SAND2016-3799C

Exceptional service in the national interest

Sandia National Laboratories



DOE / SNL Scaled Wind Farm Technology (*SWiFT*) Facility Overview

AEC2016
April 22, 2016

David Maniaci

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND NO. 2011-XXXXP

Sandia Addresses National Security Challenges

Sandia National Laboratories

1950s
Nuclear weapons
Production and manufacturing engineering

1960s
Development engineering
Vietnam conflict

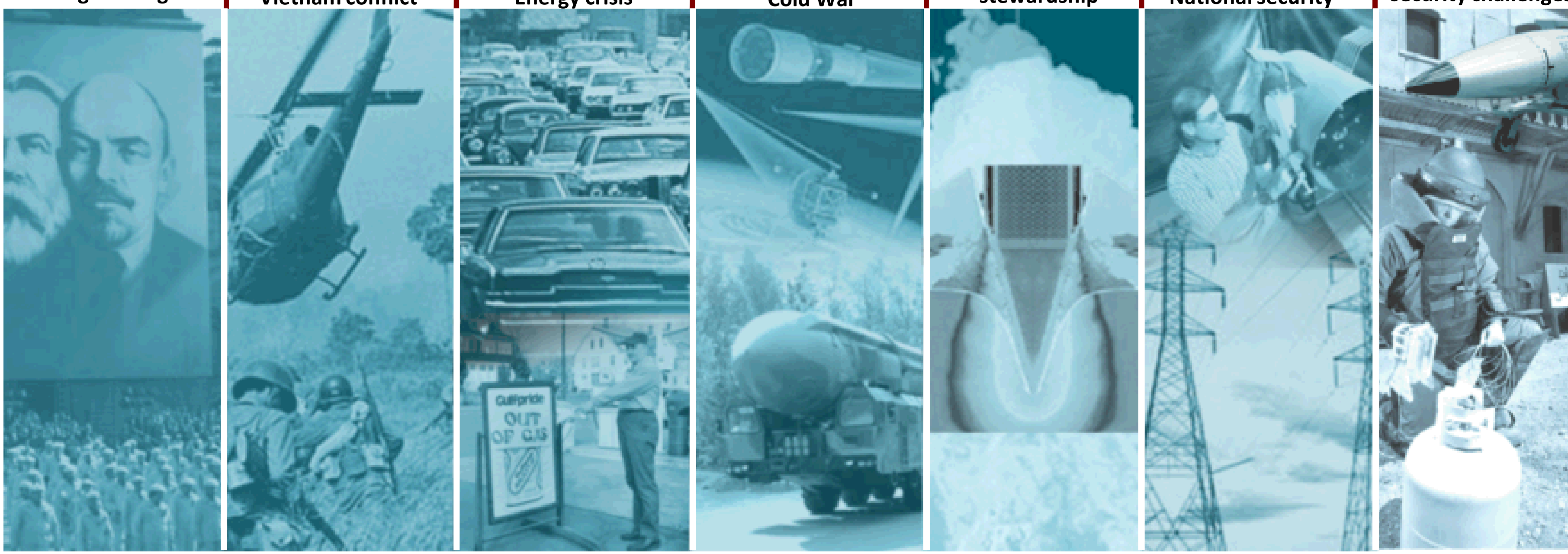
1970s
Multiprogram laboratory
Energy crisis

1980s
Missile defense work
Cold War

1990s
Post–Cold War transition
Stockpile stewardship

2000s
START
Post 9/11
National security

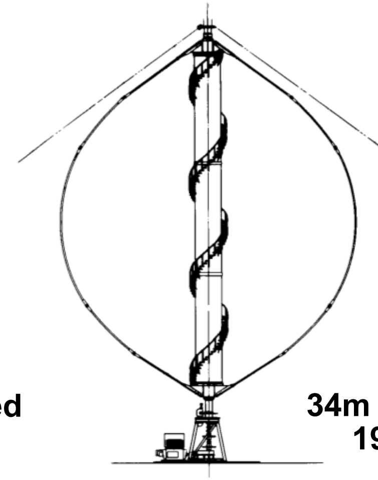
2010s
LEPs
Cyber, biosecurity proliferation
Evolving national security challenges



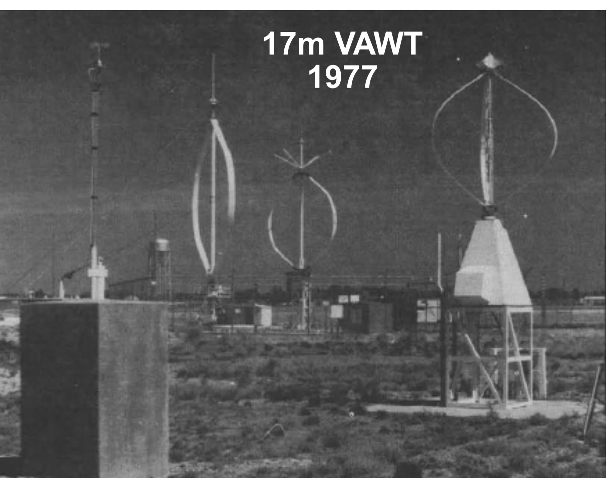
SNL Wind Program History

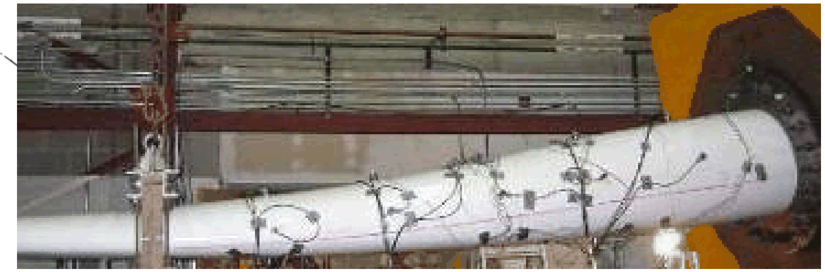
41 Years of wind R&D, primarily wind turbine rotor development

