SAND2013-9974C

Large Rotors: 100-meter Blade Research @ Sandia

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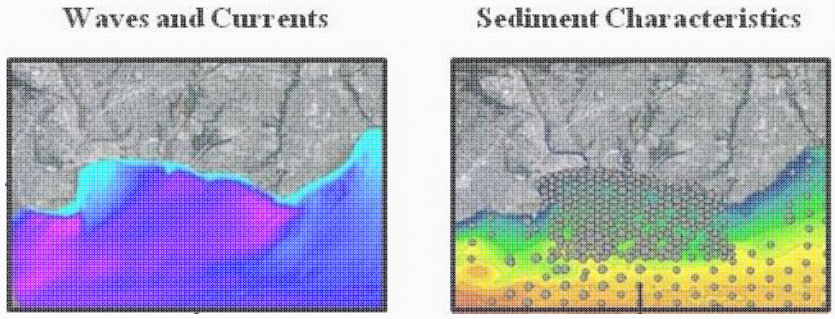
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Sandia National Laboratories

Offshore Wind @ Sandia

Sandia National Laboratories

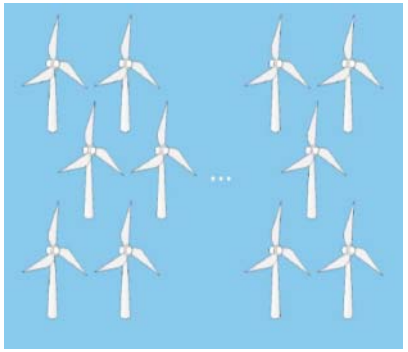
- **Vision**: Promote & accelerate the commercial OW industry and **reduce costs** through **technical innovation:**
  - Siting/Permitting: Sediment Transport & Radar
  - Large offshore HAWT rotors
  - Deepwater VAWT system
  - Structural health and prognostics management
  - Offshore wind farm modeling



Offshore Siting Analysis

Structural Health

Offshore Wind Farm



Deepwater Offshore VAWT

Large Offshore Rotors

Innovative Offshore Vertical-Axis Wind Turbine Rotors (FOA)

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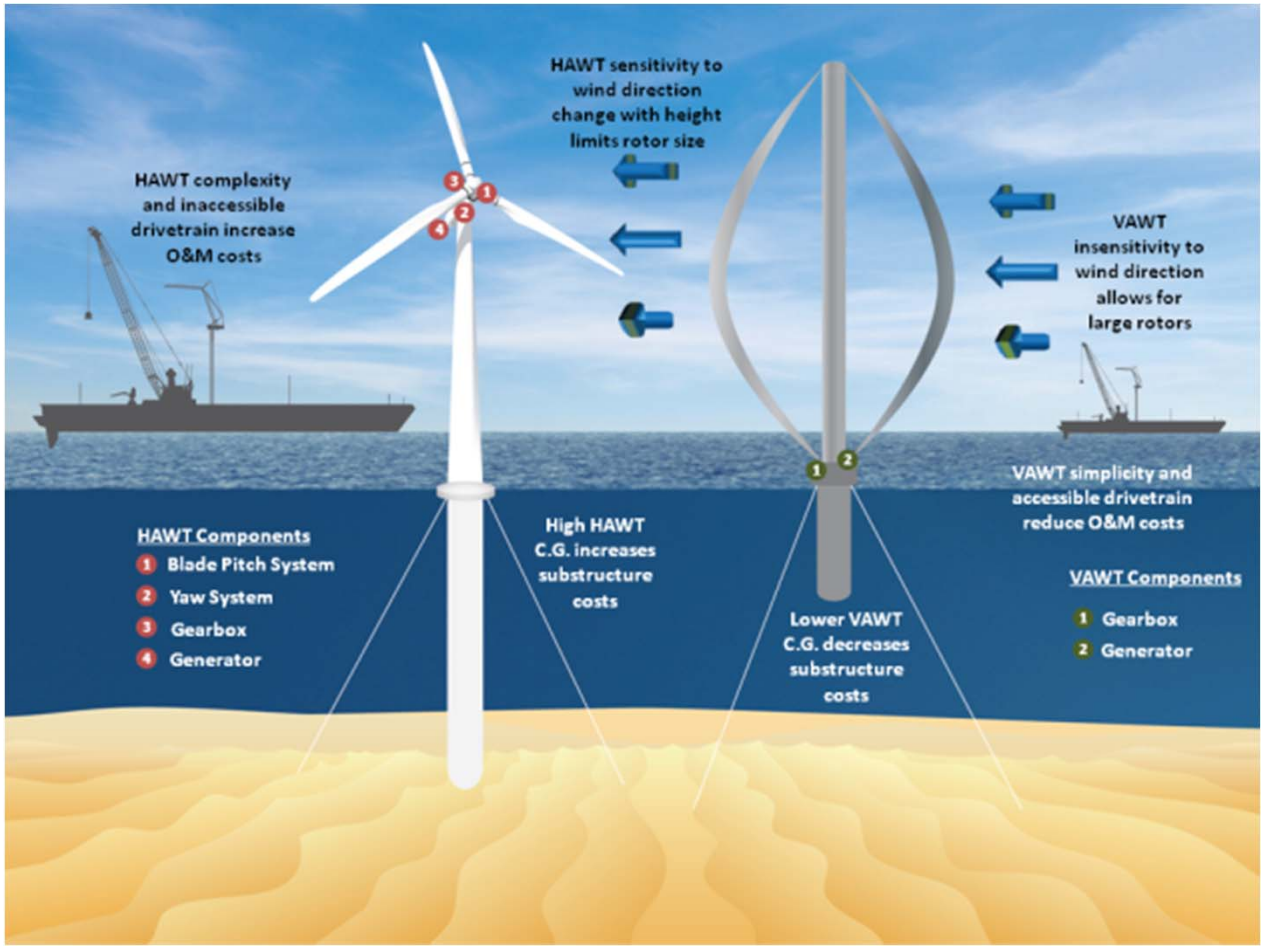
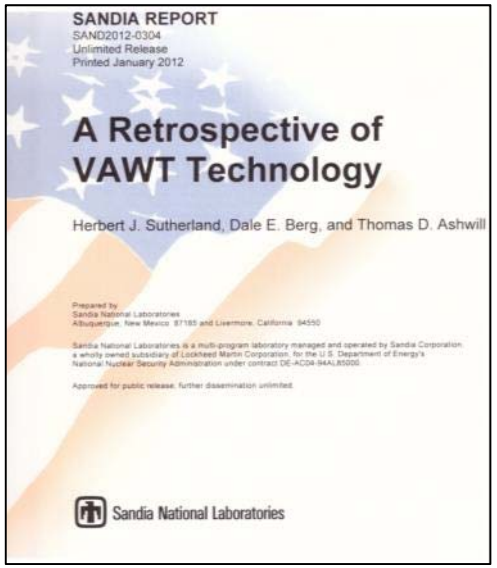
Large reduction in Deepwater Offshore COE may require non-incremental system solutions



