

# **Wind Turbine Blades Manufacturing Improvements and Issues**

TPI Composites, Inc.  
Structural Composites Division

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# Manufacturing Overview

- TPI Composites: Brief History
- SCRIMP Infusion Process
- Blade Manufacturing Improvements
- Current Issues

## **TPI Composites, Inc.**

- Fabricating Composite Parts Since 1966
- Rhode Island Facility:
  - ✓ Warren (250,000 sq. ft., 23 acres)
- Joint Venture: Vientek Blade Manufacturing – Juarez, Mexico

# Warren, Rhode Island Facility



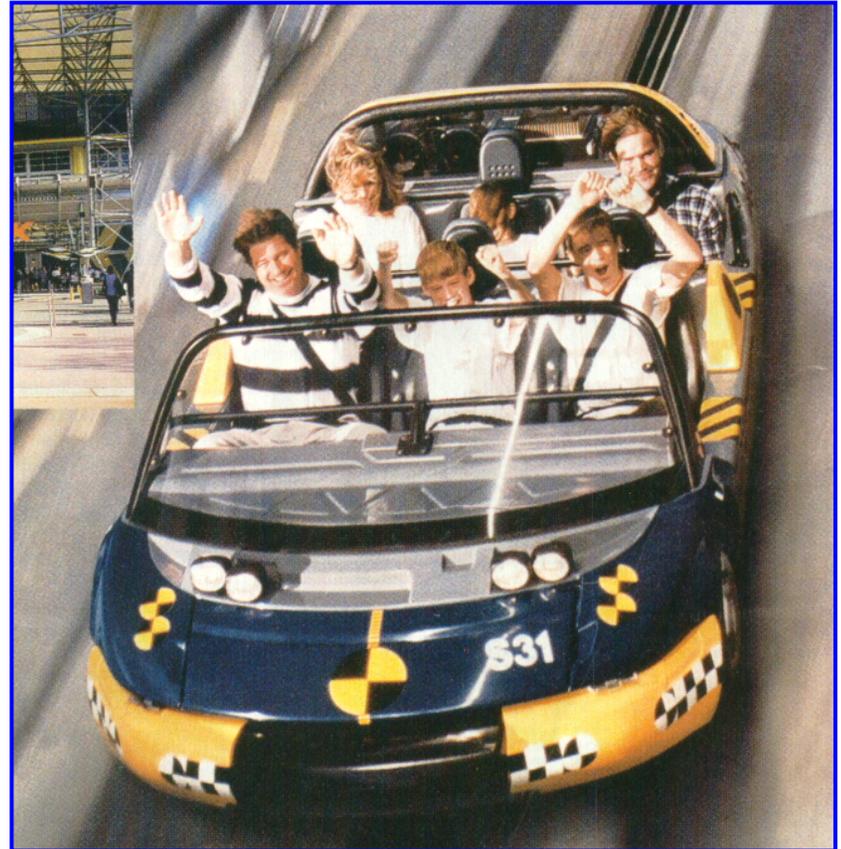
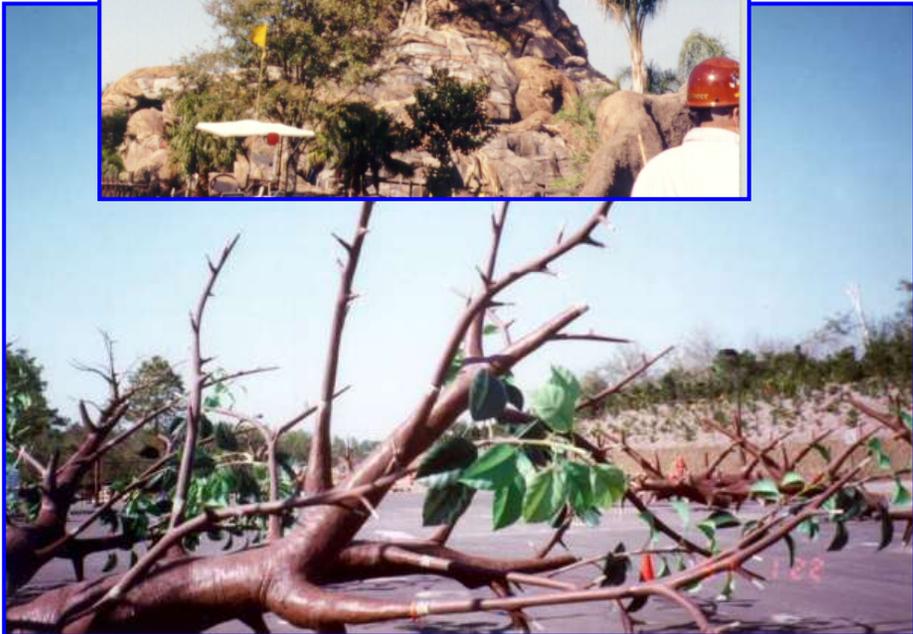
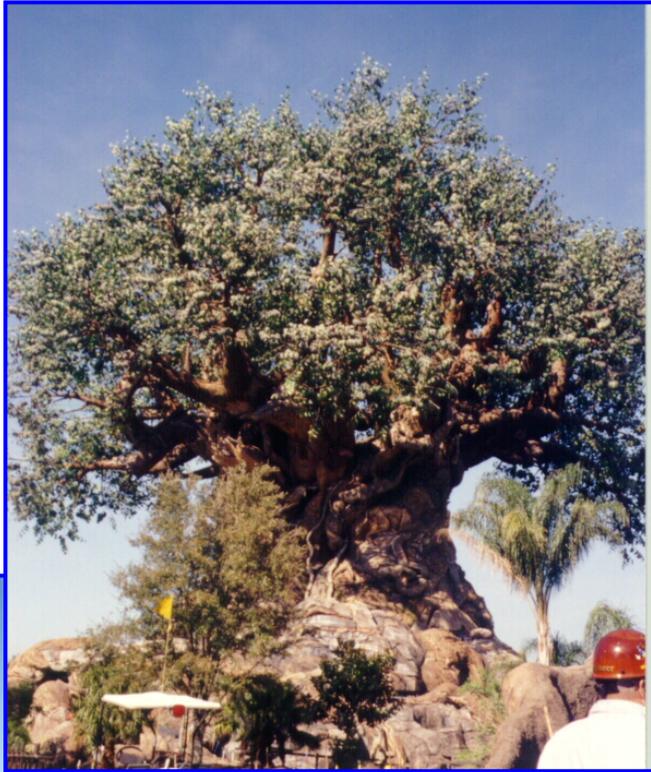
# Wind Blade Manufacturing



