2004 Sandia Blade Workshop

Sandia
National
Laboratories

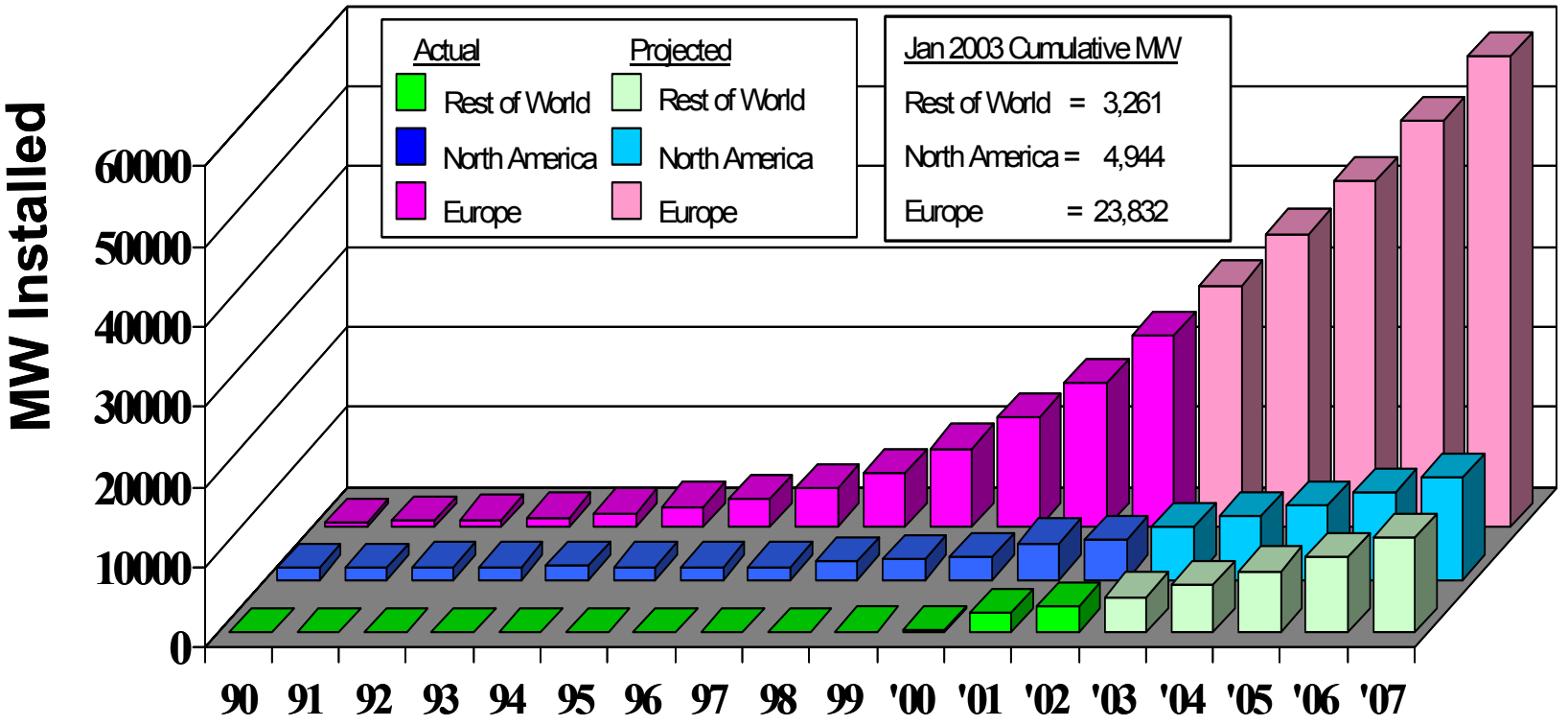
Welcome

- Thanks for Attending!!!
- Workshop Staff
  - Sam Gershin, Lenore Boulton
  - Lisa Sena-Henderson, Rachel Woodrum, Shannon Clark
- DOE Wind Technology Management Team
  - DOE – Peter Goldman (Manager), Stan Calvert, Jack Cadogan, Phil Dougherty
  - NREL – Bob Thresher (Director), Brian Smith, Mike Robinson, Dave Simms
  - SNL – Paul Veers
- DOE Albuquerque – Danny Sanchez

Why a Blade Workshop

- Increasing interest in Wind Energy
  - Growth in worldwide capacity
  - New offshore projects in the U.S.
- Interest in blades
  - Increase in blade-related papers in conferences (ASME Wind Energy Symposium)
  - Articles in non-wind-specific magazines
- Goals for further COE reduction
  - Heavily rely on blades/rotor
- ***Bring together those with common interests***
  - Discuss issues associated with design & fabrication of modern turbine blades