Available at www.sandia.gov/wind



Large Offshore Rotor Development (100-meter Blade Project)

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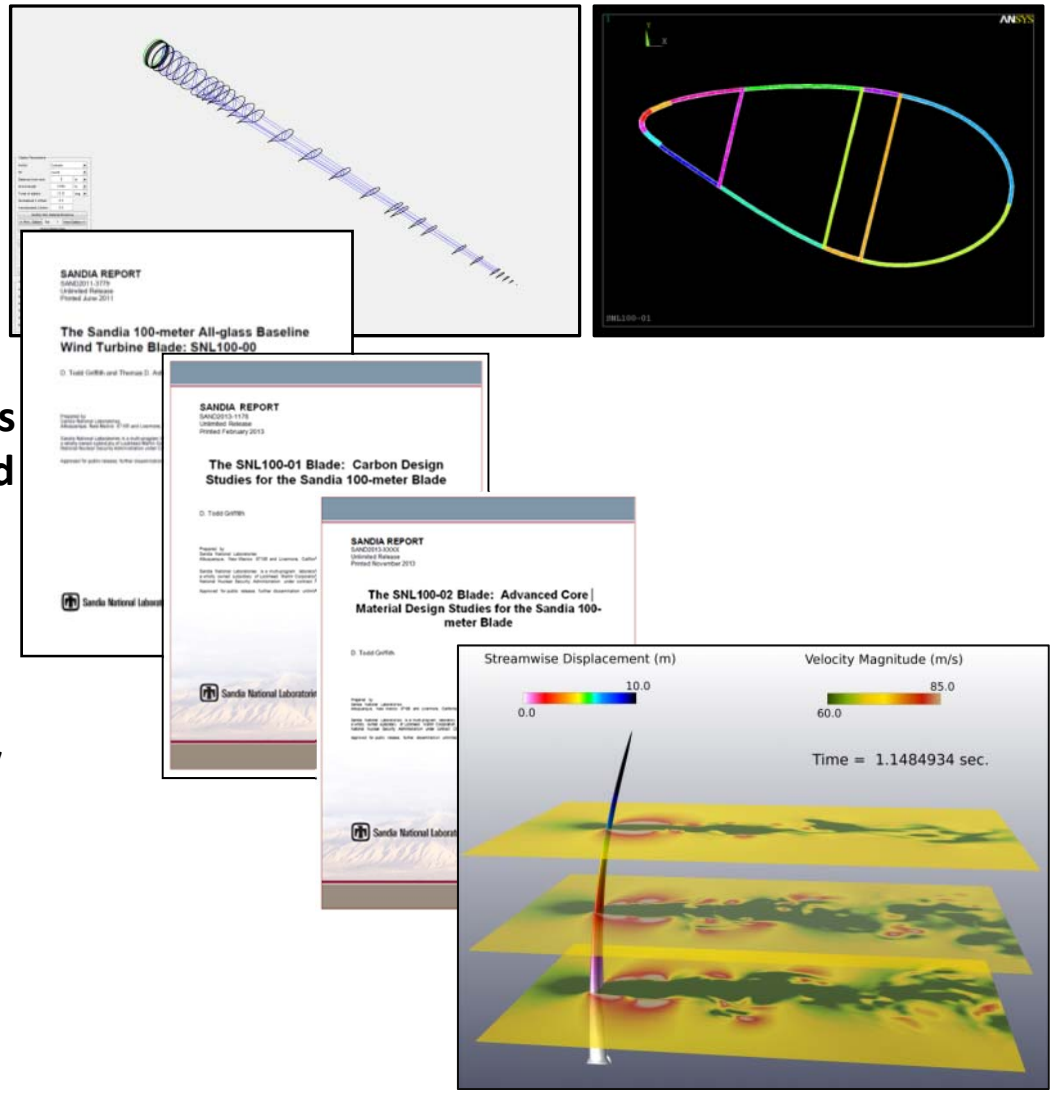
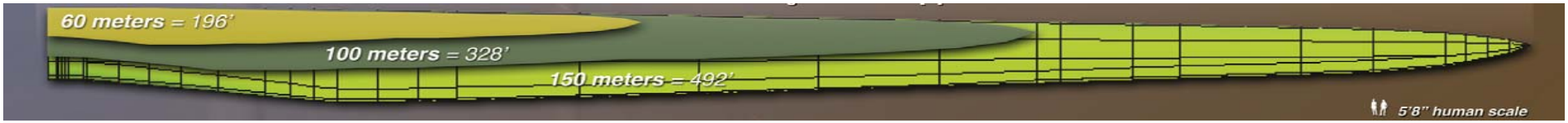
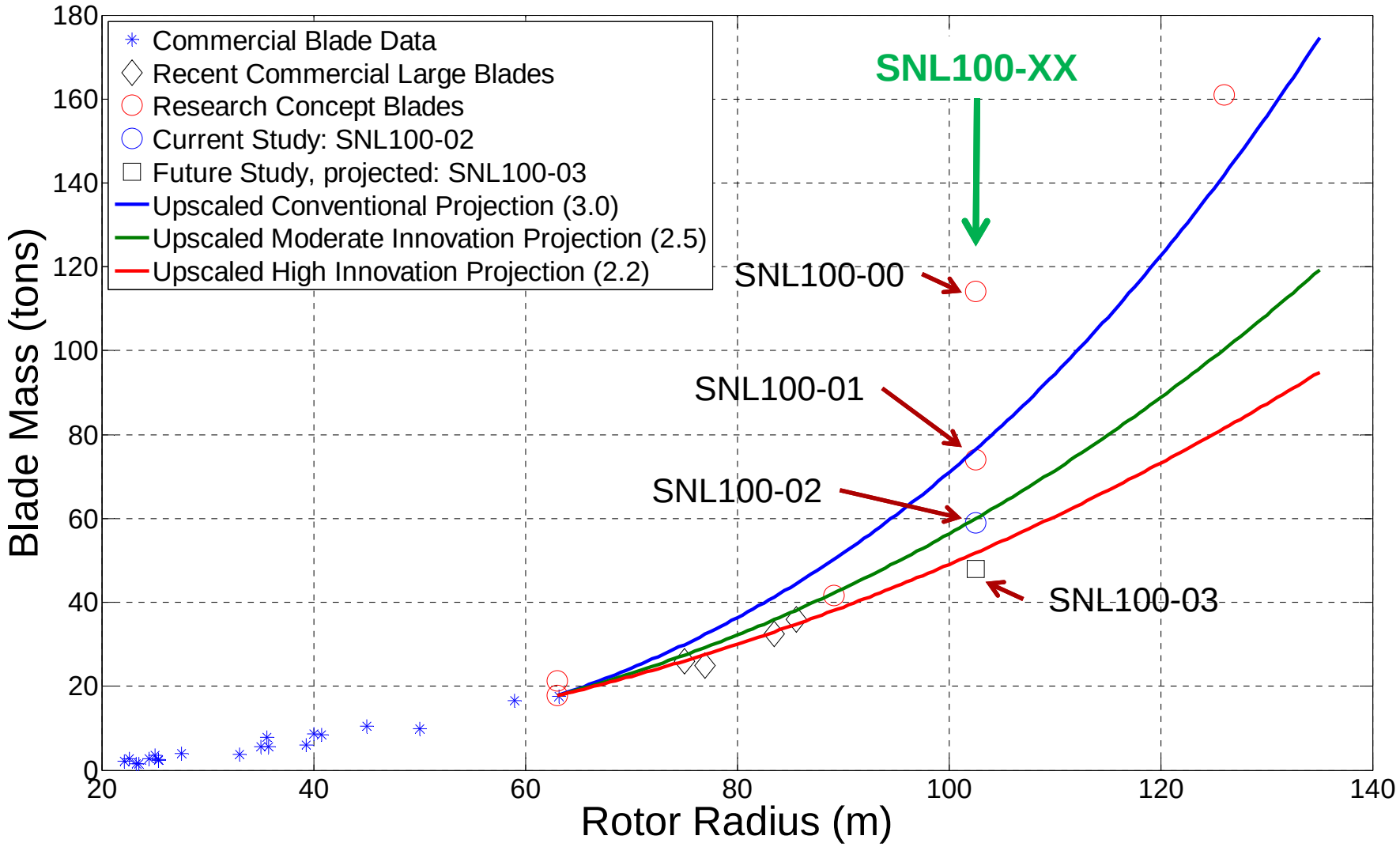
- **Summary/LCOE Impact**
  - Advanced large blade design studies
  - **Reduce technology risk**
  - Enable cost-effective large rotors
  - **Public domain blade project**
- **Objectives/Focus Areas**
  - Identify trends and challenges
  - **Detailed 100-meter reference designs**
  - **Targeted follow-on studies**: **advanced concepts, materials**, flutter, manufacturing cost trends, **thick airfoils**, CFD
- **Website**
  - **http://largeoffshorerotor.sandia.gov**
- **Partners:**
  - **None funded, 50+ users, ECN, Altair, Bristol, Stuttgart**