# Sailboat Manufacturing



# Disney Imagineering



# Airport Shuttles



# Composite Bus



# Vientek Facility



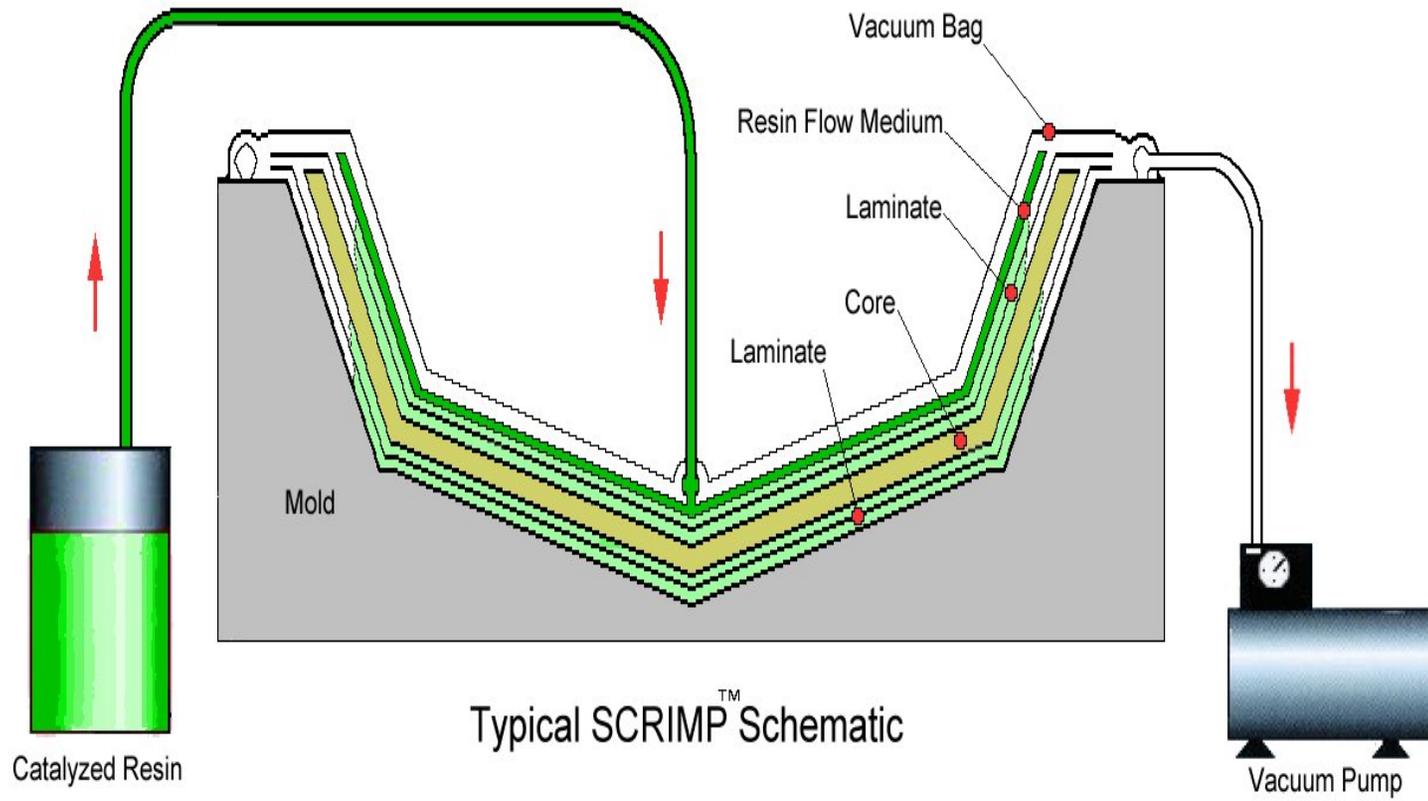
# MHI 1-Megawatt Turbine



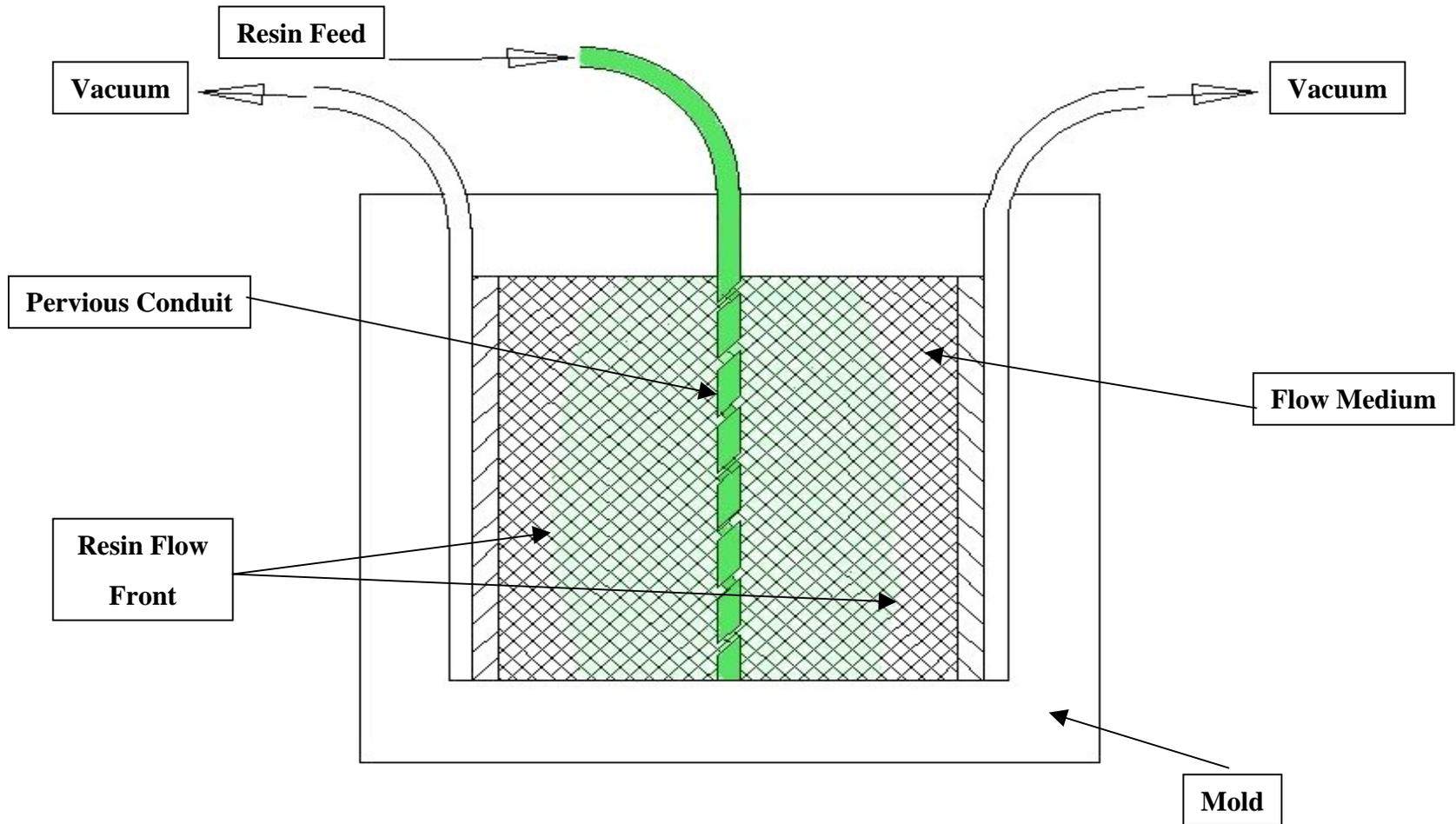
# SCRIMP

- **Seemann Composites Resin  
Infusion Molding Process**
- Vacuum Bag Resin Infusion Process
- Patented Silicone Bags
- Materials Laid-Up Dry
- Virtually Eliminates VOCs
- Aerospace Quality – Large Structural Parts

