SAND2016-2481C

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Sandia National Laboratories

Sandia Labs Wind Research Activities

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Sandia National Laboratories

Wind Energy Research Workshop

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U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

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SNL Wind Program History

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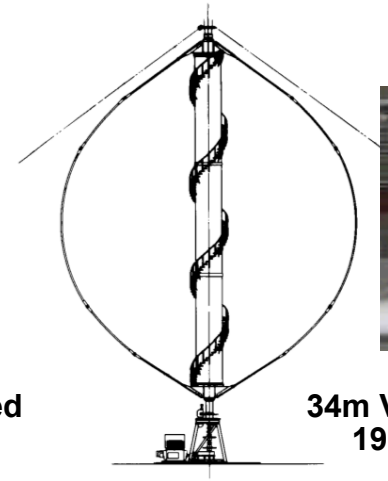
41 Years of wind R&D, primarily wind turbine rotor development

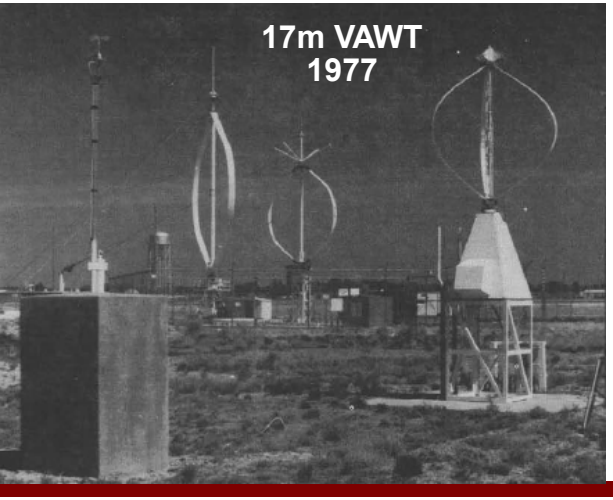
Wind Program Established 1975



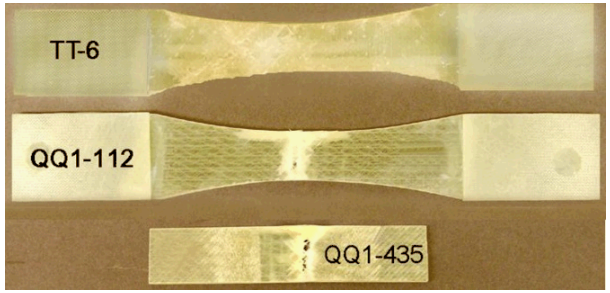
34m VAWT 1984

Blade Program 1994

SWiFT Facility 2013



Composite Materials Database 1988



Advanced Manufacturing Initiative 2008

Scaled Wind Farm Technology (SWiFT)

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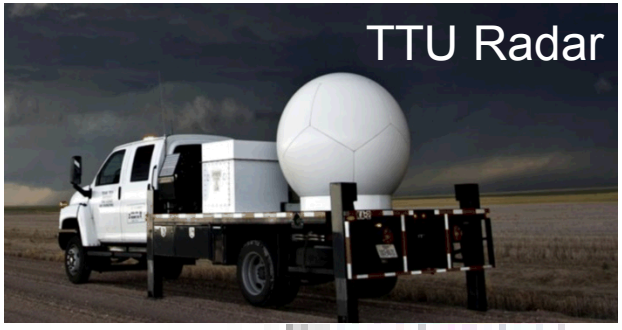
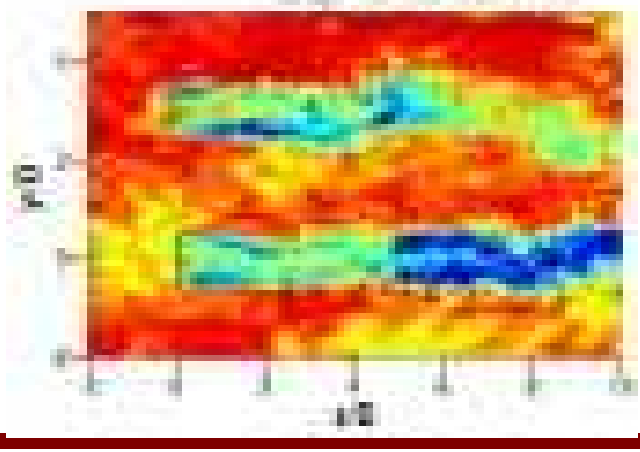
- Turbine wakes are not well understood, but can detrimentally affect wind plant performance. We are studying these effects and using them to our benefit
- A subscale test facility can reduce costs to 1/10th to 1/50th of full-scale test costs while still effectively emulating a modern megawatt scale rotor
- Optimizing wind turbine rotor development and wind plant performance
- Public, open-source info enhances collaboration