Industry and Research Blade Survey



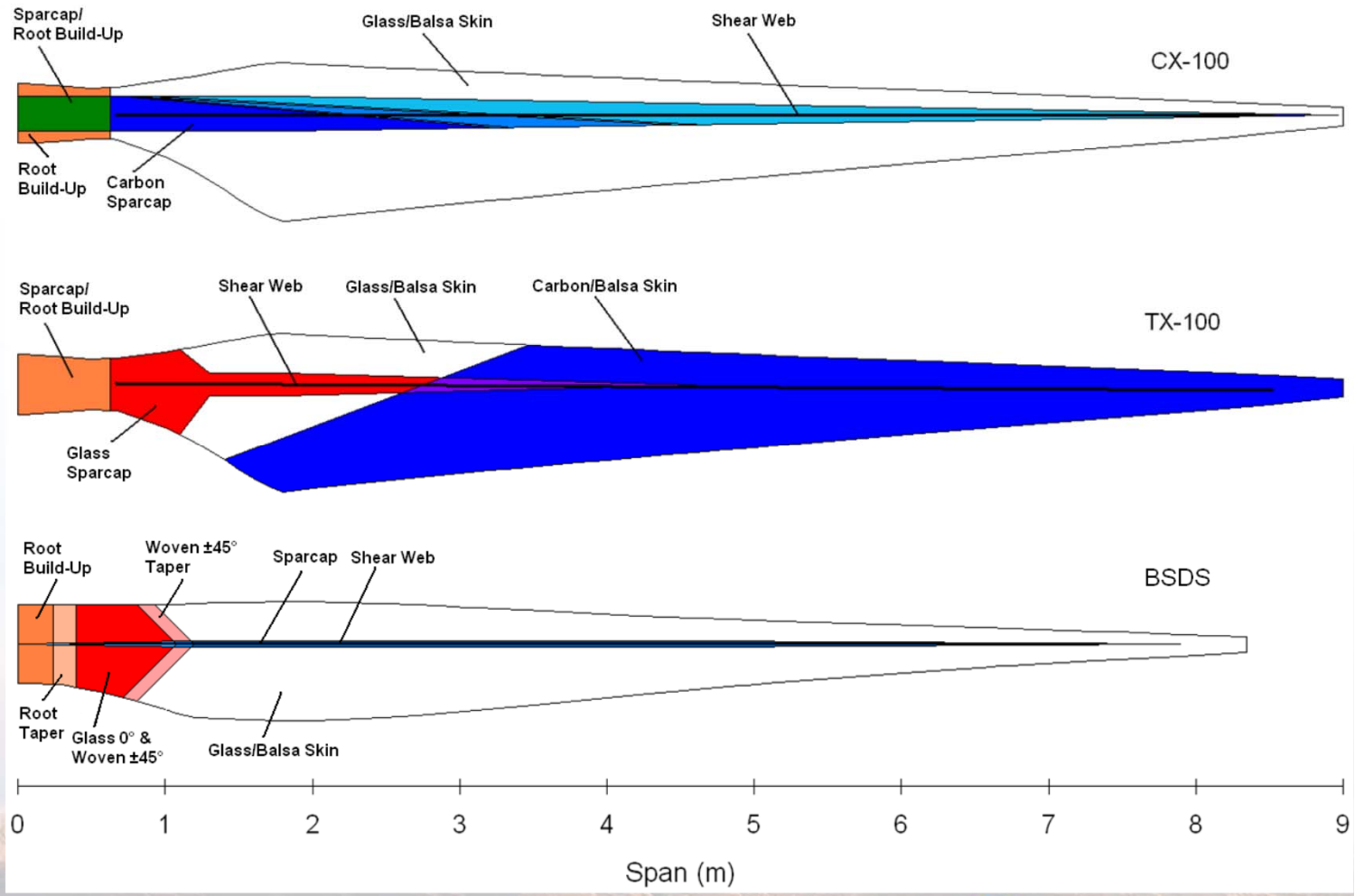
SNL Research Blade Designs:
Late 1990's to present