# The SCRIMP Process

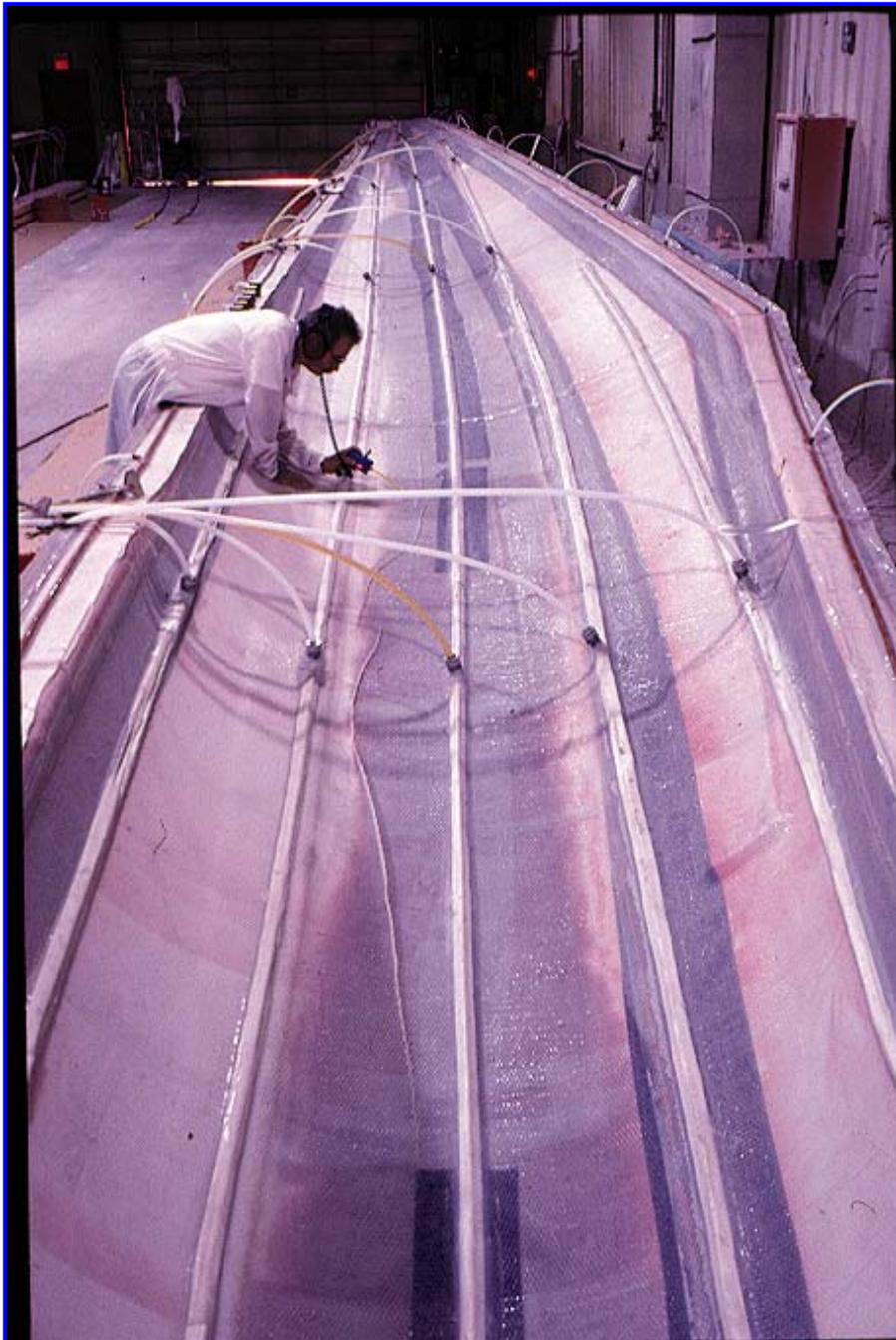


# The SCRIMP Process



# The SCRIMP Process





# The SCRIMP Process

# Manufacturing Improvements and Issues

- Blade Manufacturing Process Approaches
- Blade Construction Approaches
- Blade Manufacturing Verification Approaches
- Blade Design Approaches
- Current Blade Issues and Future Trends

# Blade Manufacturing Process Approaches

- Silicone Bags
- Remote Build
- Heated Molds

# Silicone Bag Technology

- Custom bag, formed to a part
- Patented product and process
- Resin feed conduit and distribution pattern built into the bag



# Remote Build

- Original Intent
- Lessons Learned
- Robust Process Steps:
  - Material Cutting
  - Material Kitting
  - Laminate Schedules
  - Silicone Bags