National Rotor Testbed

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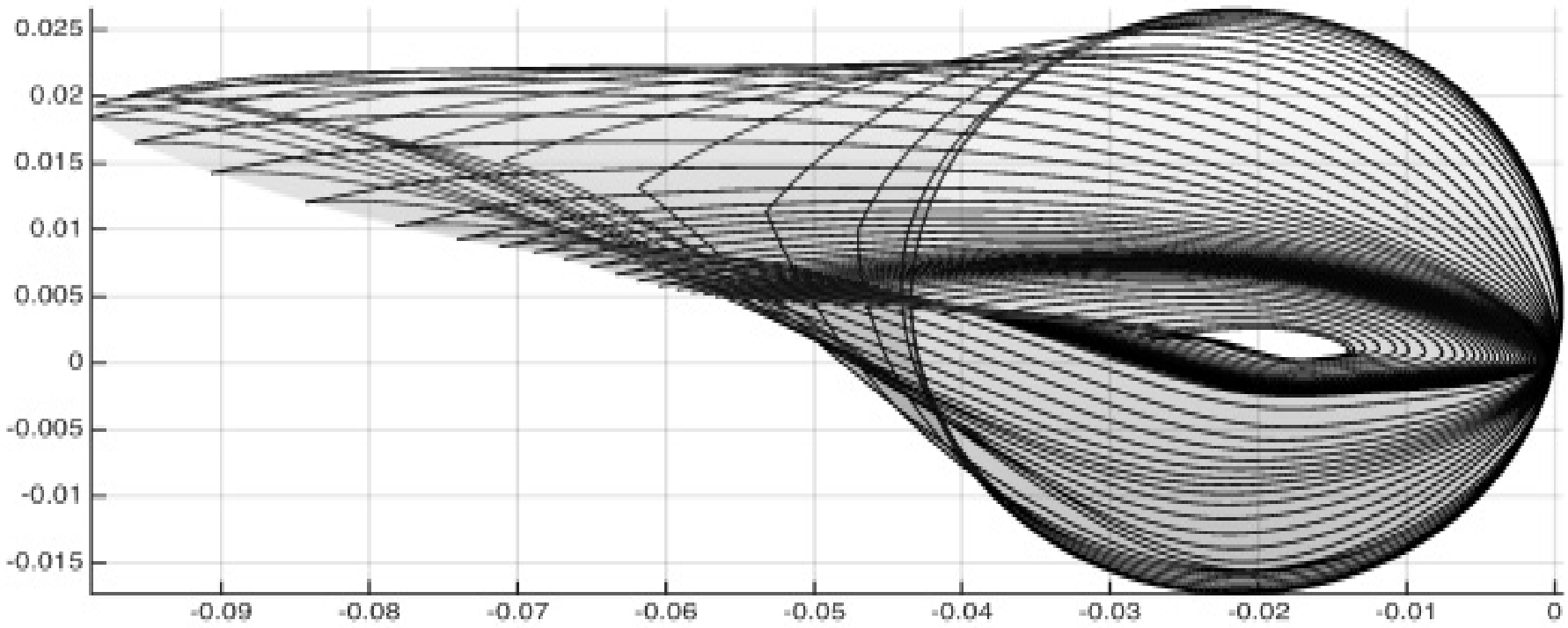
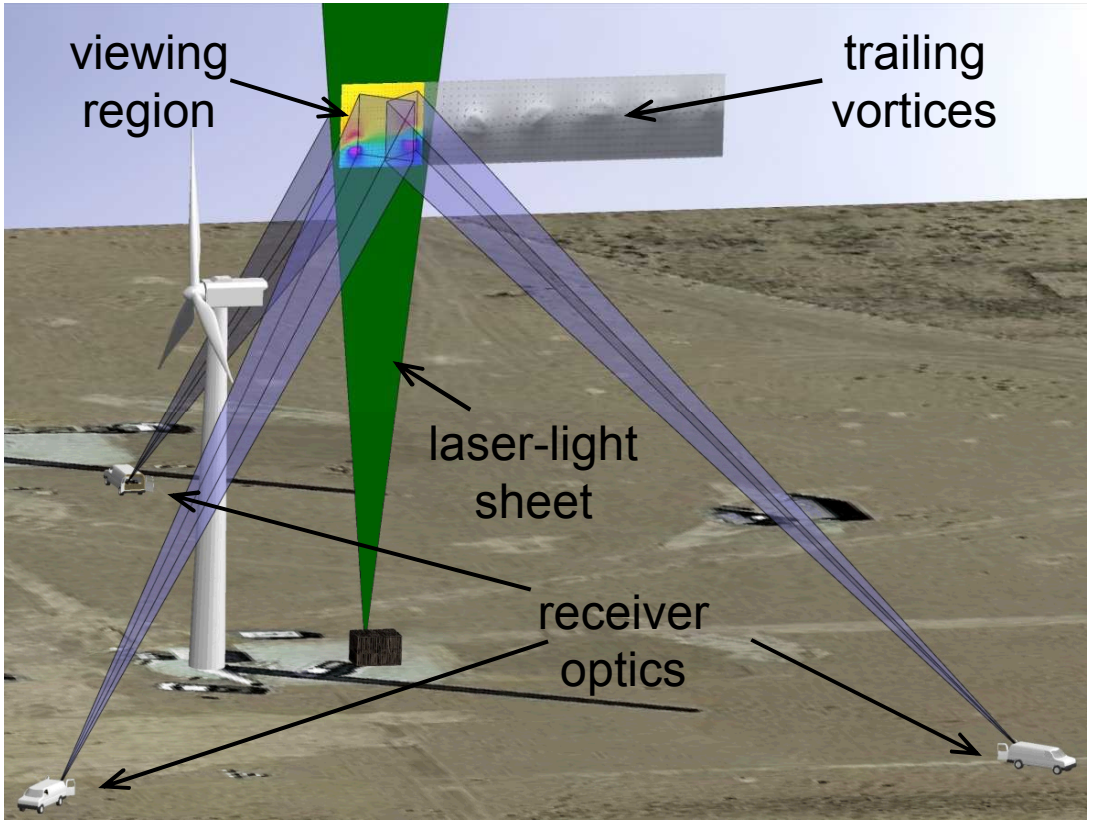
- Modern, research-quality, well-instrumented blades
- Work safely and reliably on existing turbines
- Enables model validation and data gathering
- Suite of mechanical & aerodynamic sensors support high-fidelity measurements
- First rotor will replicate wakes of most common utility scale rotor in the U. S.