Wind Program Established 1975

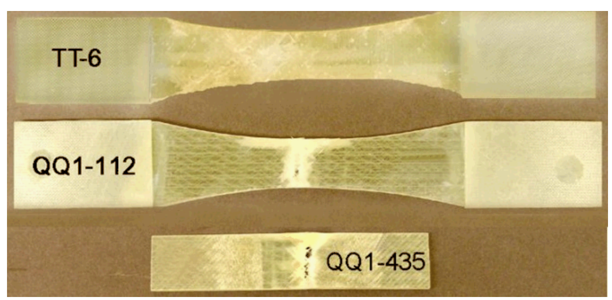


34m VAWT 1984





Composite Materials Database 1988



Blade Program 1994

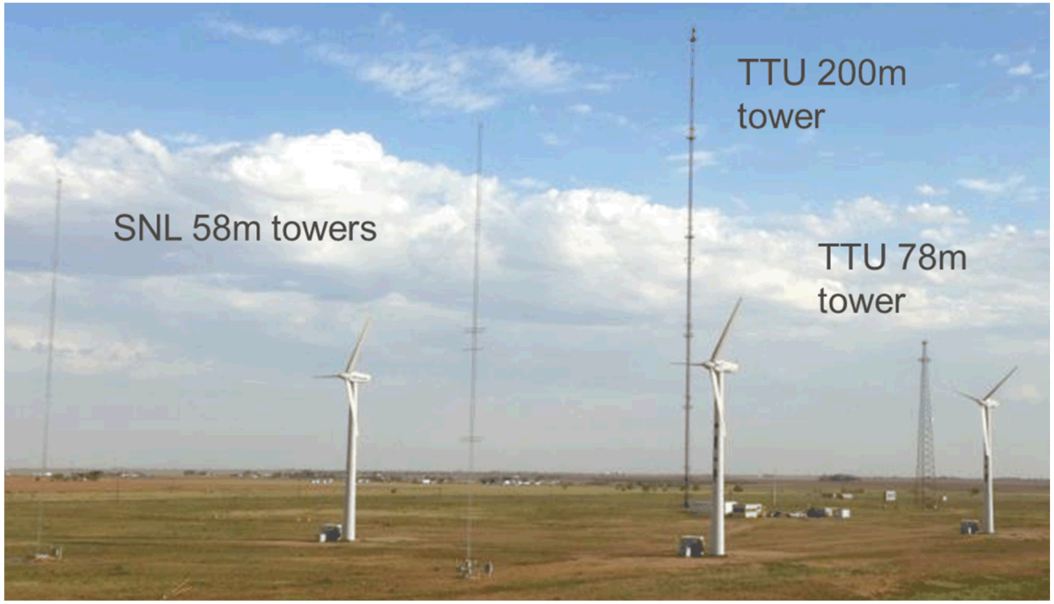
Advanced Manufacturing Initiative 2008

SWiFT Facility 2013

SWiFT Facility Overview

SWiFT Exists to:

- Produce public, open-source validation quality data to advance simulation capabilities
- Reduce wind plant underperformance by providing validation quality turbine-turbine interaction data
- Develop and test advanced wind turbine rotors



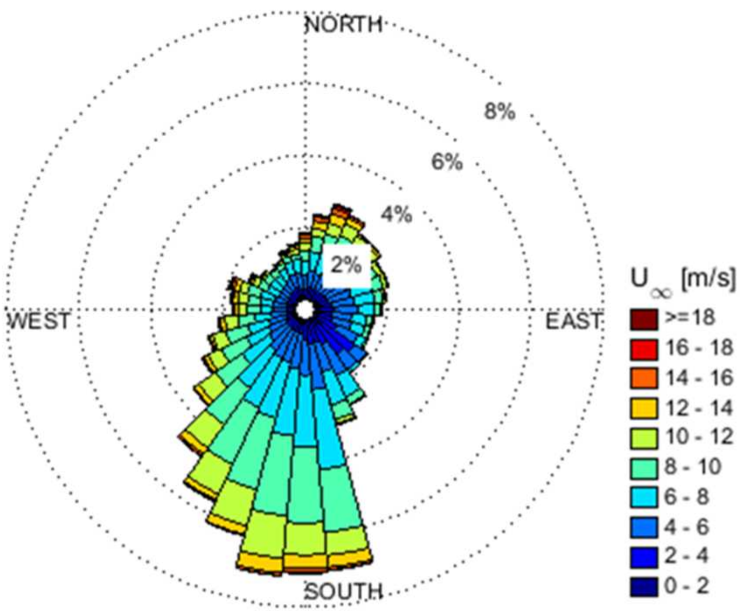
Facilities:

- Three variable-speed variable-pitch modified wind turbines with well characterized performance
- Two heavily instrumented inflow meteorological towers
- Extensive, high resolution sensor suite
- Site-wide time-synchronized data collection
- Partnership with Texas Tech University's National Wind Institute; site atmospheric measurements