# Remote Build – Material Kits





# Remote Skin Infusion Preparation



# Remote Blade Assembly

# Heated Molds



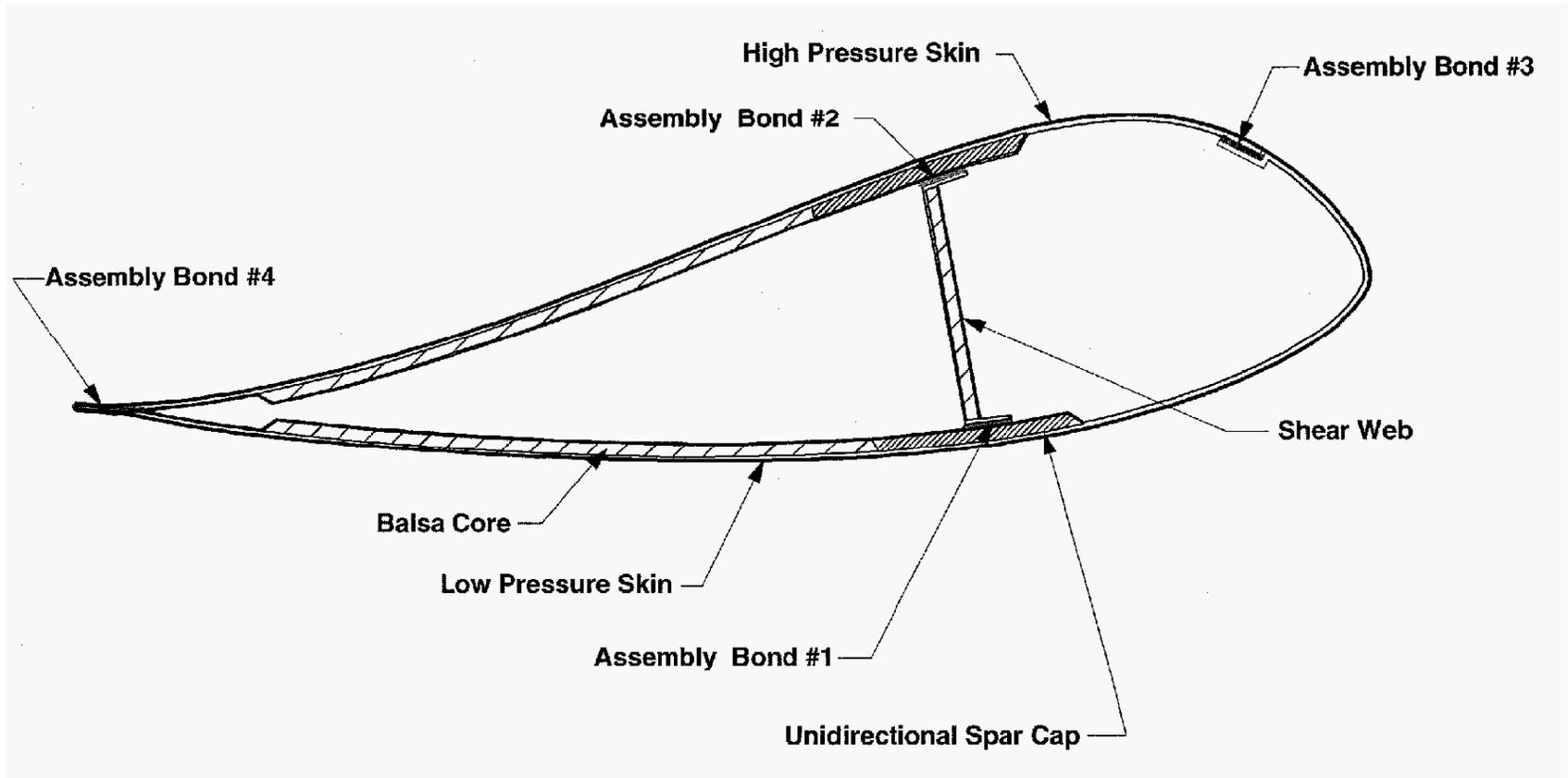
# Blade Construction Approaches

- LE Bond Line
- Spar Cap – Constant Width –  
Constant Taper
- Root Connection

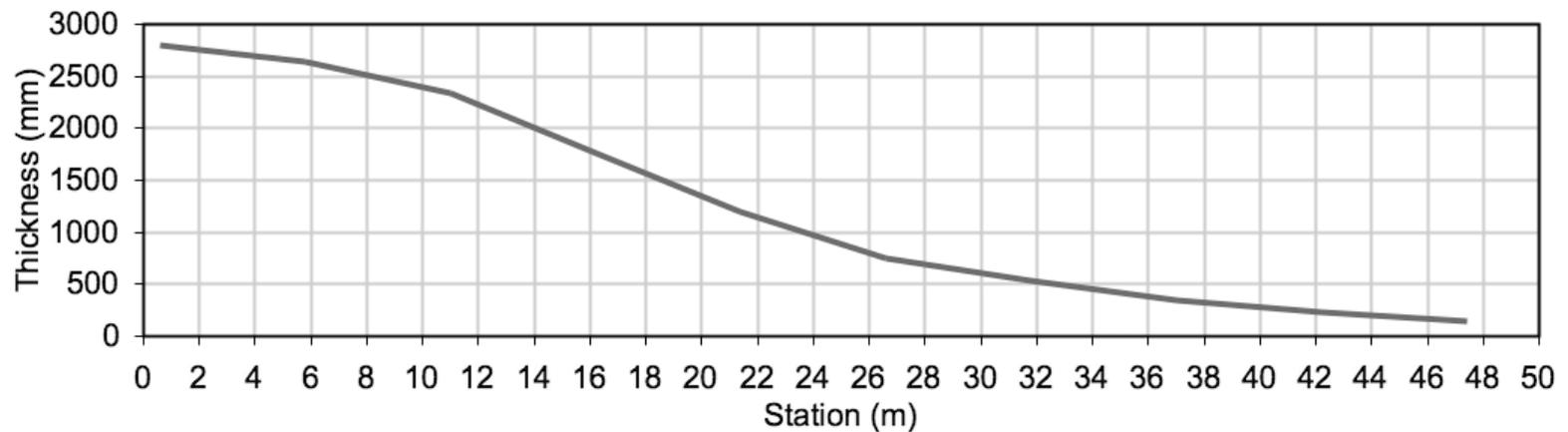
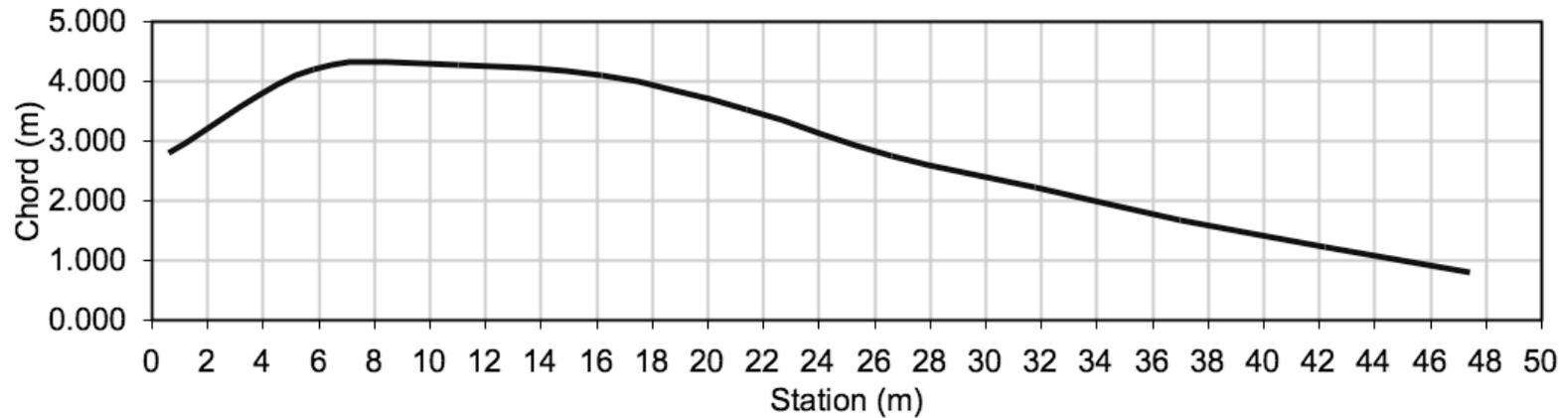
# Aerodynamicists?