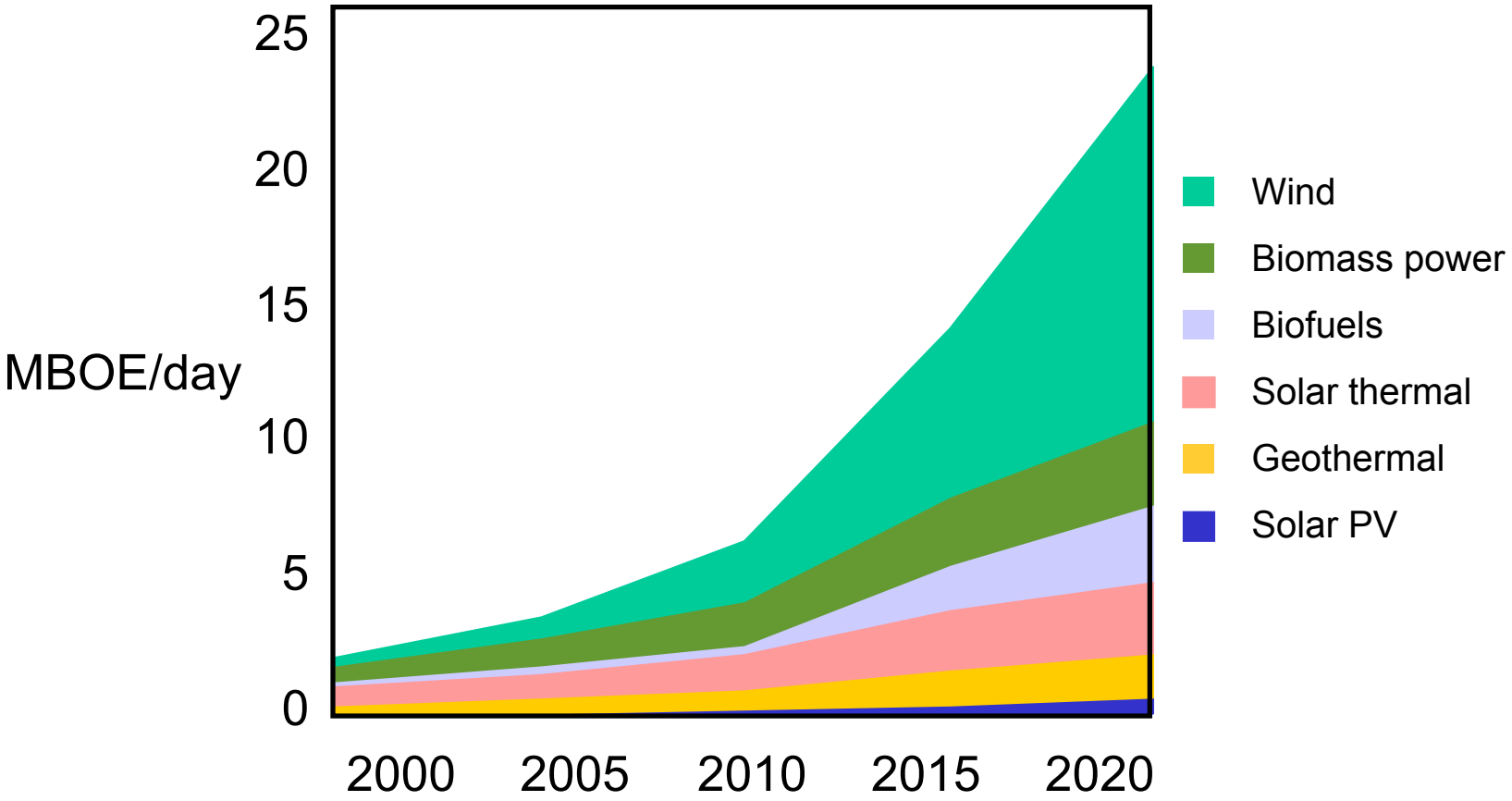
Growth of Wind Energy Capacity Worldwide