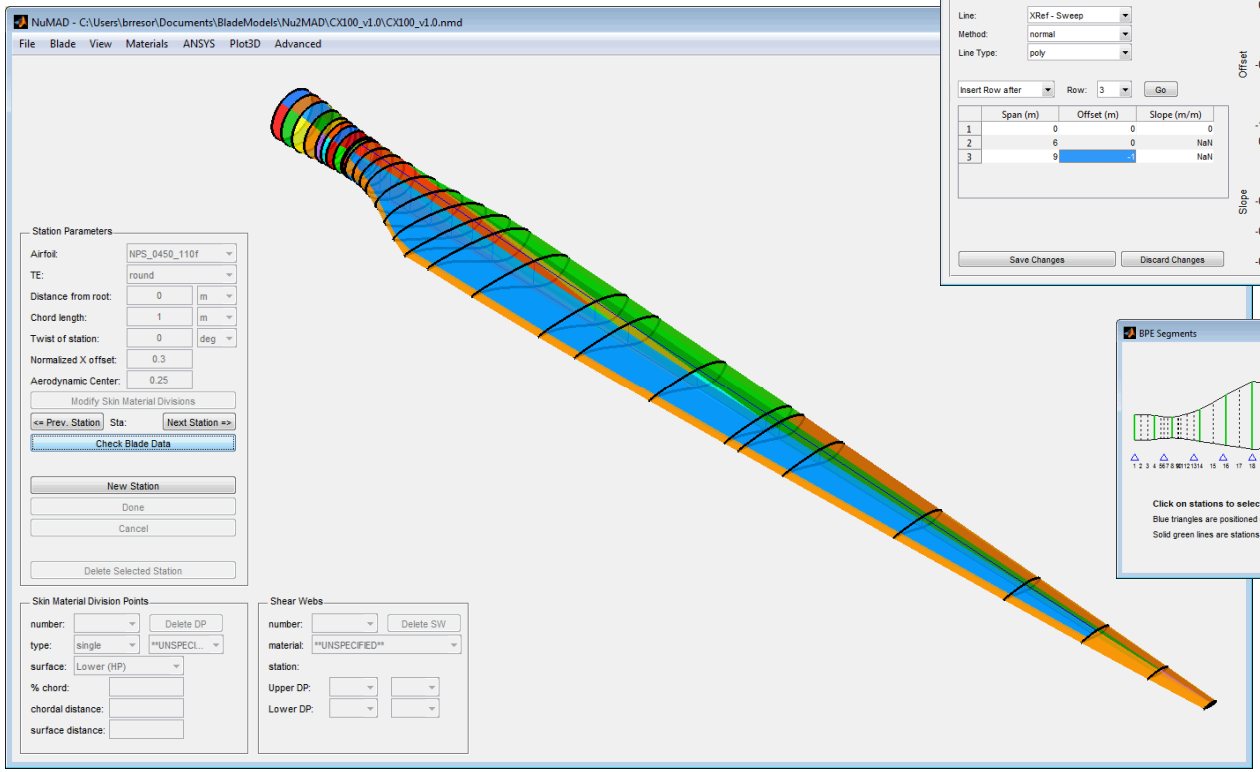


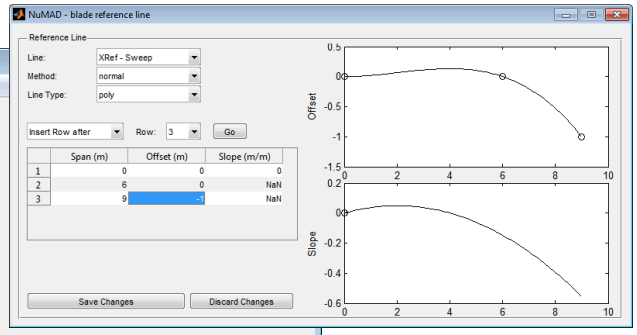
Sandia Wake Imaging System

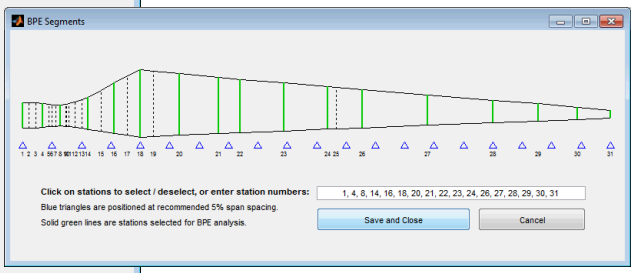
- **Turbine wakes have not been measured in adequate detail or resolution**
- **A custom laser-based tool is used to capture high resolution wake data at the SWiFT Facility**
- **Data will enable validation of codes and design tools used to optimize turbine and plant performance**

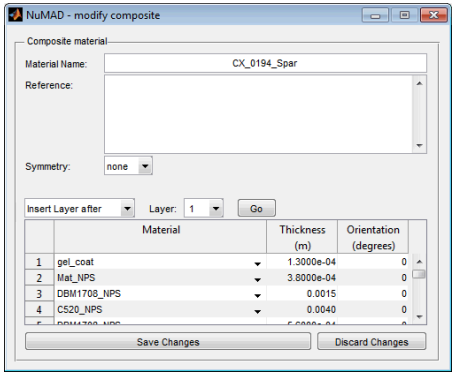


NuMAD v2.0 Interface









NuMAD interface is clean, modern, and user-friendly. The ability to examine the blade from different angles **saves time** and **reduces errors**.