# Offset LE Bond



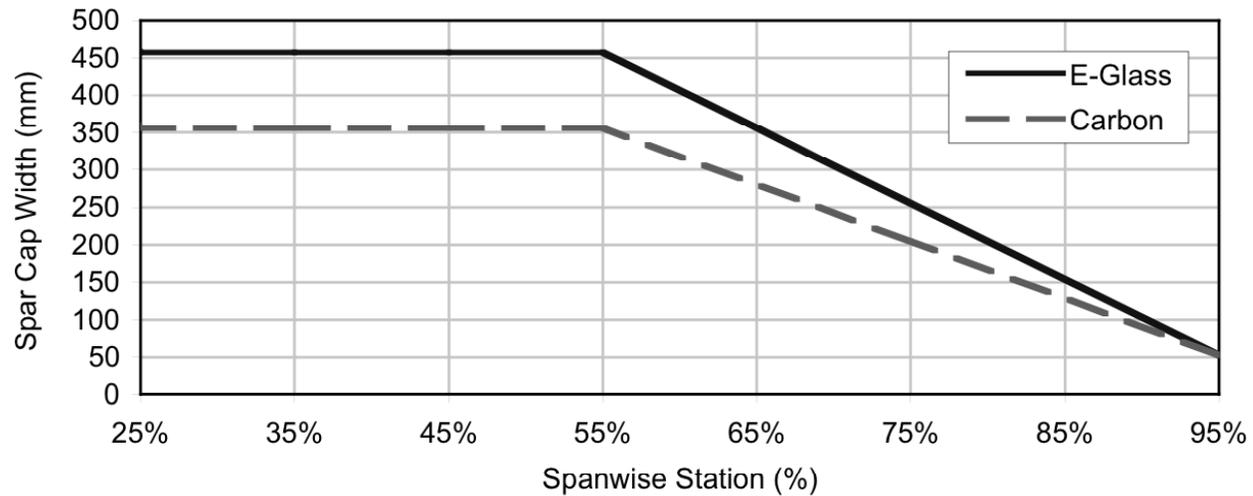
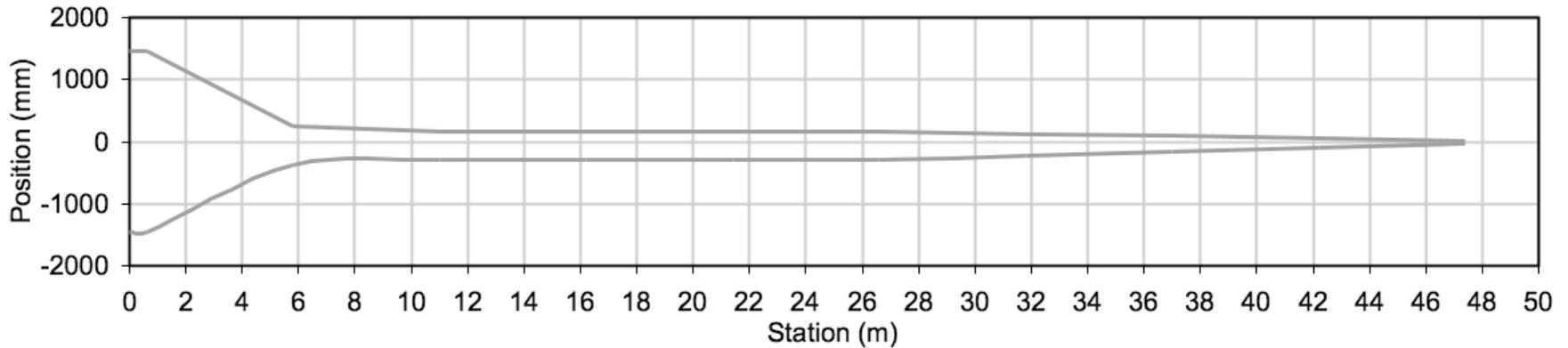
# Preliminary 50m Blade Design Planform and Thickness Distributions