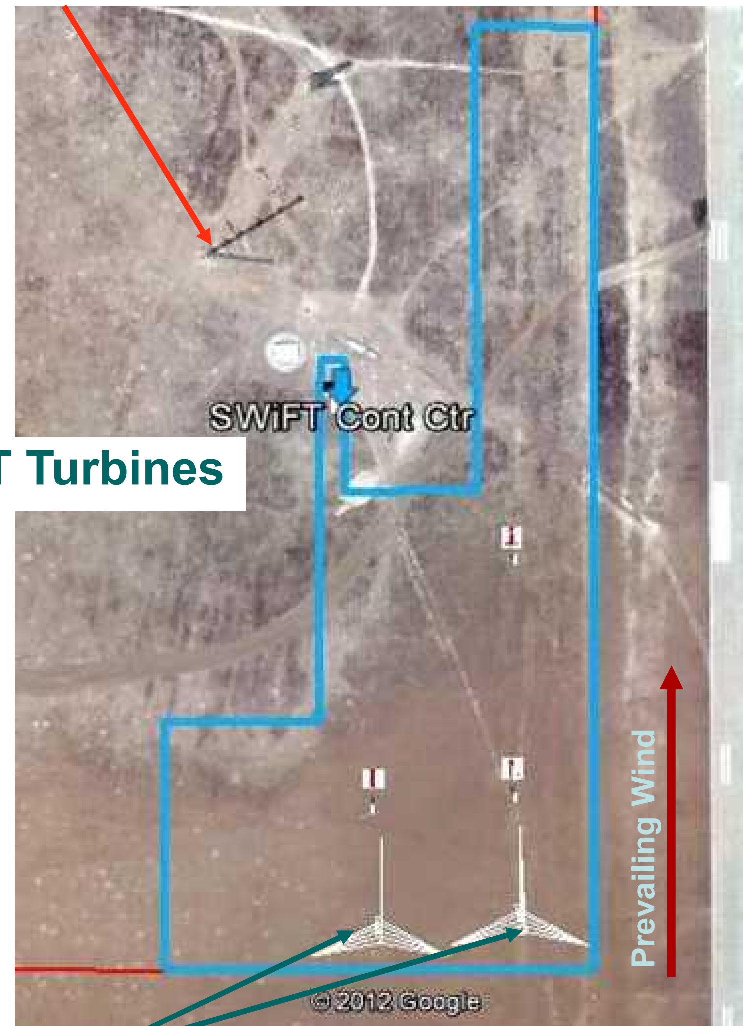
SWiFT Facility Layout

Sandia National Laboratories

- Three turbines with a triangular 3-5-6 rotor diameter spacing layout
- Wind is consistently and dominantly from the south, producing a 5 rotor diameter spacing turbine-turbine interaction
- For the SWiFT OEM rotor, wind averages are within the design Region II operation with a 60% frequency



200m MET Tower



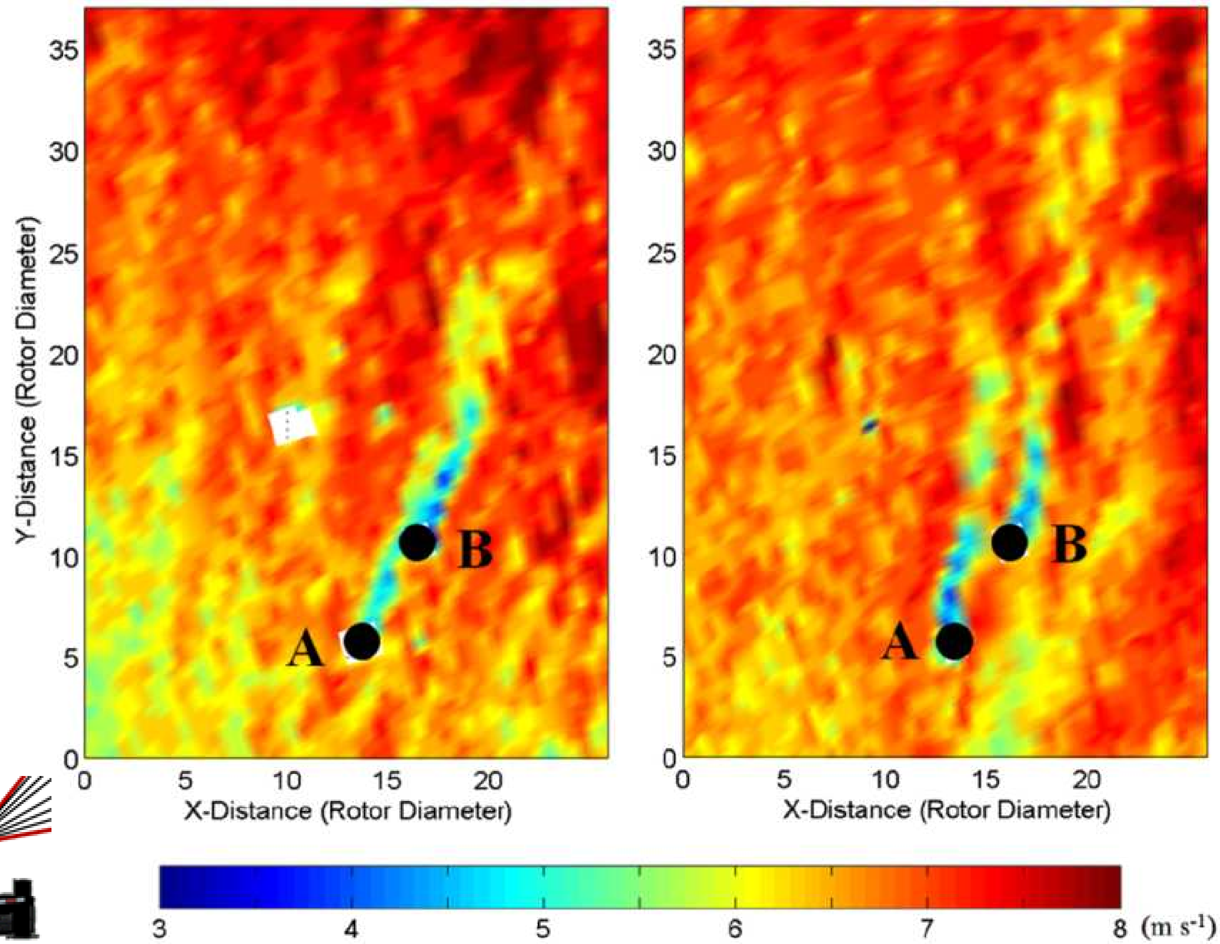
SWiFT Turbines

58.5m MET Towers

Experimental Campaigns

TTU Radar Measurements at the SWiFT Site

- No dual-Doppler data was collected, rather only single PPI sector scans
- Lightly precipitating environment
- Turbine yaw manually offset for brief period of time
- Turbine wake structure and evolution evident