Blade Reliability Collaborative

MONTANA STATE UNIVERSITY

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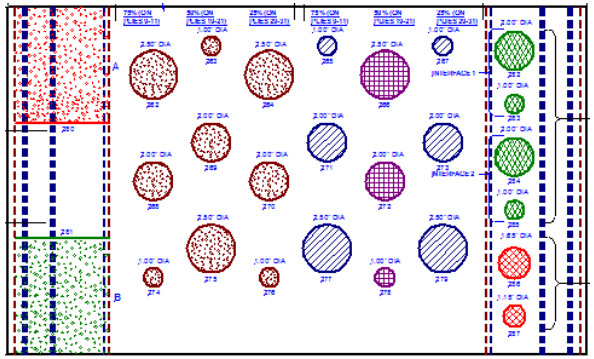
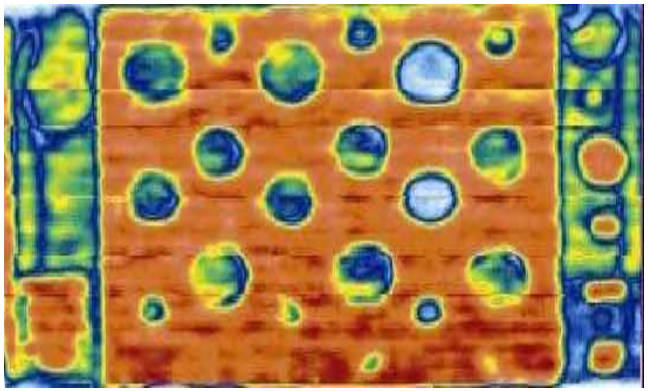
Improve the reliability of blades through field investigations, non-destructive inspection technology, evaluating effects of defects, testing specimens, improved design, analysis and certification