# Preliminary 50m Blade Design

## Constant Spar Cap

Spar Cap Location



# Root System Study

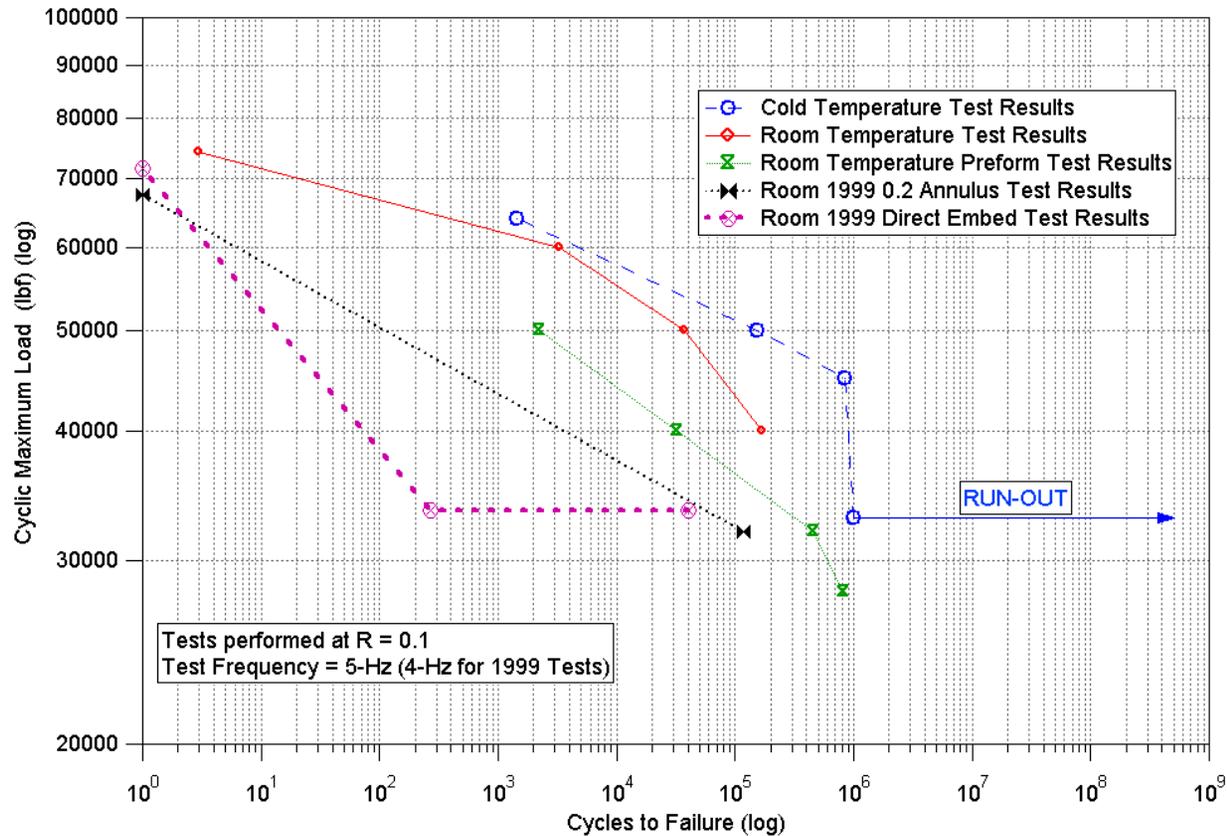




## Root Stud Testing at NREL

- Back to back root stud configuration
- Static testing
- Fatigue testing

# Root Stud Fatigue Test Load – Life Results



# Post Mortem of Epoxy Bonded Stud



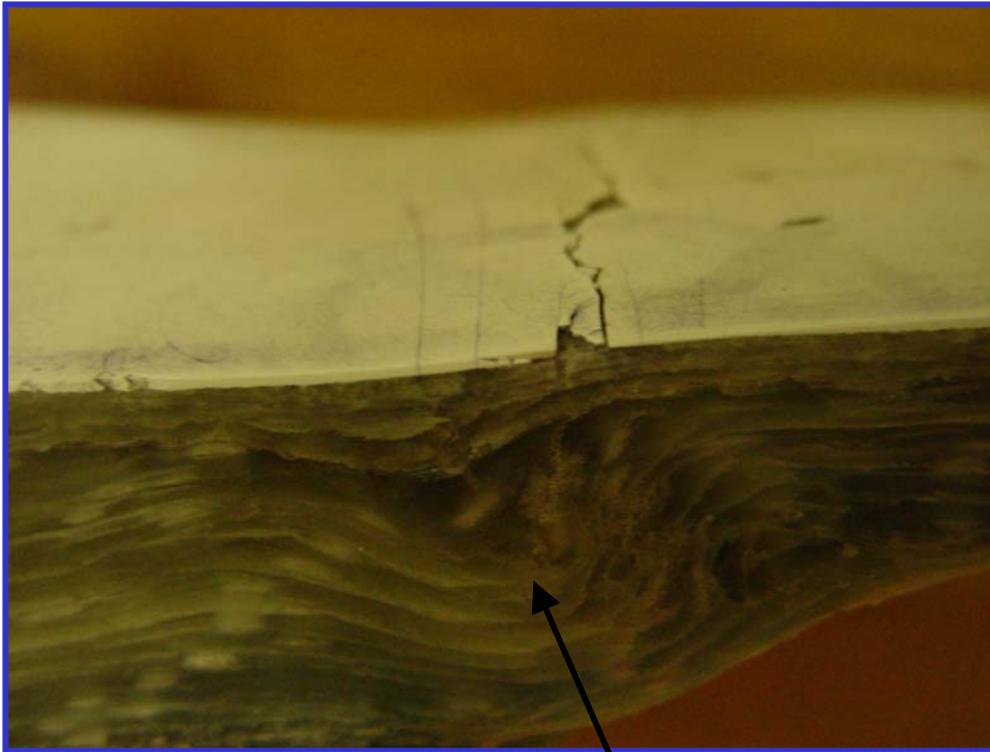
# NPS-100 – Bonded Root Inserts



# Blade Manufacturing Verification Approaches

- Blade Sectioning
- NDT – UT: Bond Lines