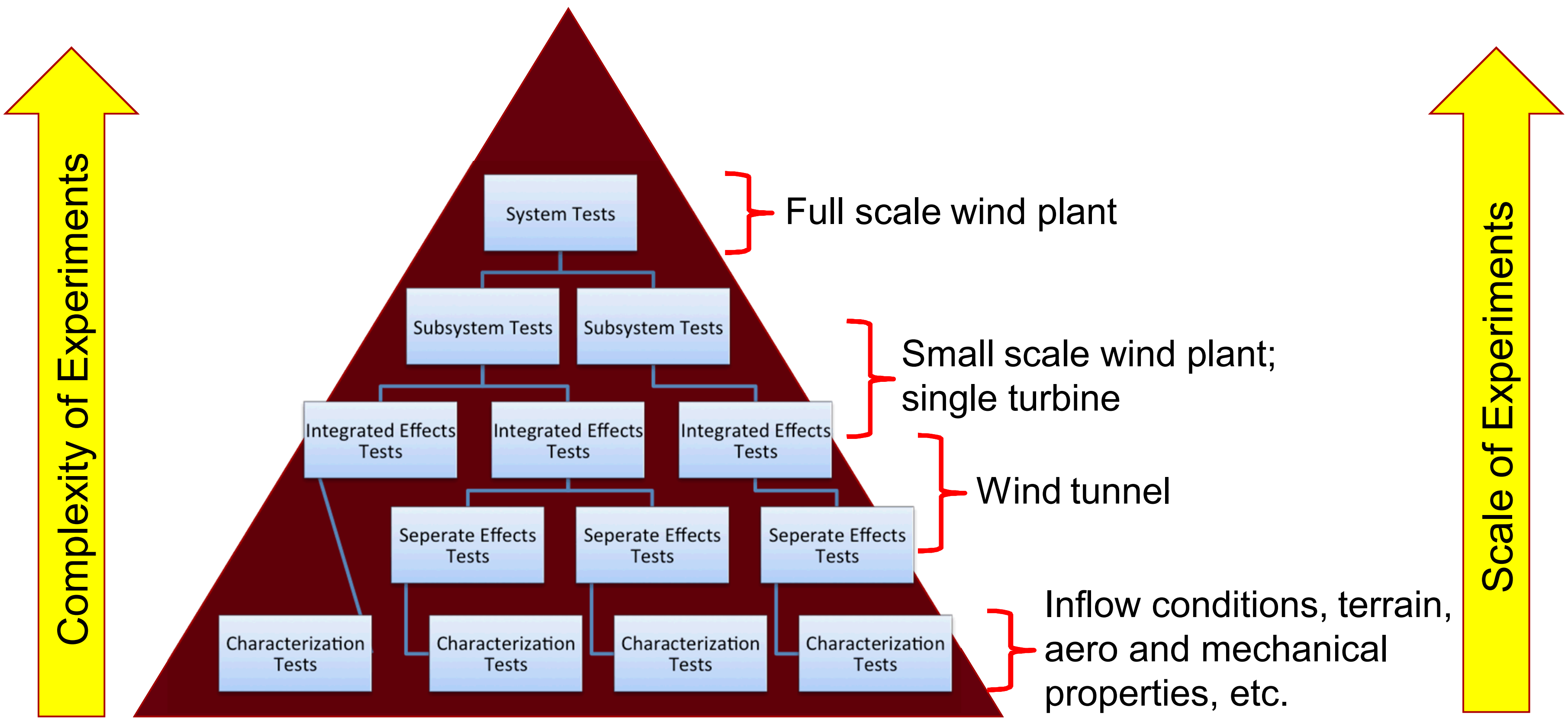


TTUKa-1

What is a Validation Focused Program?

- Formalized highly collaborative approach to planning and executing **joint experimental/modeling** programs for the purpose of characterizing model accuracy for an intended application