Research Goal

CX-100
Strategic use of carbon fiber

TX-100
Bend-twist coupling

BSDS
Flatback/thick airfoils



SNL100-XX: Design Review

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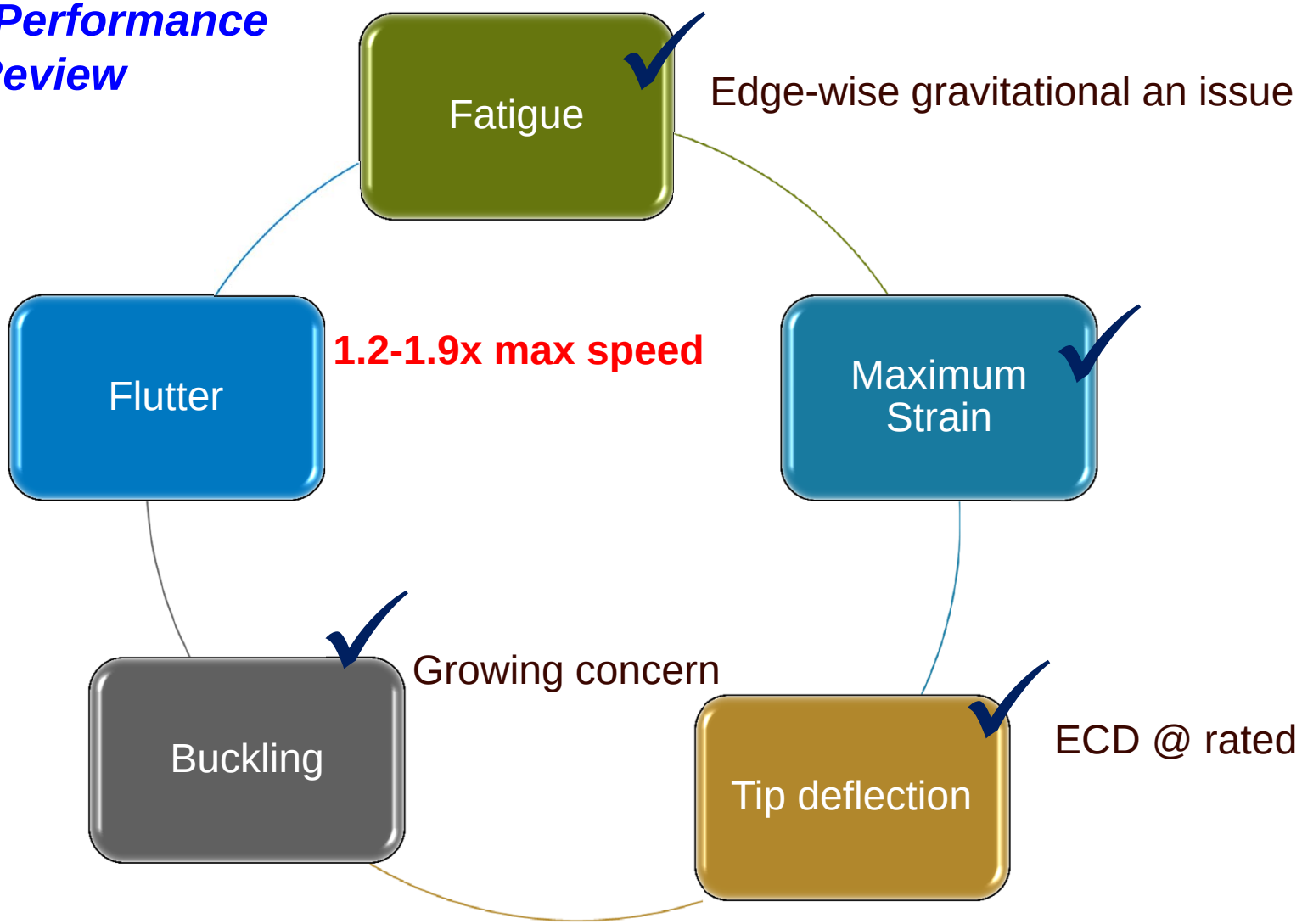
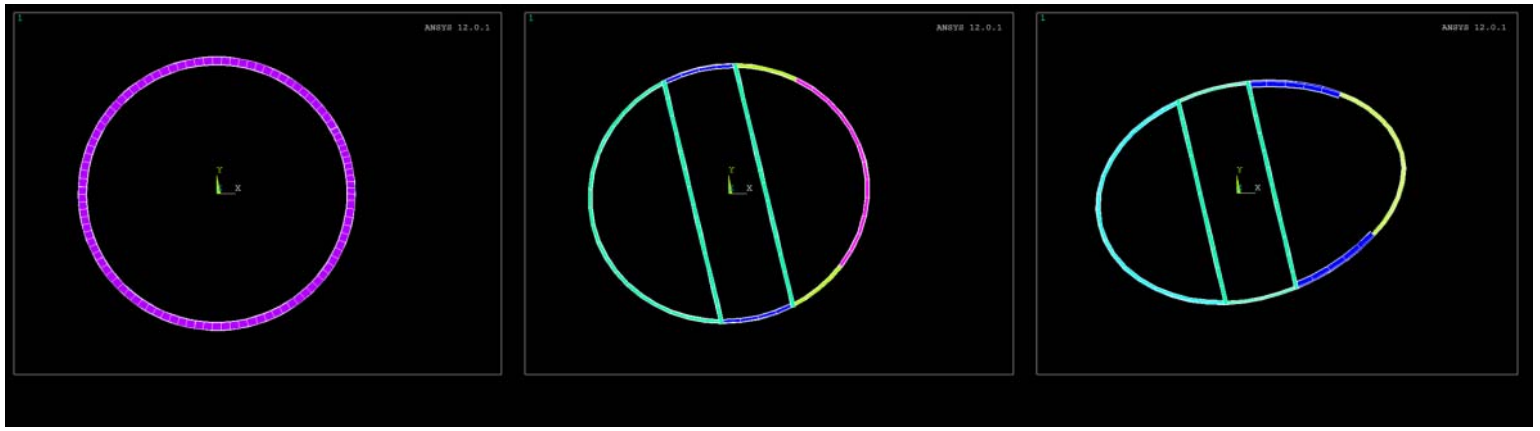
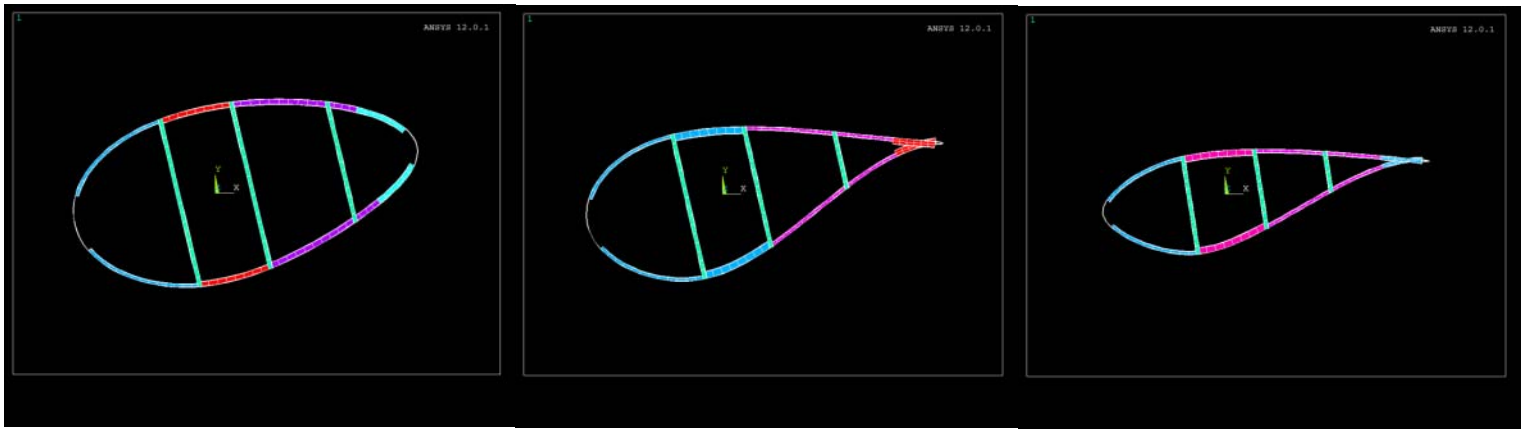
Design Performance Review



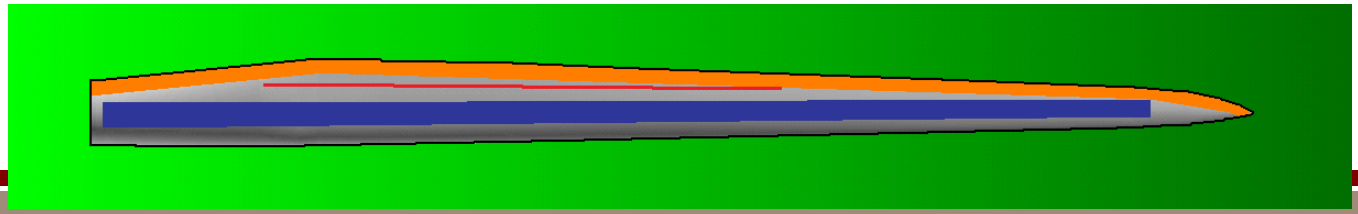
SN100-00: Layup



(a) 0.0 meters (root circle) (b) 2.4 meters (shear webs begin) (c) 8.9 meters(transition)



(d) 14.6 meters (third web begins) (e) 19.5 meters (max chord) (f) 35.8 meters



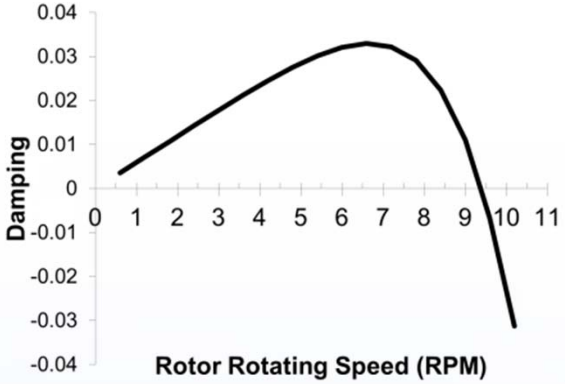
SNL100 Follow-on Projects

These are the follow-on study areas addressed by Sandia; many additional issues addressed by users of the 100-meter blade reference models.