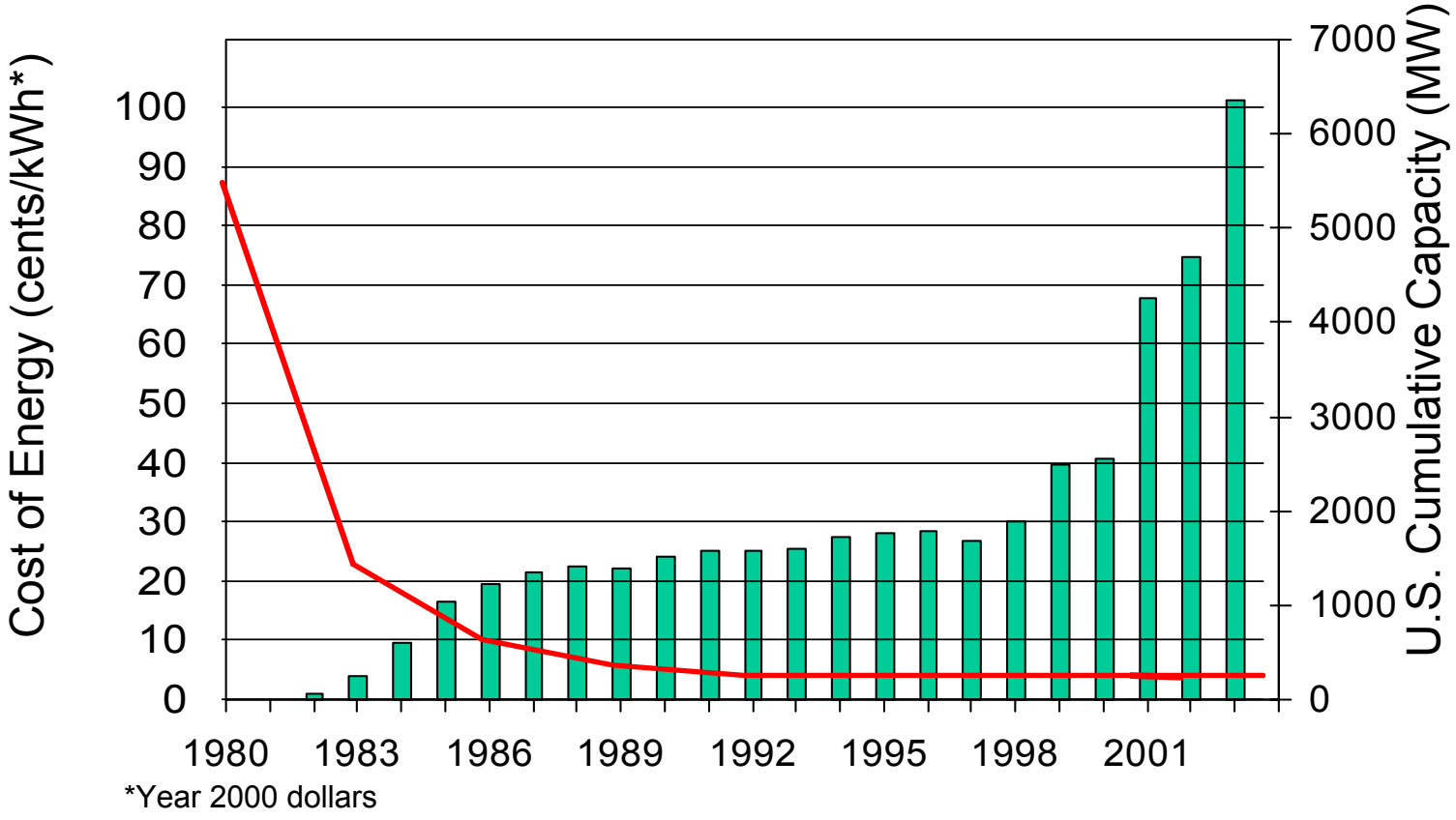
Sources: BTM Consult Aps, March 2003
AWEA/EWEA Press Release 3/3/03

RE Growth Predictions

Source: Shell Global Scenarios



Cost of Wind Energy is Falling



Increased Turbine Size - R&D Advances - Manufacturing Improvements

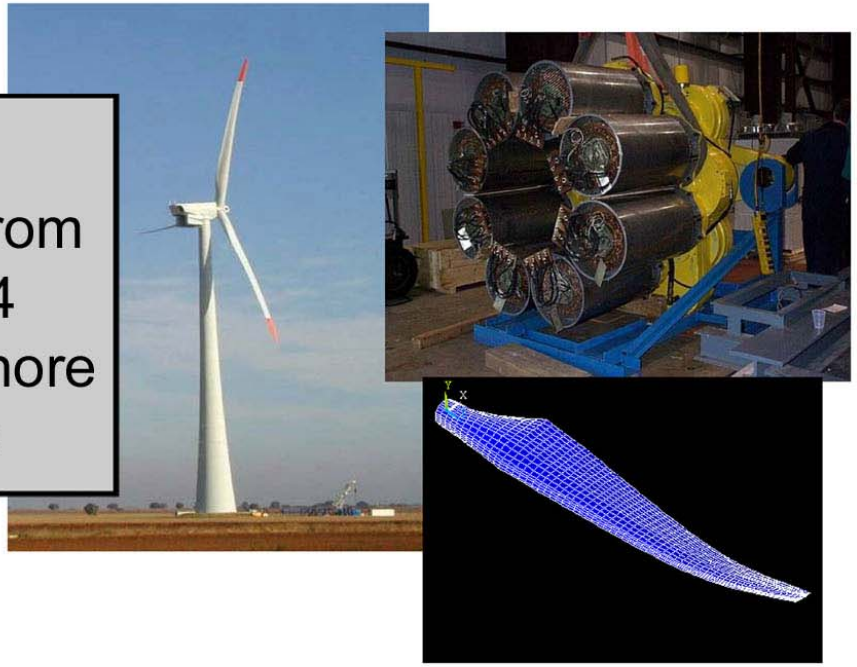
Current Wind Industry Market

- Costs
  - System < $3/lb
  - Blades < $5/lb
  - ~ $0.75/Watt
  - $0.04-0.05/kWh

- Size
  - **1.5**-5.0 MW
  - Towers: **65**-100 m
  - Blades: **34**-50m
  - Weight: **150**-500t

Low Wind Speed Technology

Goal:
By 2012, reduce COE from large systems in Class 4 winds 3 cents/kWh onshore or 5 cents/kWh offshore