The Validation Hierarchy

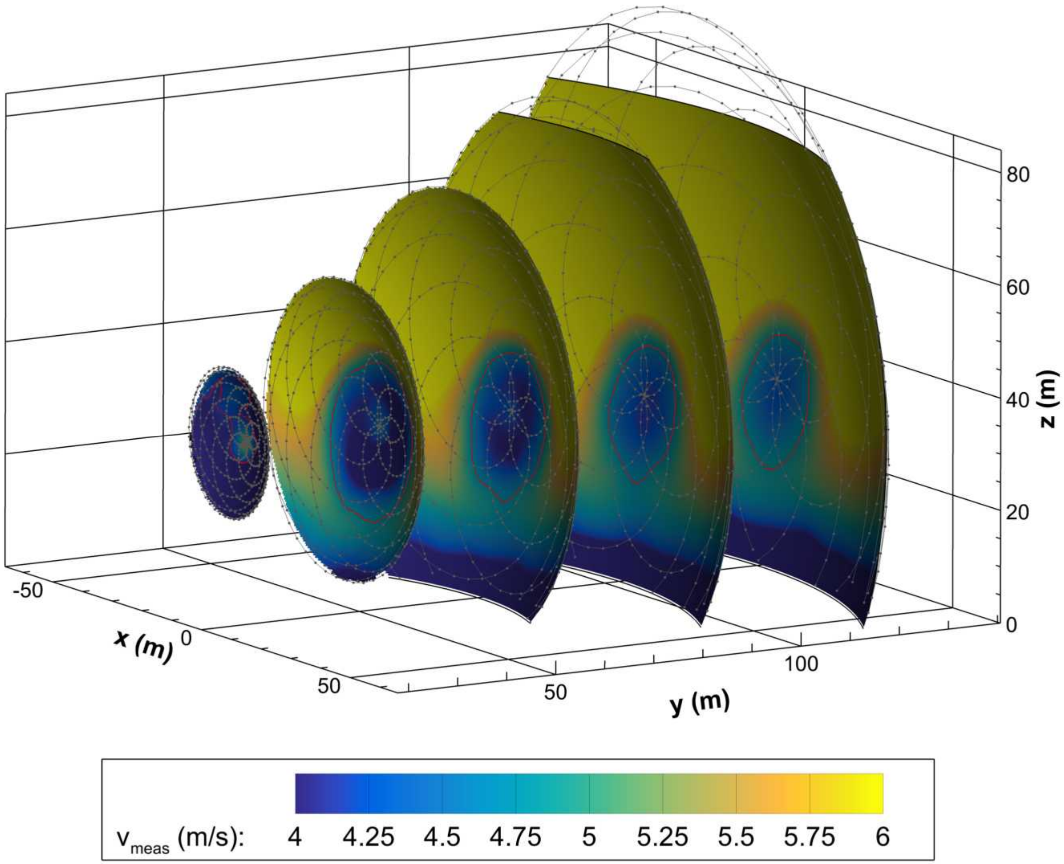


Types of SWiFT Facility Experiments

- **Tech demonstration**: Perform subscale technology demonstration tests, but do it with rotors which meet full-scale similitude requirements
- **Model validation:** Accurately predict, assess and optimize wind plant performance utilizing High Fidelity Modeling (HFM) tools to understand and accurately predict the fundamental physics and complex flows of:
  - the atmospheric boundary layer
  - interaction with the wind plant
  - the response of individual turbines to the complex flows within that plant
- Other types of experiments include calibration, phenomena discovery, mathematical model development, or phenomena exploration