1. **Sandia Flutter Study**
2. **Altair/Sandia CFD Study**
3. **Sandia Blade Manufacturing Cost Model**
4. **Carbon Design Studies**
5. **Advanced Core Material Design Studies**
6. **Geometry, Thick Airfoils (Flatbacks)**
    1. Blade Slenderness – reversing the trends
    2. Aero-structural design objectives

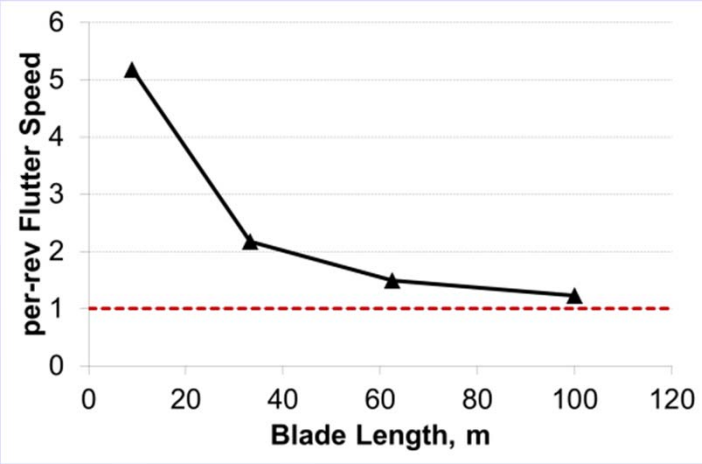
(#1) Sandia Large Blade Flutter Study

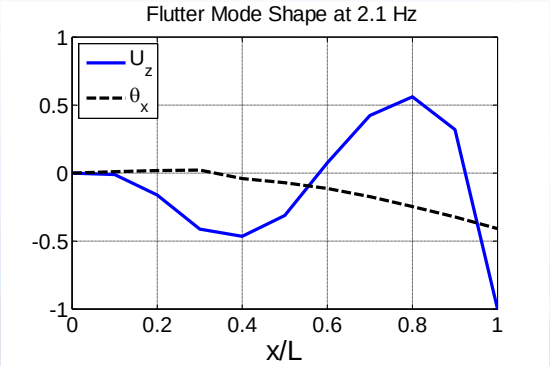
- **Resor, Owens, and Griffith. "Aeroelastic Instability of Very Large Wind Turbine Blades." Scientific Poster Paper; EWEA Annual Event, Copenhagen, Denmark, April 2012.**

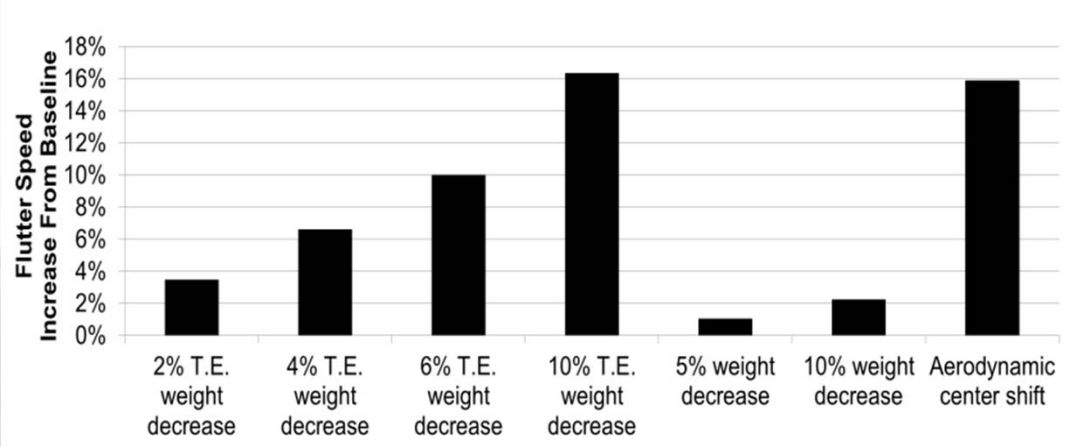


Data shown are from classical flutter analyses:

- **SNL CX-100; 9-meter experimental blade**
- **WindPact 33.25-meter 1.5MW concept blade**
- **SNL 61.5-meter blade (preliminary design)**
- **SNL100-00 Baseline Blade**