Distributed Wind Technology

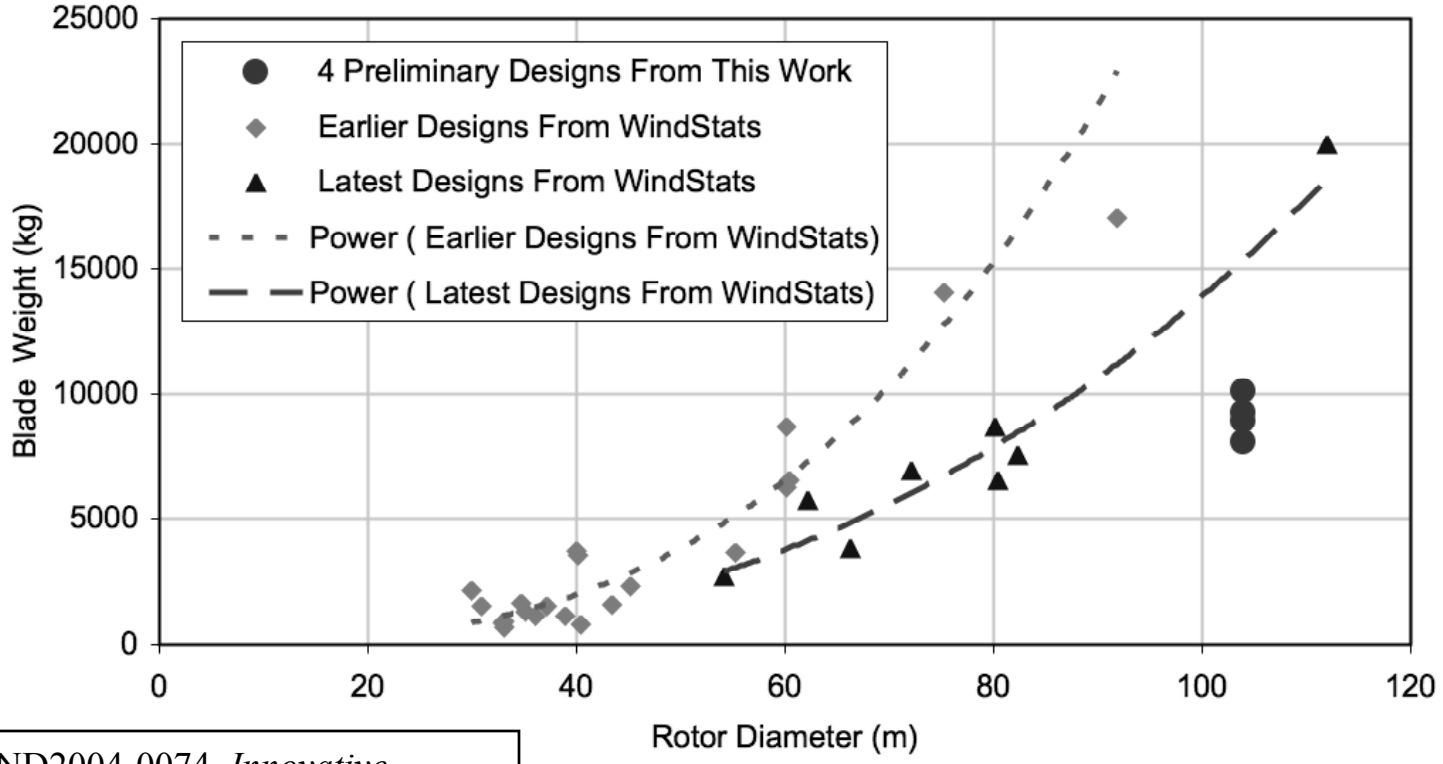
Goal:
By 2007, reduce COE from distributed wind systems 10-15 cents/kWh in Class 3

How Do We Reduce the Cost of Energy from Wind Turbines?

(Thresher: 5/02)

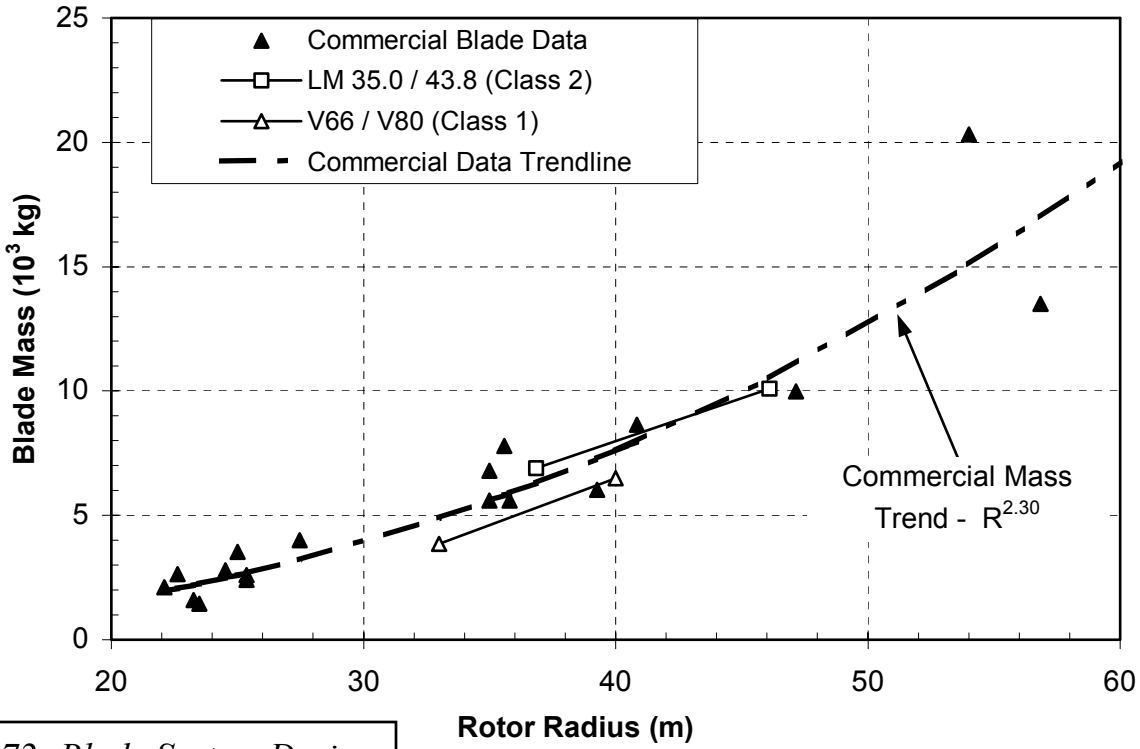
Technology Improvements	Estimated COE Improvement
• **Larger-scale 2 - 5MW -** (rotors up to 120m)	0% ± 5%
• **Advanced rotors and controls –** (flexible, low-solidity, higher speed, hybrid carbon-glass and advanced and innovative designs)	**-15% ± 7%**
• **Advanced drive train concepts -** (Hybrid drive trains with low-speed PM generators and other innovative designs including reduced cost PE)	-10% ± 7%
• **New tower concepts** - (taller, modular, field assembled, load feedback control)	-2% ± 5%
• **Improved availability and reduced losses** - (better controls, siting and improved availability)	-5% ± 3%
• **Manufacturing improvements** - (new manufacturing methods, volume production and learning effects)	**-7% ± 3%**
• **Region and site tailored designs** (tailoring of larger 100MW wind farm turbine designs to unique sites)	-5% ± 2%
TOTAL	**-44% ± 32%**