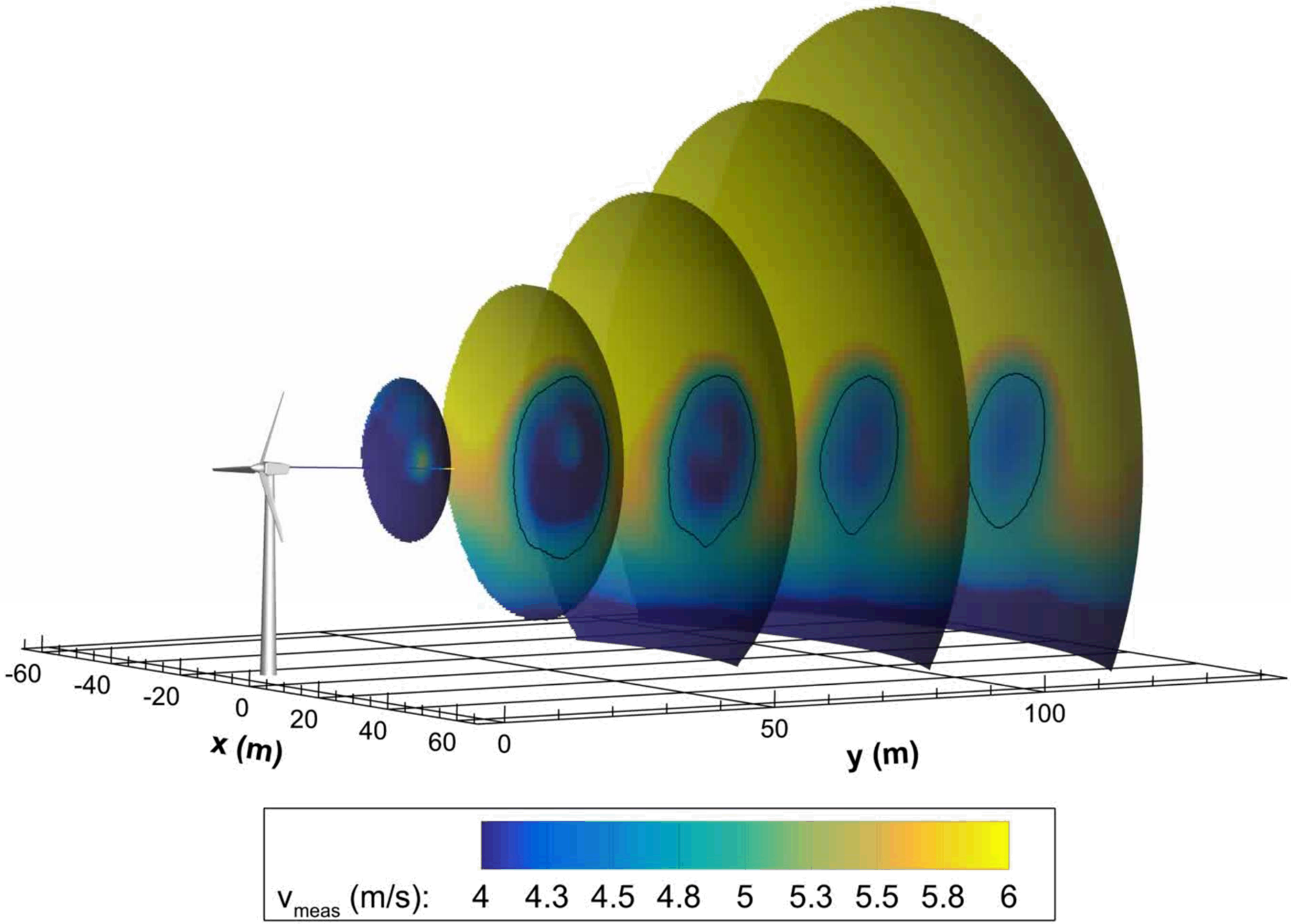
Wake Steering Control Validation

DTU Spinner Lidar



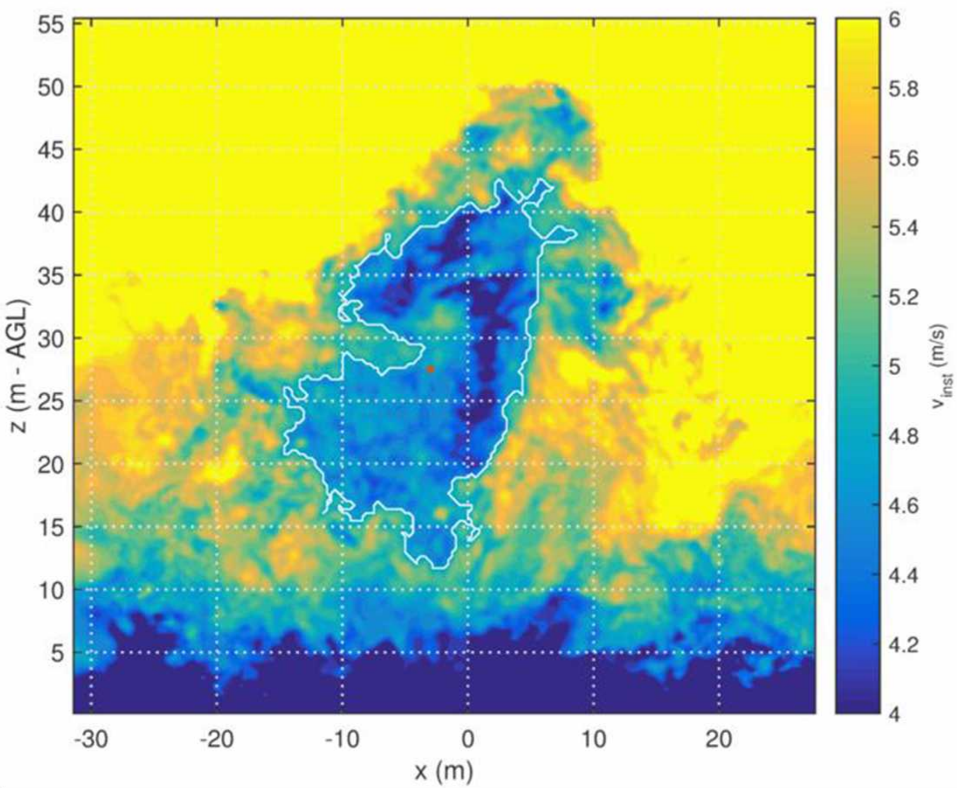
- Lidar mounted in rear of WTGA1 nacelle
- Scans Rosette pattern at set focal length
- Scan duration 1 – 2 s for a set focal length
- Focal length changes in ~ 0.5 s between scan patterns
- Measures line-of-sight velocity over a "probe length" that increases in length as the focal length increases
- Velocity values interpolated from measurement location onto regular grid