- Testing

# Blade Sectioning



- Laminate design
- Internal blade geometry
- Blade adhesive
- Chordwise CG
- Static Balance
- Manufacturing variations

Laminate Fabric Wrinkle

# Blade Proof Testing



# Blade Proof Testing

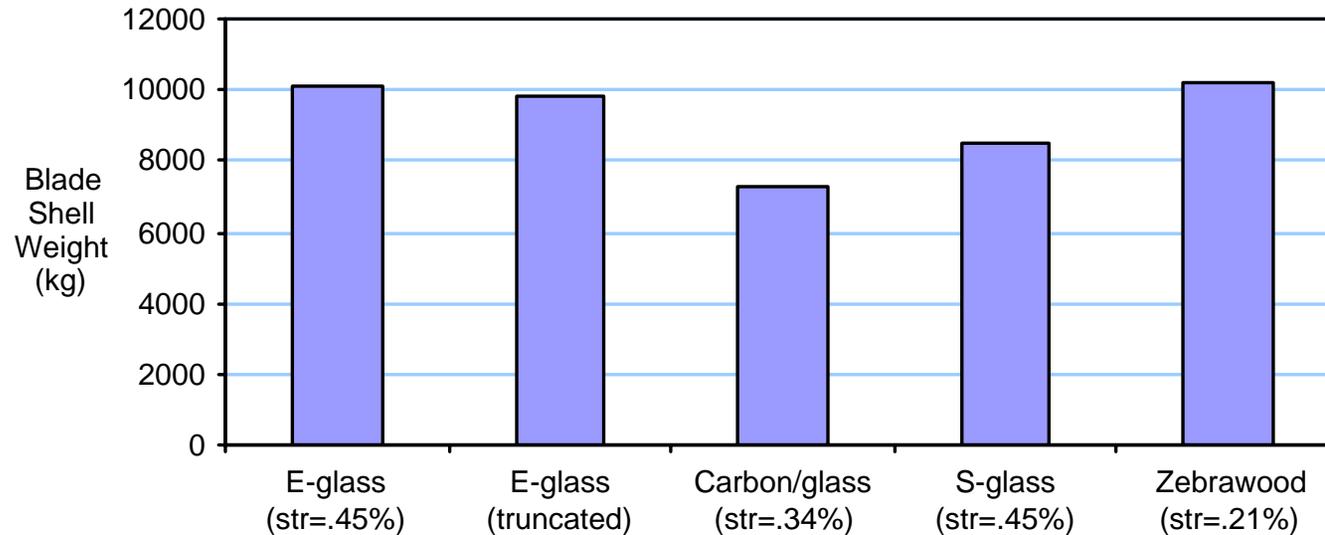


# Blade Design Approaches

- Blade Materials
  - E-glass
  - Carbon / E-glass hybrid
  - S-glass
  - Carbon / Wood / E-glass hybrid  
(zebra wood)
- Blade Geometry
  - Thick Airfoils
  - Flat-Back Airfoils