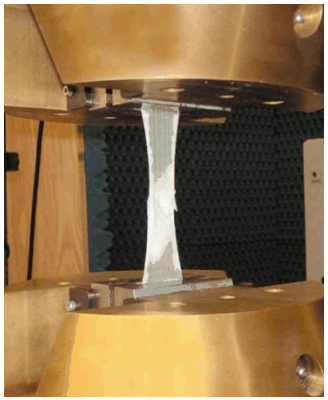
Test Specimen of Known Flaws



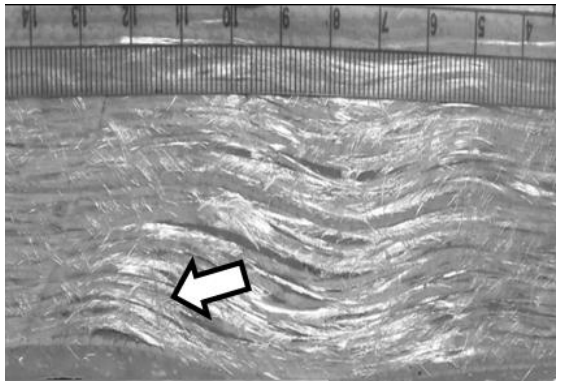
Ultrasonic Scan



Field Examination



Coupon Testing



Intentional Defect Testing

Blade Testing

Radar Mitigation