DTU Spinner Lidar SWiFT Deployment

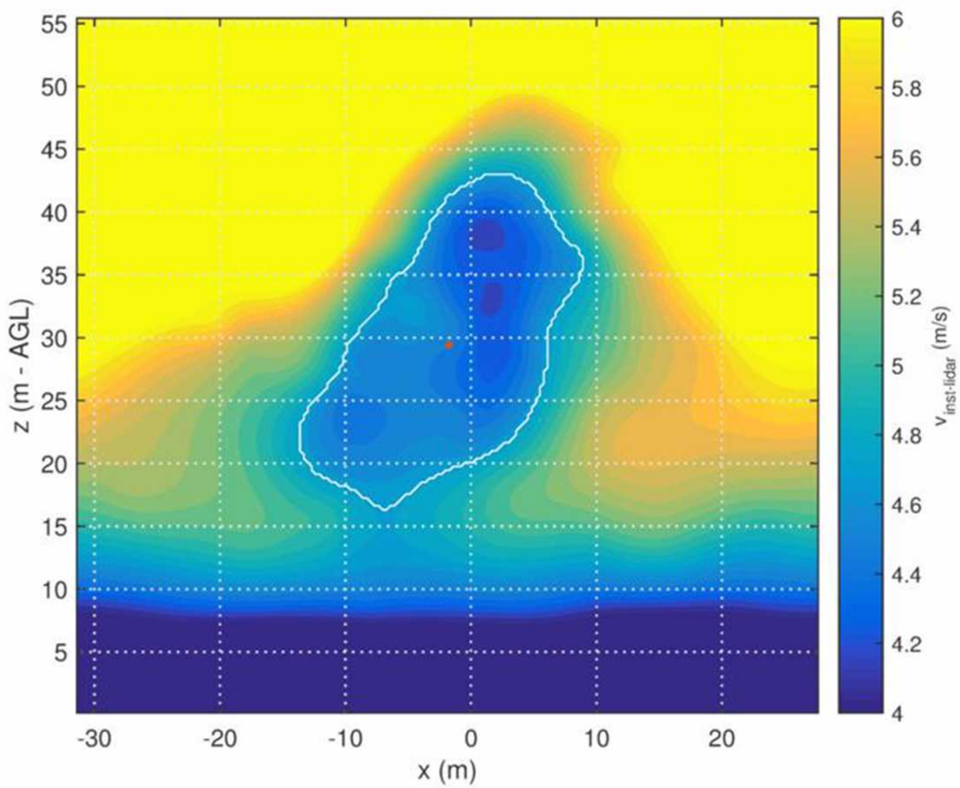


Instantaneous Wake Velocity

SOWFA Simulated Velocity

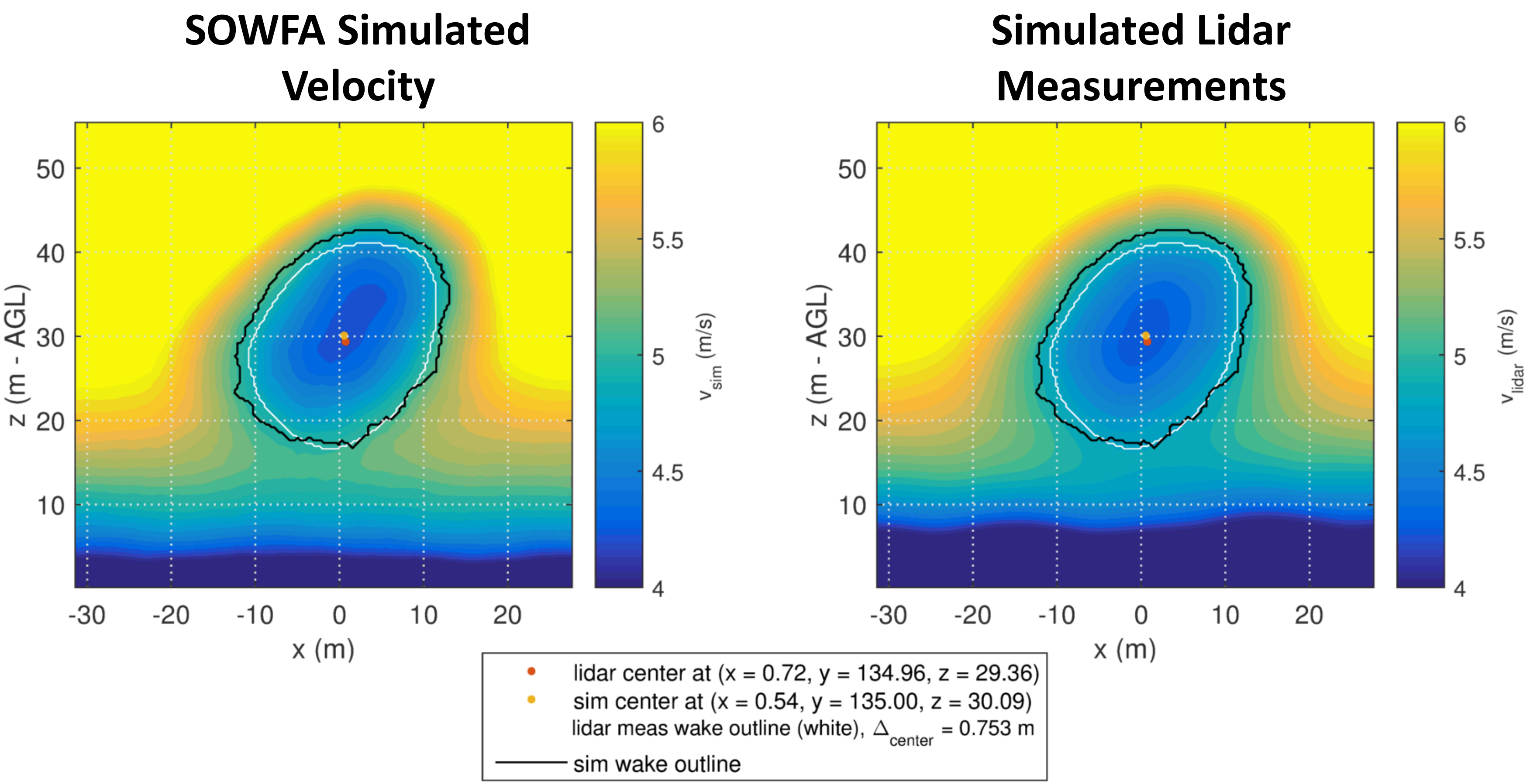


Simulated Lidar Measurements



- Comparison of identical time steps in order to show effect of Spinner Lidar on measurements and how that impacts wake position determination
- Measurements at 5D downstream of turbine

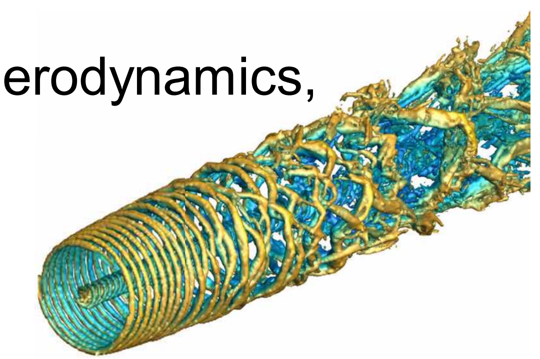
Average Wake Velocity

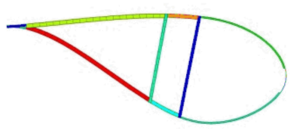


- SOWFA simulations and simulated lidar measurements were averaged over the same duration taking into account the scan pattern time and refocusing duration. Results at 5D downstream of turbine