Comparison of Weight Trends WindStats Data & Preliminary Designs



SAND2004-0074, *Innovative Design Approaches for Large Wind Turbine Blades; Final Report*, TPI

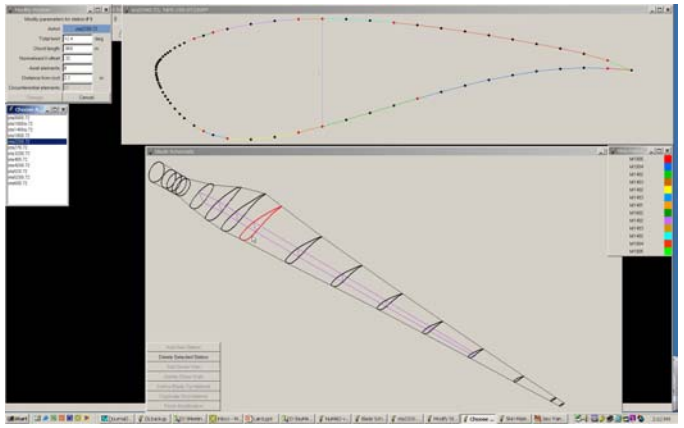
Mass Growth for Commercial MW-scale Blades (primarily fiberglass)

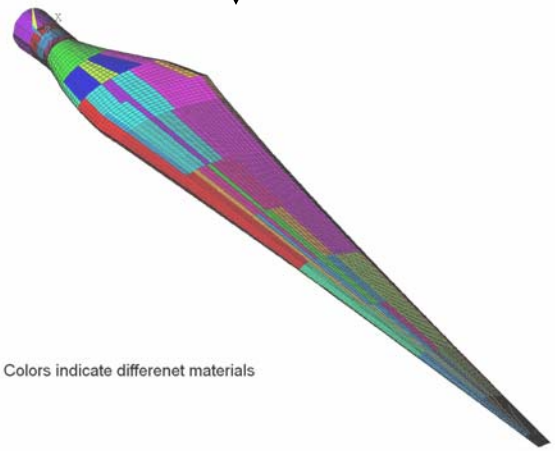


SAND2004-0073, *Blade System Design Studies Volume II: Preliminary Blade Designs and Recommended Test Matrix*, GEC

Design Process Trends

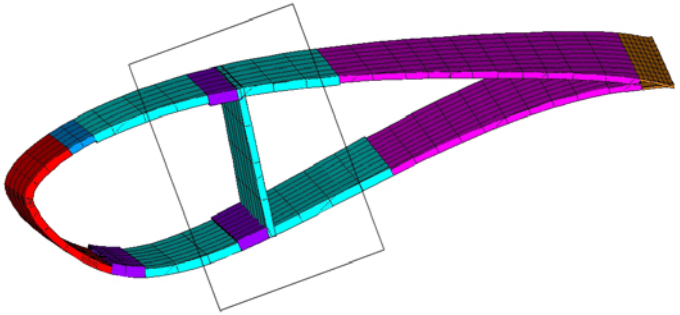
- Have matured significantly over the past 10 years
- Back-of-envelope calculations to in-house computational tools
- Now some codes available at labs and commercially
  - BLADED
  - ADAMS
  - FAST
  - FEM codes and preprocessors, ANSYS/NuMAD