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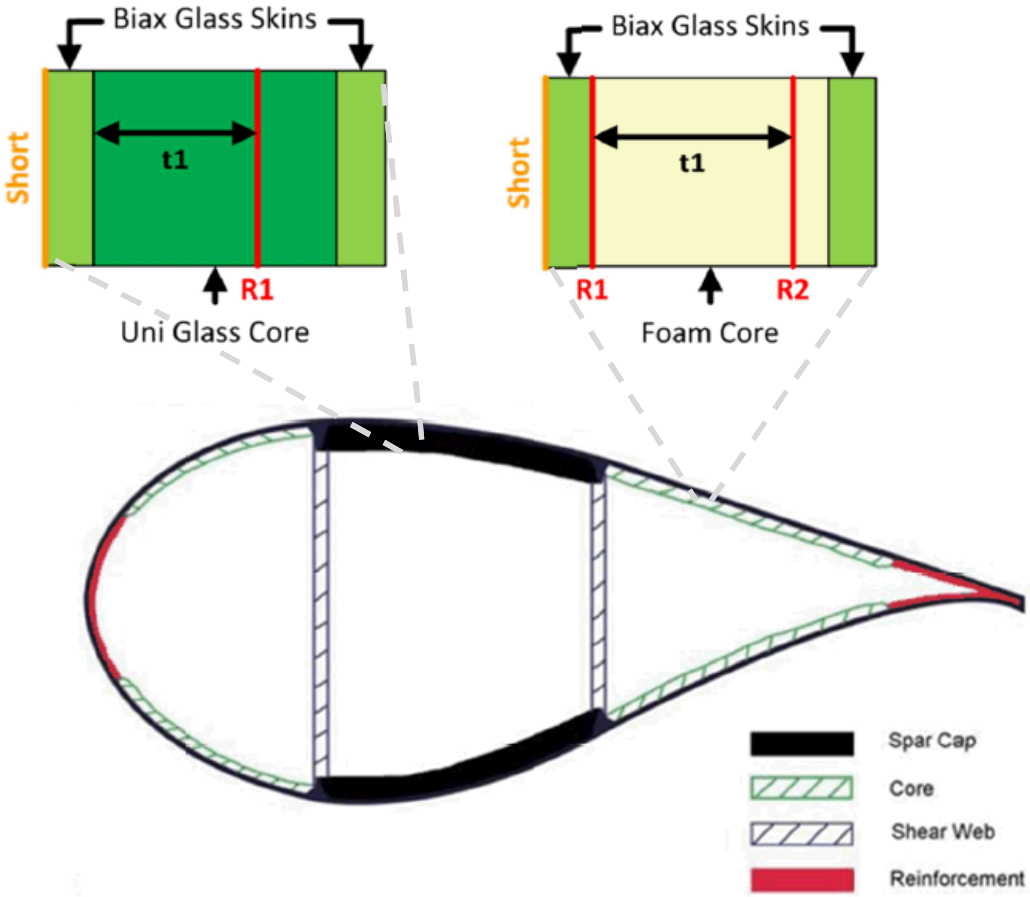
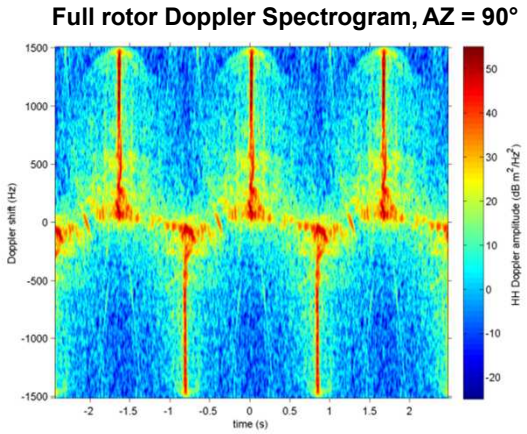
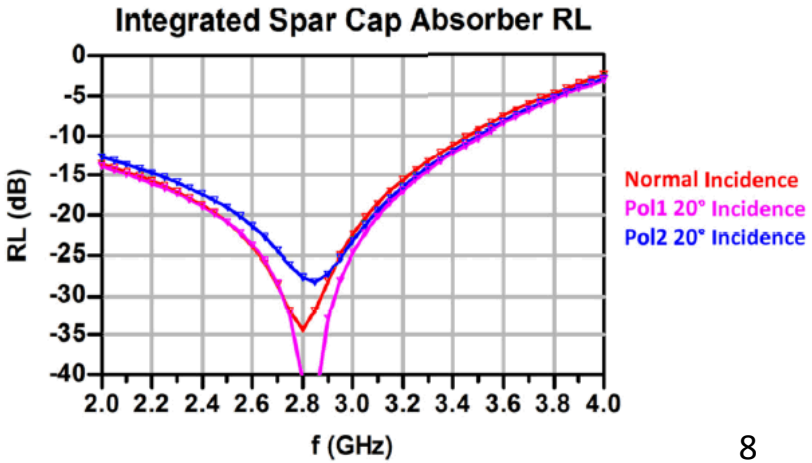
Developed a low-cost material treatment compatible with current manufacturing processes that can reduce the RCS by 20 dB