# Innovative Design Results

## Alternate Blade Materials



Shell Weight Comparison for Alternative  
Spar Cap Materials

# Examples of Thick Airfoils

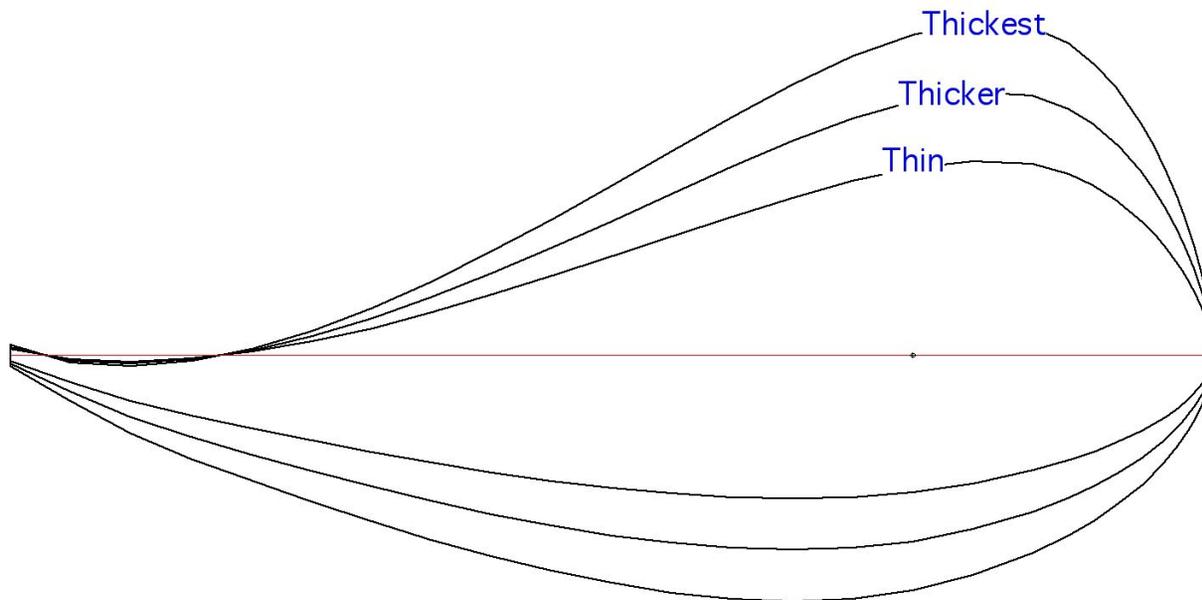
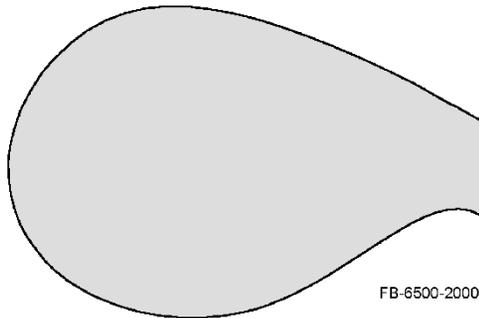


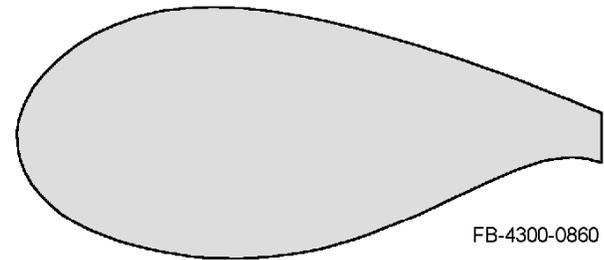
Illustration of Blade Sections at 25% Span

# Examples of Flatback Airfoils

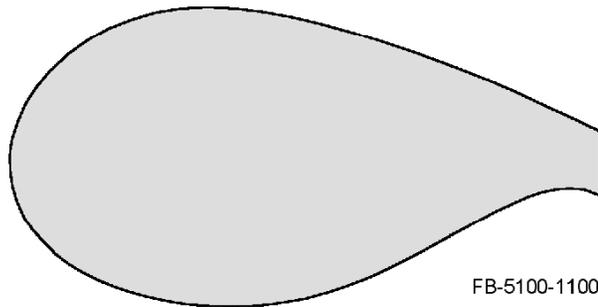
**FB-6500-2000 at 15% Radius**



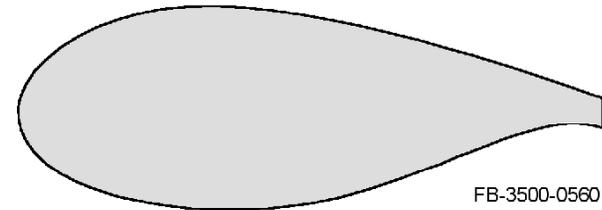
**FB-4300-0860 at 35% Radius**



**FB-5100-1100 at 25% Radius**



**FB-3500-0560 at 45% Radius**



# Current Blade Issues and Future Trends

- Adaptive Blades
- Increased use of Carbon Fiber
- Split Blades – Spanwise Joint
- Pultruded Spar Caps
- **Iterative Design Process**