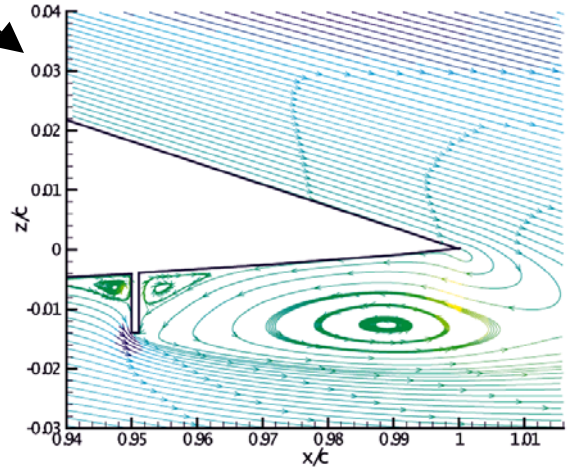
Design Process Trends

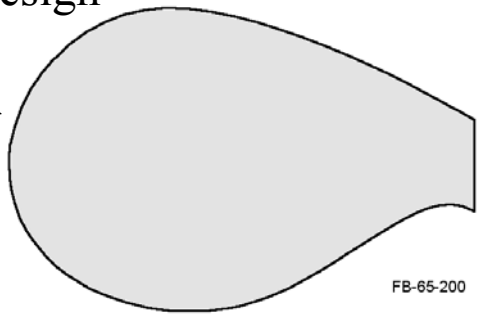
- Load models continually upgraded to reflect improvements from research
- Certification & Standards GL, IEC, now UL
  - Designs enhanced by consistent modeling practices to get certification
  - Designers can use a set of commonly accepted load cases & not re-invent



Design Advancement Opportunities

- Load alleviation
  - Passive - twist coupling
    - Sweep twist
  - Active devices - microtabs
- Performance enhancement & control devices
  - Pitch – collective & individual
  - Flaperons, ailerons
  - Active devices
- Efficient internal blade architecture
  - Anti-buckling concepts
- Slender blades
- Integrated structural/aerodynamic design
  - Thickened airfoils
- Safety factor shakeouts





Trends in Materials

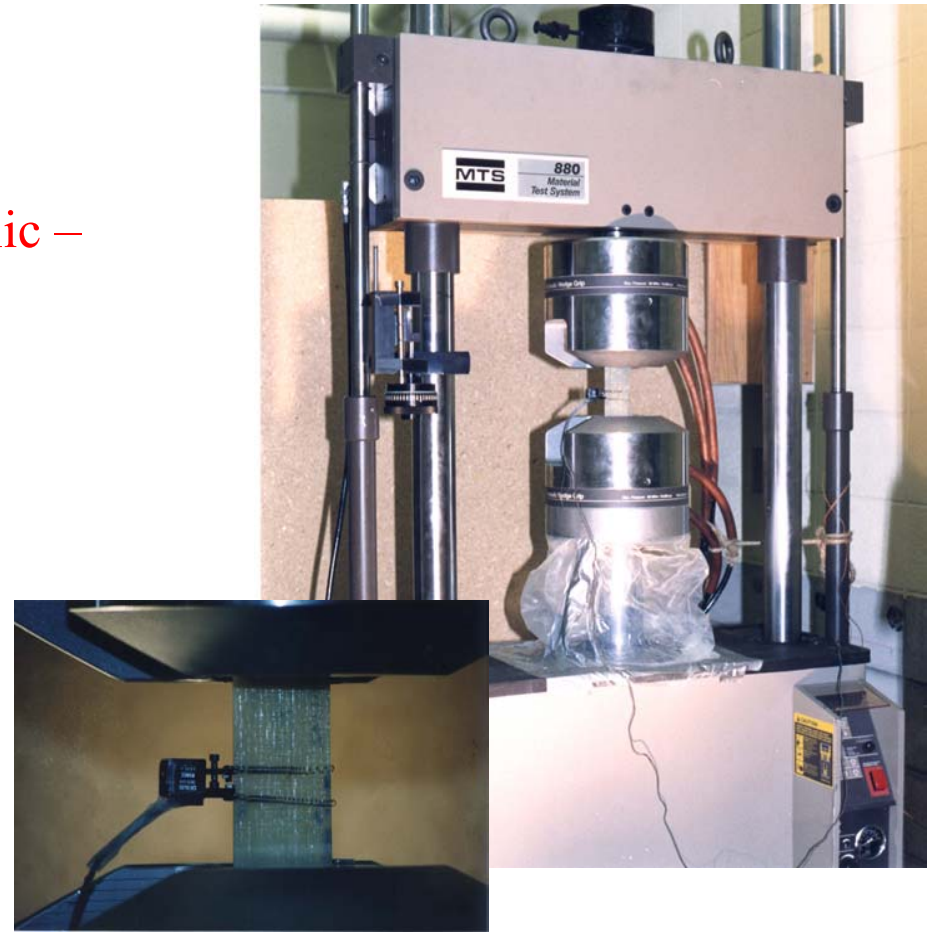
- Continuation of material characterization
  - Data bases available to public – DOE/MSU & FACT

DOE/MSU Fatigue Data Base

•Material Properties (8800 Data Points for 158 Materials)
  - –Industry Materials (23)
  - –Specialized Materials

•Expanded Programs
  - –Spectral Loading
  - –Matrix Materials
  - –Carbon Fibers

