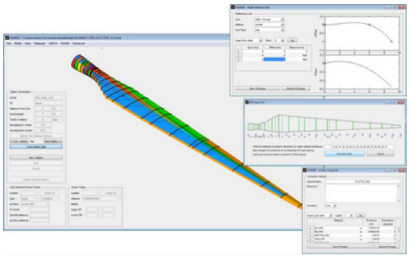
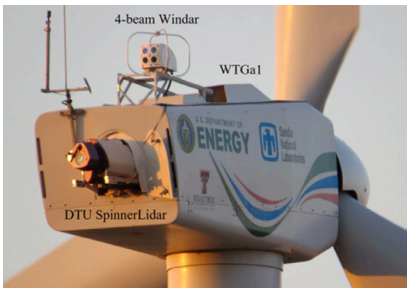
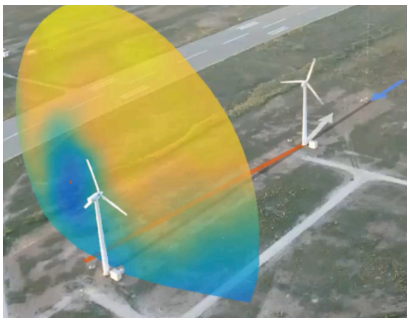






Sandia National Laboratories

Offshore Wind Research and Development Capabilities

Rotor design: Sandia has been researching wind turbine rotor systems with programs studying vertical-axis wind turbines (VAWT) and evolving to horizontal-axis wind turbine designs. Sandia has conducted research on the rotor system spanning composite materials and structural optimization to active and passive aerodynamic load control designs. Specific capabilities include:

- Recent experience in scaled design with the National Rotor Testbed design project – a highly instrumented blade design to validate design models
- Numerical Manufacturing and Design (NuMAD) blade structural optimization tool and design tool to assess aeroelastic performance
- Extensive experience in composite materials research, including reliability and damage detection, and material optimization for rotor designs
- Assessment of aerodynamic improvements and degradation (e.g., erosion)

Scaled Wind Farm Technology Facility (SWiFT): Sandia operates an experimental wind plant facility with three open-source wind turbines and two meteorological towers, all highly instrumented and time synchronized through a fiber-optic data acquisition system. The terrain is flat without significant vegetation and has a single predominant wind direction from the south, enabling the study of wake impacts within a wind plant. A few relevant capabilities include:

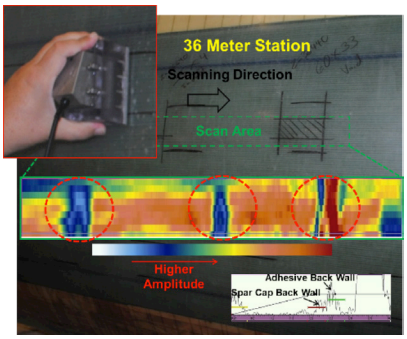
- Hub height atmospheric inflow conditions are commonly representative of offshore sites with turbulence intensity values less than 5% and low wind shear
- High-resolution temporal and spatial wake characterization and analysis using the DTU SpinnerLidar, Windar 4-beam, and Pentalum SpiDAR lidar
- Established uncertainty quantification methods on measurements and derived quantities of interest for the baseline site instrumentation
- Open-source and well-characterized wind turbines that can be modified to operate innovative blades, sensors and validate blade add-on performance

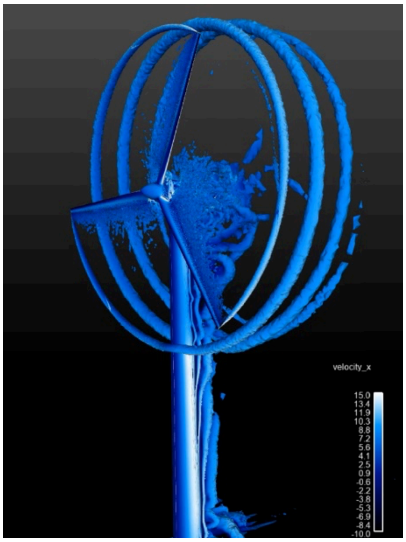
Control system design and testing: Sandia has developed a completely open-source controller for the SWiFT turbines, enabling the software development, testing and deployment of novel control concepts in an operating wind plant environment that is integrated with the data acquisition system. This enables any sensor at the site to serve as a control input for the turbines. Capabilities include:

- Open-source Simulink controller code and hardware-in-the-loop system to rapidly develop, simulate, and test new control concepts on a realistic hardware system prior to deployment on the actual turbines at SWiFT
- Development of a coupled turbine-floating platform controller to optimize power and manage loads, computing the optimal control profile

Extreme load detection and structural health monitoring: For the past 10 years Sandia has been developing rotor sensing technologies to monitor blade loading and damage. Acceleration and strain-based force and deflection estimation methods have been developed for normal and extreme operations of modern wind turbines. Damage detection methods have been developed that can be used in wind turbine controllers to control damage growth rate. This work has involved:

- Instrumenting over 25 field-operating wind turbine blades at various scales and locations with accelerometers, fiber optic strain gages, pitot tubes, pressure taps, hot-film sensors, and other sensors throughout the turbine
- Performance assessment and wake impact quantification via SCADA data





Autonomous and nondestructive inspection (NDI): Sandia has engaged in research projects to apply advanced non-destructive inspection technology to wind turbine blade inspection. Specific capabilities include:

- Experience with a wide array of NDI systems for inspection of composites
- Knowledge of environmental aspects of automated drone inspection
- Large composite specimen collection with engineered flaws and damage

Floating system design and testing: Sandia has extensive experience with analyzing floating systems using a range of numerical modeling and experimental testing methods. These tools have been applied to complete case studies following international design standards. Specific tools and capabilities include:

- Design, execution, and processing of large-scale wave tank tests for system identification (SID) and control
- Recent experience in floating system design and analysis through industry partnership for a floating VAWT system
- Metocoean environmental analysis to identify/project extreme sea states and resulting device loads
- High-fidelity computational fluid dynamics simulations of floating bodies with multi-physics coupling, including mooring system representations

High Fidelity Modeling: Sandia has built on decades of investment in high-performance computing hardware and software development to tailor computational fluid dynamics codes for the wind plant application. This is further supported by an array of codes used to perform uncertainty quantification and multi-fidelity analysis tailored to the specific problem. Sandia capabilities include:

- Nalu – an open source computational fluid dynamics code scalable to petascale computing platforms
- A Verification and Validation framework to systematically assess and improve the predictive capability of the computational code
- DAKOTA code for optimization and uncertainty quantification

Oceanography and sediment stability: Accurately assessing seabed stability helps minimize risks to offshore wind infrastructure, and helps reduce financing, installation and maintenance costs throughout the structure's lifecycle. For example, physical and numerical tools can be used to analyze sediment stability and determine optimal cable routing and the ideal cable burial depth. Sandia offers streamlined guidance and tools for comprehensive coastal assessments.

Wind turbine radar interference modeling and mitigation: Sandia has conducted research as part of the federal multi-agency Wind Turbine Radar Interference Mitigation (WTRIM) working group to assess and mitigate the impacts of wind turbines on radar systems. Sandia recently began work with the DOD to develop new lightning protection systems for offshore wind turbines that currently impact surveillance radars in the US. Sandia has computational siting tools to assess the potential impact of a wind plant on radar systems deployed in the US.

Contacts:

Geoff Klise, Manager, Wind Energy Technologies Dept., gklise@sandia.gov
Brandon Ennis, Offshore Wind Technical Lead, blennis@sandia.gov

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. SAND 2019-1923 M