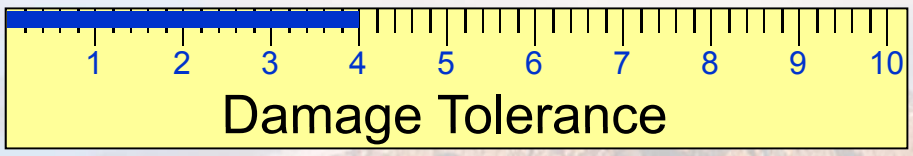
Activity Leader: Doug Cairns



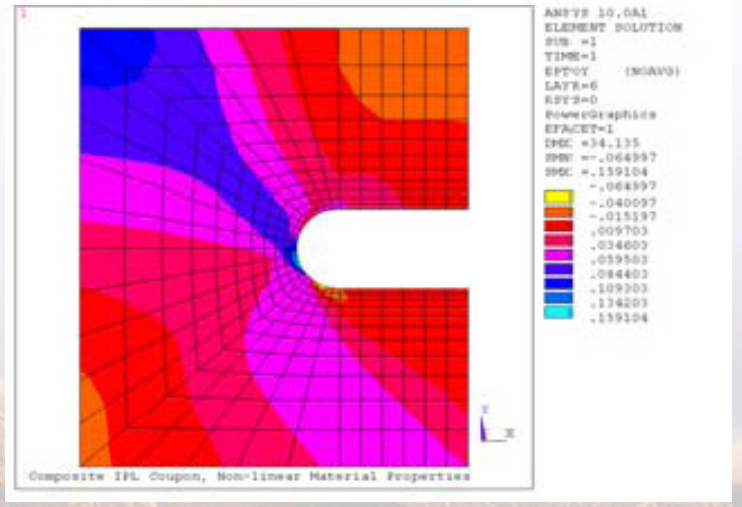
- **Coupon-level testing to determine how flaws and defects propagate under load**
- **Montana State University has expertise in this area and know wind turbine blade materials from over a decade of testing (100,000 coupons tested and archived)**

Detectable Flaw Size





Allowable Flaw Size



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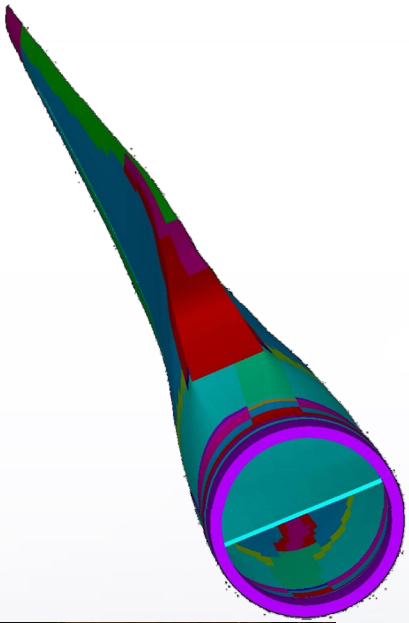
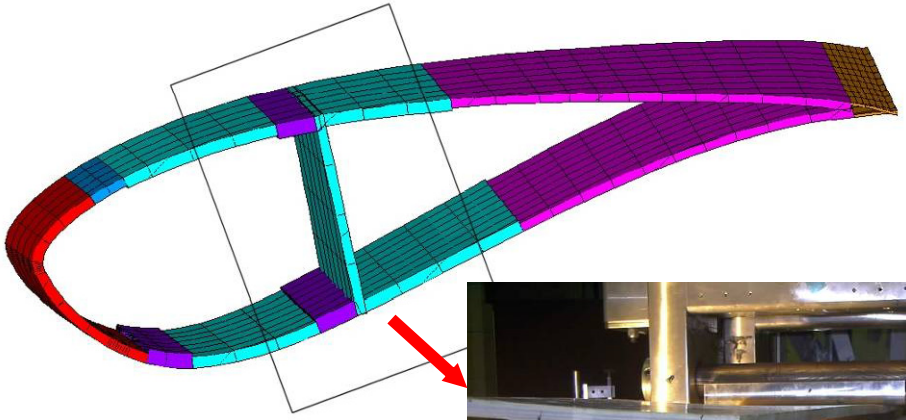
Design Analysis Evaluation

Activity Leader: Josh Paquette

- Check design loads against material capability
- Create the ability for the analysis to be a predictive tool for evaluating blade design
- Highly instrumented laboratory testing to determine first failure and damage progression





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Certification Testing – NREL

Activity Leader: Scott Hughes

- **Heavily instrumented blades subjected to certification tests**
  - Good blades
  - Pre-damaged blades
- **Evaluate how the test works the critical areas and failure modes**
- **Develop improvements to certification testing**
- **NREL element of the program**

LM Glassfiber

- Full-scale blade testing: Fatigue tests reveal hidden flaws
  - Production blades
  - Detailed inspection
  - Typical manufacturing quality resulting capability

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Current Participating Partners

Blade Reliability Collaborative

- Sandia
- Montana State University
- Knight and Carver
- Rope Partners
- NREL
- University of Massachusetts – Lowell
- TPI
- EPRI
- GE
- LM
- Dantec