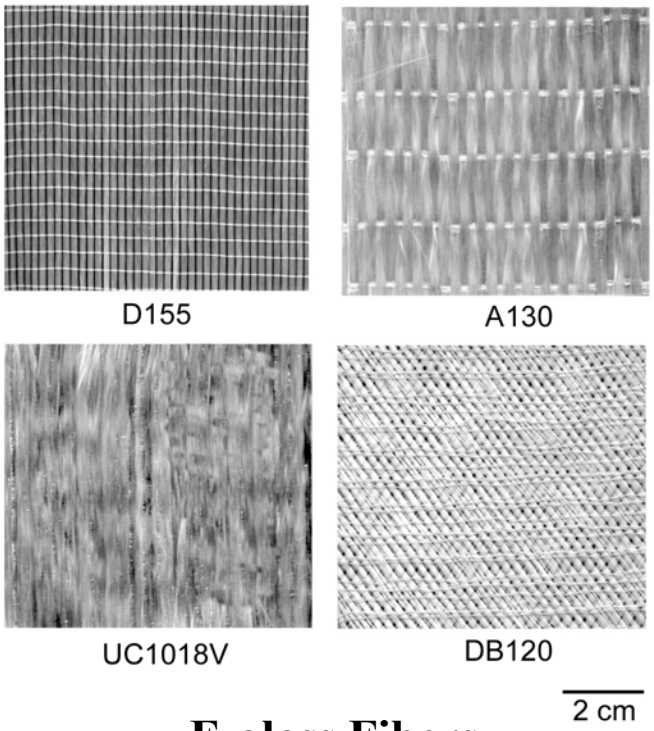
•Updated Yearly - sandia.gov/wind/



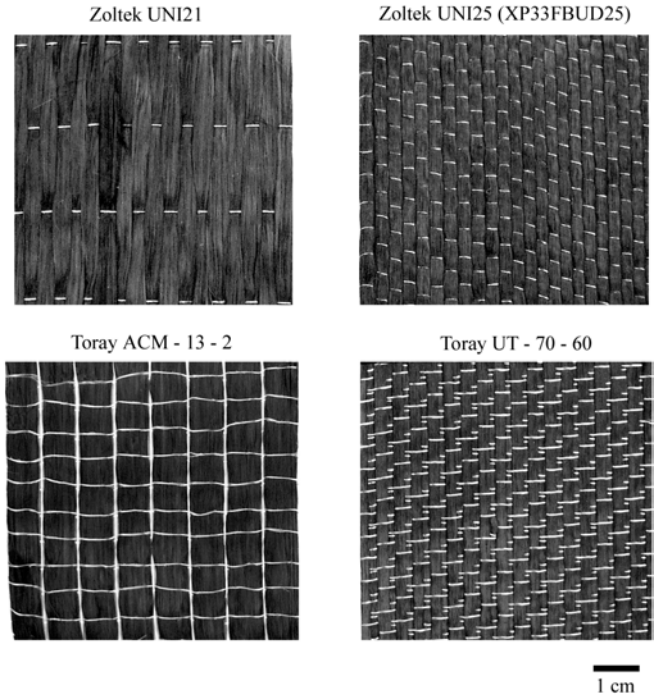
Trends in Materials

- Availability of new materials and new material forms
  - Traditional forms of glass
    - Woven
    - Stitched
    - Bonded
  - Carbon
    - Large tow & medium tow – less expensive
  - Carbon-Hybrid
  - Pre-preg glass & carbon
  - 3D weave
  - New matrix materials

Carbon & Carbon-Hybrids Provide Enhanced Strength for Less Weight



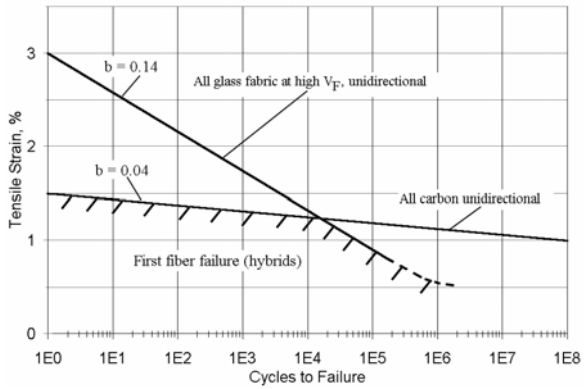
E-glass Fibers



Large Tow Carbon Fibers

Additional Research in Materials

- Continued characterization of new or modified materials
- Thin v. thick coupons v. full blade properties (transfer function)
  - Determine properties in as-built structure
  - More efficient composite design
- Understanding design details and substructures
  - Effect of defects, ply drops
  - Material combination (hybrids) introduce strain concentrations
  - Carbon-glass interfaces
  - Concerns about waviness & compressive strength



Failure of the Fiberlass Drives the Failure of the Hybrid Composite

Manufacturing Process Trends

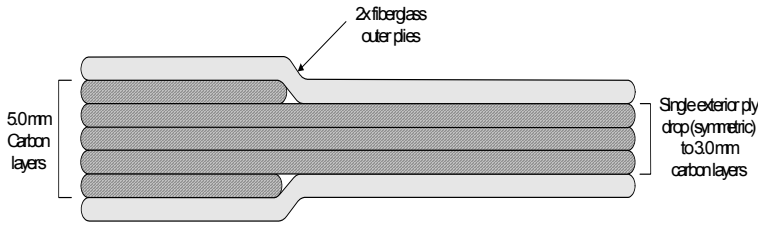
- Gone from hand lay-up to more automated processes
  - Pre-preg
  - Infusion – various forms
  - Re-emergence of wood-carbon blades