Source: Sandia National Laboratories

CREW Database

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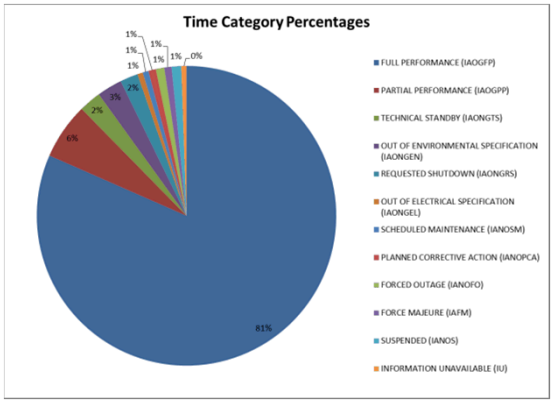
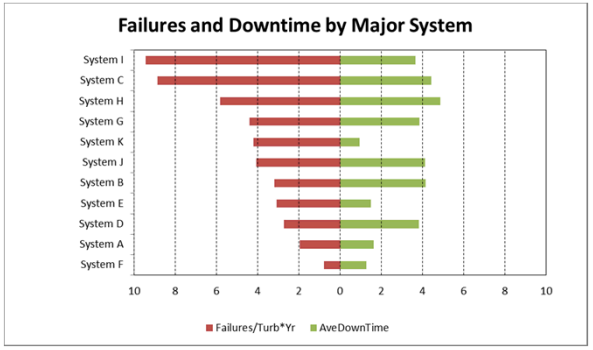
Wind Plant Reliability

- Improve US wind fleet reliability
  - through strategic technology improvements driven by an extensive quantitative baseline of performance and reliability
- Strategic technology improvements are accomplished by:
  - Establishment of a US wind fleet benchmark that can be used to drive DOE technology investments and as a baseline to which owner/operators can identify improvement opportunities.

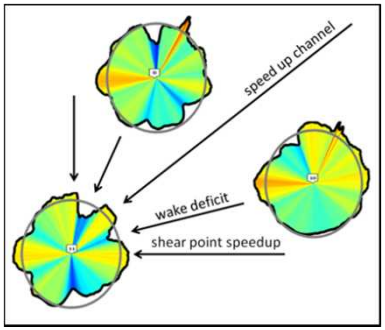
(Notional)

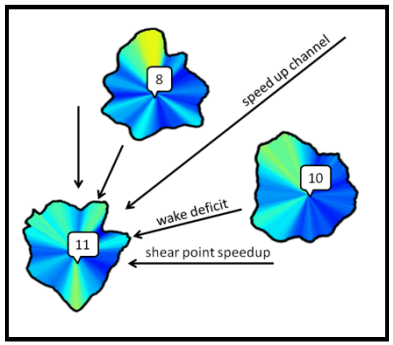




Wake Visualization Analysis

- Wake analysis and visualization of the wind flow based on SCADA data in two Mid-West wind farms of different layouts
- Analysis shows wake deficits as expected, but has also revealed new speed-up effects associated with upstream turbines
- New effects appear to have a positive upside on power production while at the same time also reducing power variability
- The analysis methods can potentially impact the way we:
  - Design wind farms
  - Operate and analyze under-performance
  - Quantify reliability issues and life time fatigue





Wind Turbine Generator Modeling

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Background

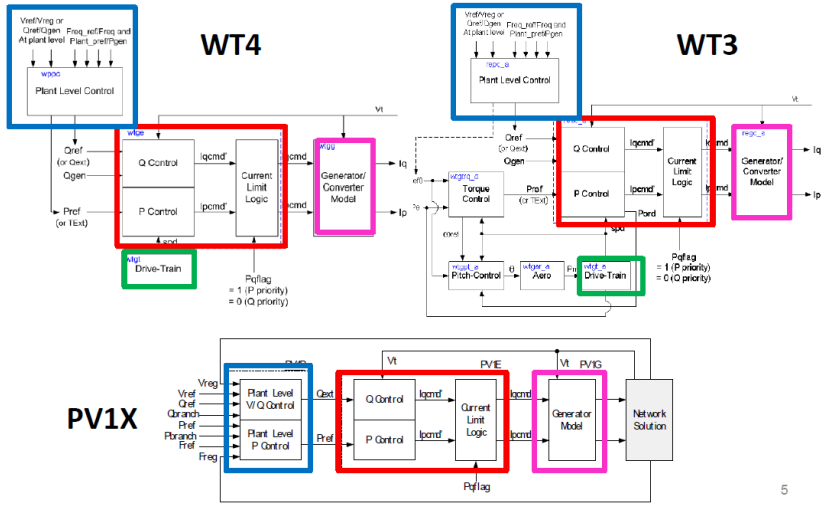
- Dynamic models are required for power system reliability compliance and for planning system expansions. Wind power plants must be represented in power system dynamic simulations.
- Models have been problematic due to the lack of suitable generic, non-proprietary models. To address this gap, Sandia has been working with the WECC and others to develop generic models, modeling guidelines, and model validation.