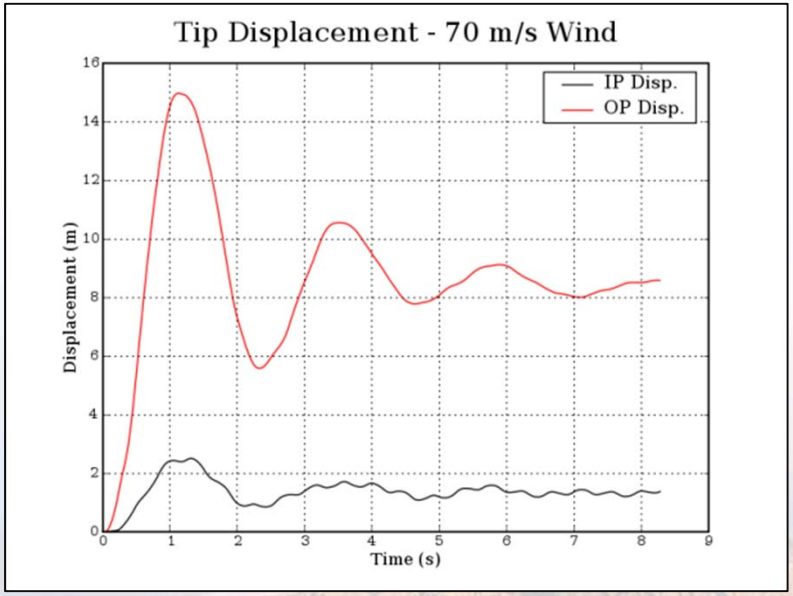


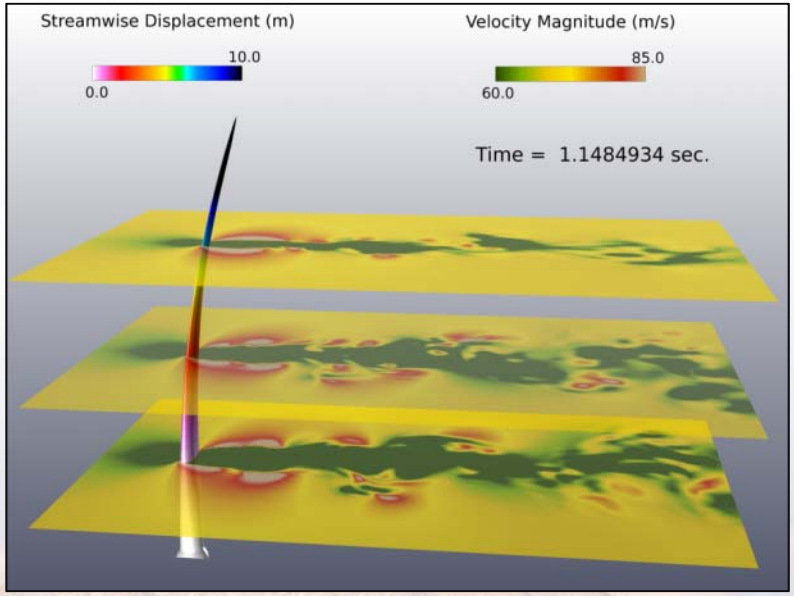


(#2) High-fidelity CFD Analysis of SNL100-00

Fully coupled fluid/structure interaction model of Sandia's 100m blade has been developed using *AcuSolve*

- *AcuSolve* CFD solution validated against existing tools
  - Good agreement with WT_Perf for all quantities
  - Some curious results when comparing *AcuSolve* and WT_Perf to FAST
  - Model extended to handle wind gusts and blade flutter simulations





Corson, D., Griffith, D.T, et al, "Investigating Aeroelastic Performance of Multi-MegaWatt Wind Turbine Rotors Using CFD," AIAA Structures, Structural Dynamics and Materials Conference, Honolulu, HI, April 23-26 2012, AIAA2012-1827.

HyperWorks

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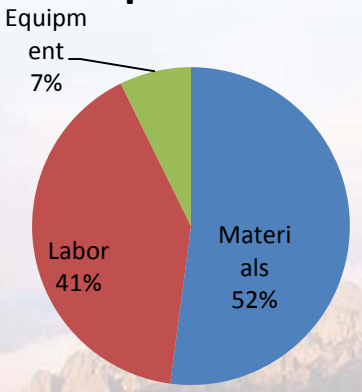
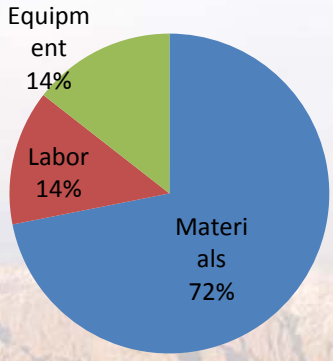
(#3) Sandia Blade Manufacturing Cost Model

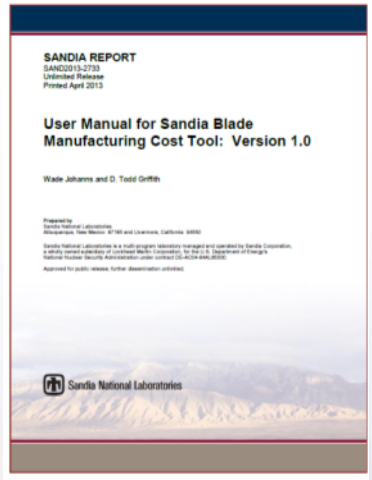
- **Components of the Model:**
  - Materials, Labor, Capital Equipment
  - Detailed Labor Breakdown by major operation
  - Reports: SAND2013-2733 & SAND2013-2734

40m All-Glass Blade Cost Components



100m All-Glass Blade Cost Components




SANDIA REPORT
SAND2013-2733
Unlimited Release
Printed April 2013

User Manual for Sandia Blade Manufacturing Cost Tool: Version 1.0

Wade Johanns and D. Todd Griffith

Sandia National Laboratories

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(#4) Carbon Design Studies: SNL100-01

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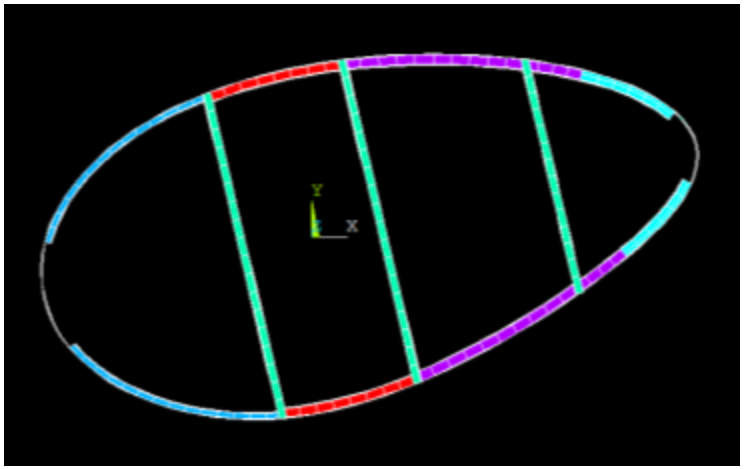
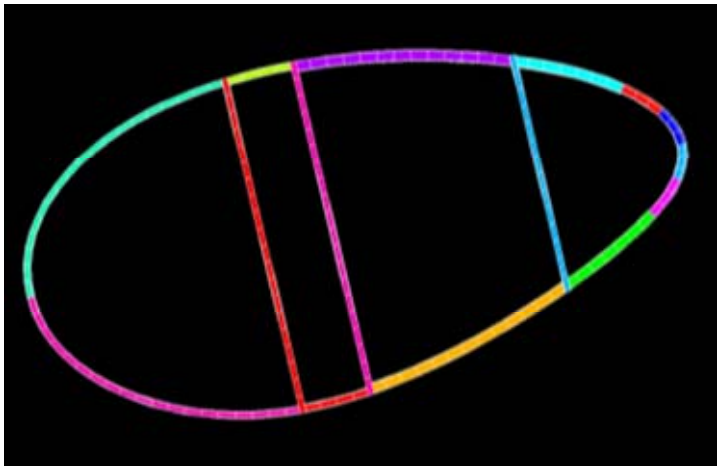
Cross-sections at 14.6m station