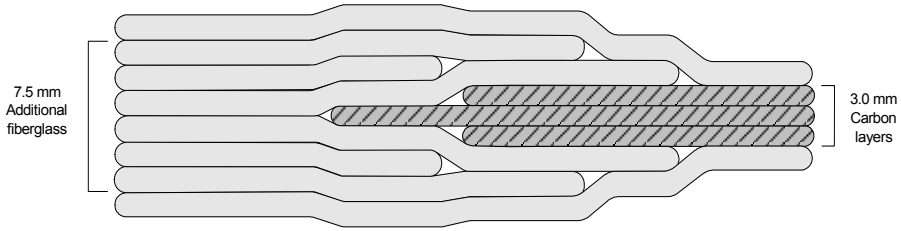
Manufacturing Process Trends

- Coupling of two or more processes
  - Pre-preg and infusion
  - Automated lay-up with pre-preg or infusion
  - Incorporation of pultrusions
    - MSU/Cairns
    - WindPACT Studies/Zuteck

Potential Improvements in Manufacturing

- Manufacturing processes
  - Process designed/optimized around different forms
    - Modeling of process itself
  - Material/resin combinations that infuse well to achieve desirable fiber content
  - Pre-form use in thickened areas
- Increased reliability in general
  - Quality & repeatability (reduce uncertainty)
  - More of test-validate-redesign cycle
- Automation
  - Tape laying
  - Pre-forms





Tuesday, February 24

7:30 am	*Early Registration & Continental Breakfast*
	Introduction
8:30am	Tom Ashwill, SNL, *Welcome to Conference and Overview of Blade Technology*
	Keynote
9:00am	Peter Jamieson, Garrad-Hassan, *Evolution of Modern Wind Turbine Rotors*
	Design & Manufacturing
9:30am	Brian Glenn, Clipper, *The Evolution of Blade Manufacturing*
10:00am	***Break*
10:30am	Ramesh Gopalakrishnan, GE Wind, *Blade Design & Manufacturing: A GE Perspective*
11:00am	Derek Berry, TPI, *Blade Manufacturing Improvements*
11:30am	Dayton Griffin, GEC, *Cost Performance Trade-offs for Carbon Fiber*
12:00pm	***Lunch*
1:00pm	Richard Palmer, SP Systems, *An Integrated Approach to Successful Blade Development*
1:30pm	Kyle Wetzel, Wetzel Engineering, Inc., *Large and Small Blades, Design & Manufacturing*
2:00pm	Jean Lonjaret, Southwest Wind Power, *Design & Manufacturing of Injection Molded Small Blades*
2:30pm	Bill Leighty, Alaska Applied Sciences, *High Compression Bladder Molded Prepreg (HCBMP) for Low-Cost Production of a 6-m Blade*
	Materials & Codes
2:45pm	Tom Lemire, Toho, *Carbon Fibers-What's in the Wind?*
3:10pm	***Break*
3:30pm	Jeff Engbrecht, Toray, *Relevant Issues of Carbon Fiber for the Emerging Wind Market*
4:00pm	Mansour Mohamed, 3Tex, *3d Weaving Technology*
4:25pm	Martin Kokoshka, Grafil Inc., *Value Chain of Carbon Fibers in the Wind*
4:45pm	*Announcements and Adjourn*
7:00pm	*Banquet (Guest Speaker - Mike Zuteck)*

Wednesday, February 25

7:30 am	*Late Registration & Continental Breakfast*
	Materials & Codes(continued)
8:00am	John Mandell, MSU, *Materials Characterization*
8:30am	Bruno Boursier, Hexcel Research & Technology, *Compression Testing of Carbon Composites for Structural Applications in Wind Blades*
9:00am	Scott Schreck, NREL, *Turbine Aerodynamics & Modeling Uncertainties*
9:30am	Craig Hansen, Windward Engineering, *Blade Load Modeling*
10:00am	***Break*
10:20am	Daniel Laird, SNL, *Codes for Blade Design*
	Testing & Certification
10:40am	Walt Musial, NREL, *Testing & Certification*
11:10am	Arno van Wingerde, Knowledge Centre WMC, *Design & Testing of Rotor Blades*
11:35am	Bill Colavecchio, Underwriters Laboratories, *Certification*
11:55pm	***Lunch*
1:00pm	Jan Hornbech, Risoe National Laboratory, *Blade Testing*
1:25pm	H.B Ben Hendriks, ECN, *Application of Optical Fibers for Blade Load Measurement & Condition Monitoring*
	Future Trends
1:45pm	Paul Veers, SNL, *Session Introduction*
1:50pm	Case van Dam, UC Davis, *Airfoils for Structures*
2:20pm	Marco Zvanik, Owens-Corning, *Blade Manufacturing Issues & Trends*
2:50pm	***Break*
3:15pm	Don Lobitz, SNL, *Stability Concerns for Large Blades*
3:40pm	Doug Cairns, MSU, *Design Manufacturing & Material Trends in Wind Turbine Blade Structures*
4:10pm	Peter Fuglsang, Risoe National Laboratory, *Aeroelastic Blade Design- Slender Blades with High Lift Airfoils Compared to Traditional Blades*
4:30pm	Ken Fisher, Goodrich De-icing and Specialty Systems, *Integrated Protection & Self Monitoring Rotor System*
4:50pm	Paul Veers, SNL, *Rotor Blade Research-Where Do We Go From Here?*
5:05pm	*Adjourn*