Modular structure for wind and PV models
- Easier to implement and maintain models

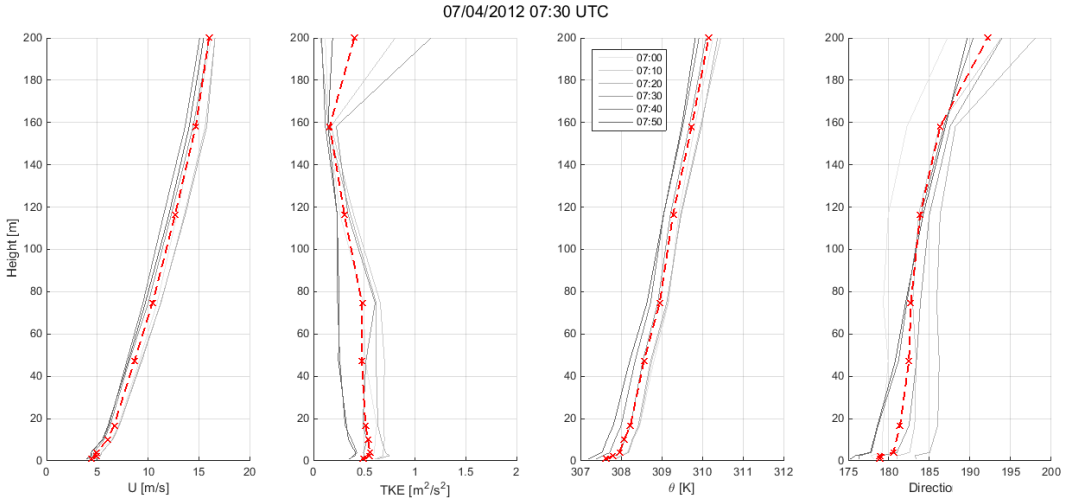
Module	Use			
REPC_A	Wind/PV plant controller	PV1X	WT4	WT3
REEC_A / REEC_B	Wind /PV inverter electrical controls	PV1X	WT4	WT3
REGC_A	Generator-Converter model	PV1X	WT4	WT3
WTGT_A	Simplified Drive Train		WT4	WT3
WTGAR_A	Aerodynamic Model			WT3
WTGPT_A	Pitch Control Model			WT3
WTGTQ_A	Torque Control Model			WT3
lhvrt	Voltage/Frequency Protection Model (any generator model)			

Impact

- Generic wind turbine generator models suitable for grid planning studies have been developed for each of the four major topologies
- These models are updated with improved capability
  - Inertial response, governor control, reactive compensation
- A WECC Power Flow Guide and Dynamic Modeling Guide have been approved and published
- WECC adopted a guideline that address NERC MOD requirements
  - Makes specific references to wind modeling

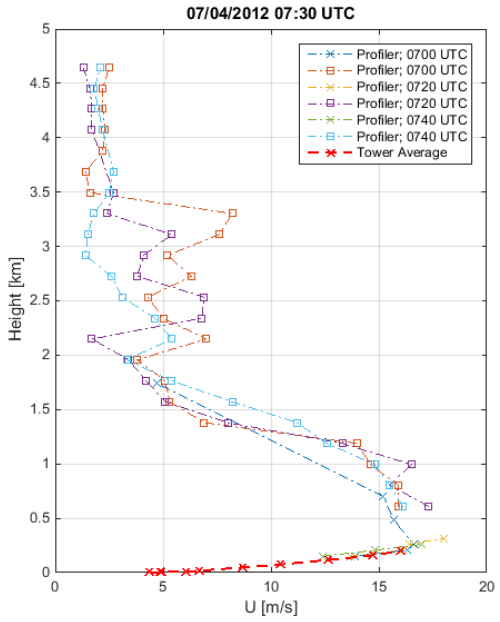


Meso-Microscale Coupling (MMC)



Initial Benchmark Identification and MMC modeling:

- SNL Role is case identification from TTU historical data sets at the SWiFT site.
- Identification of stationary near-neutral, stable, and convective atmospheric boundary layer from 200m met tower
- Numerical weather prediction model reanalysis performed to filter for idealized cases
- Radar profiler data are used to approximate geostrophic forcing
- Low Level Jet development typical of SWiFT site
- Important phenomena to wind energy industry



Thank You!

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