SNL100-00: Glass Spar



SNL100-01: Carbon Spar



- **Spar width reduced by 50%**
- **Shear web thickness reduced by 25%**
- **35% weight reduction**

(#5) Advanced Core Material Strategy: SNL100-02

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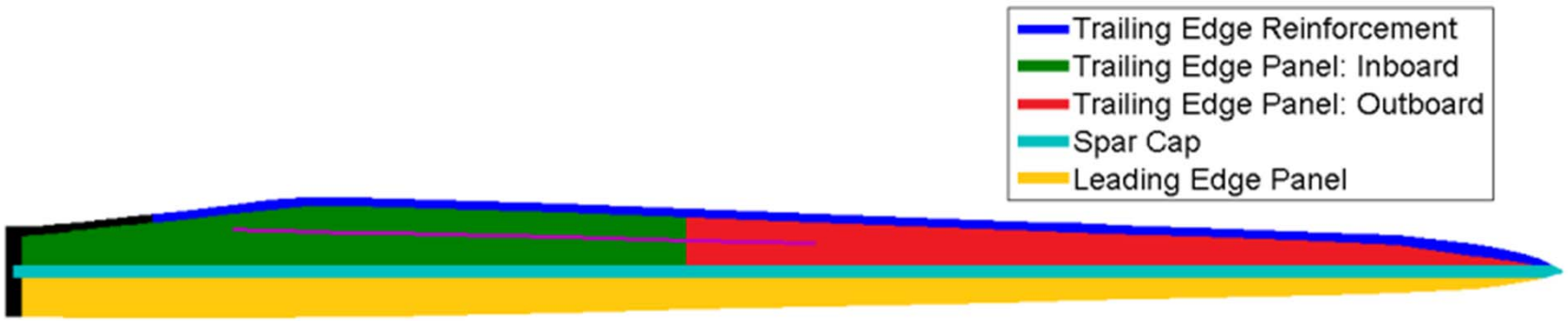
Performance Focus:

- Balsa in critical buckling areas
- PET foam (recyclable) in non-critical buckling areas and shear webs
- ~20% weight reduction

Secondary Benefit:

- Eco-friendly core materials approach (regrowable and recyclable)



(#6) New Geometry: Flatback Airfoils Future SNL100-03

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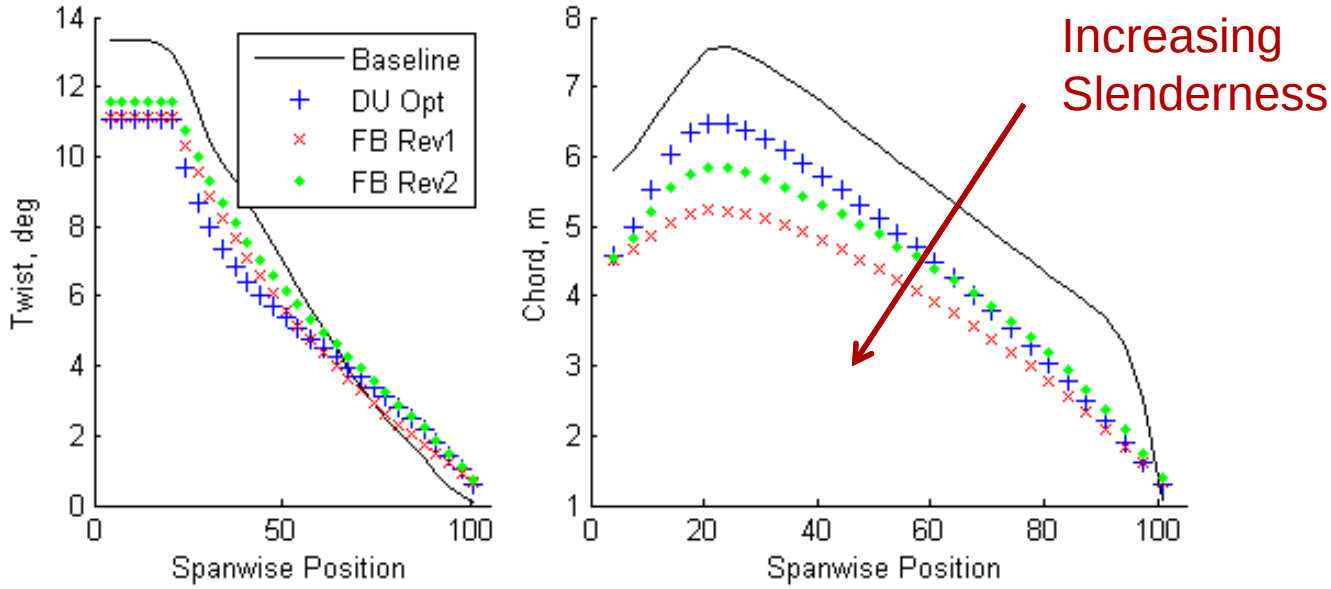
Focused on effect and limits of blade slenderness

Opportunity to reverse many trends, including:

- Weight growth – *innovative weight projection anticipated*
- Buckling
- Flutter
- Surface Area Driven Labor Operations



Summary of SNL100 Recent Projects

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