National Rotor Testbed

- Baseline blades represent functionally scaled-down aerodynamics of a modern megawatt-scale rotor
- Baseline blade design is public and open
- Focused on research in wake interaction, inboard aerodynamics, controls, and aeroelastic dynamics

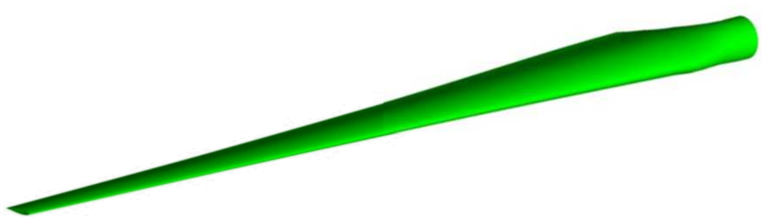


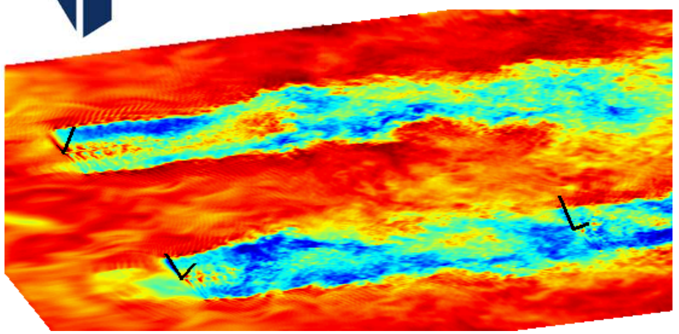


Aero-structural rotor design

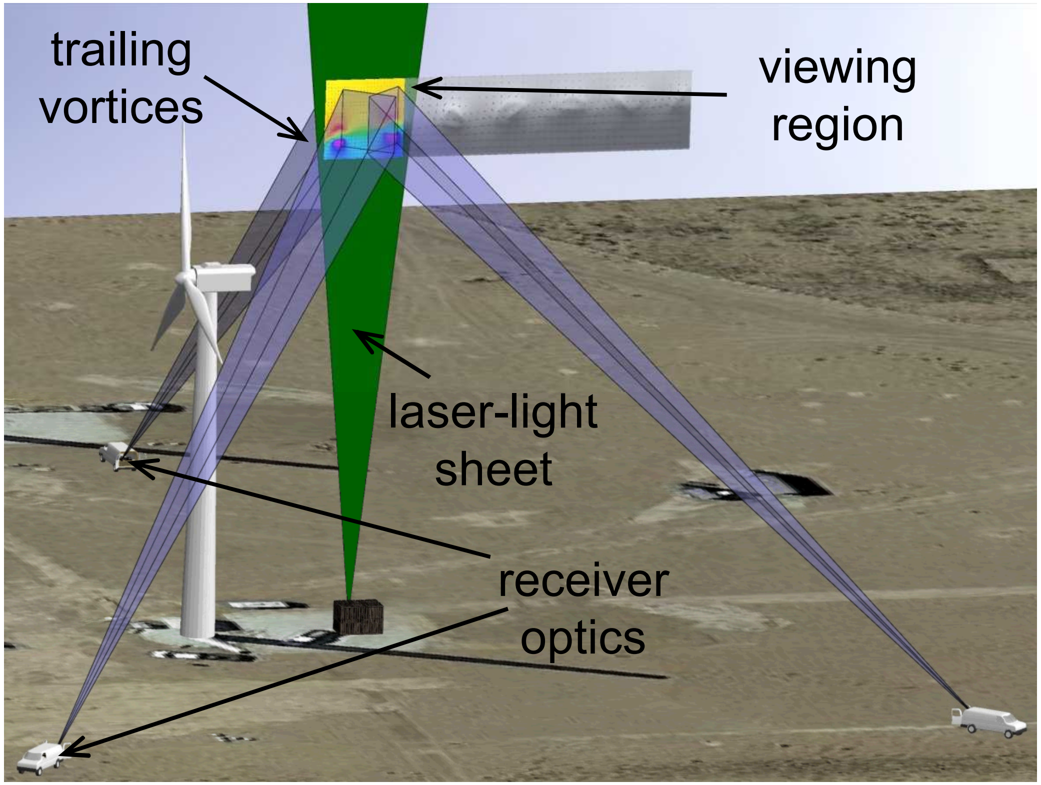
Building connections between rotor designs and rotor wake research

Wakes and turbine-turbine interaction





Sandia Wake Imaging System

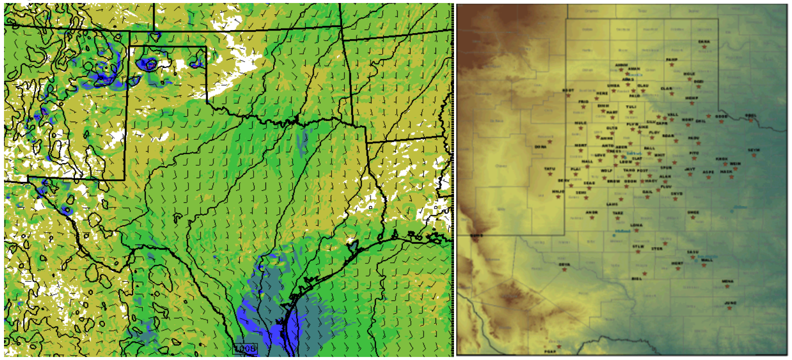


- Imaging allows for fast scanning sufficient to capture sub-rotor scale turbulent flow structures
- High spatial resolution: 16,000 data points per sample
- Enables direct comparison with high-fidelity and engineering level models

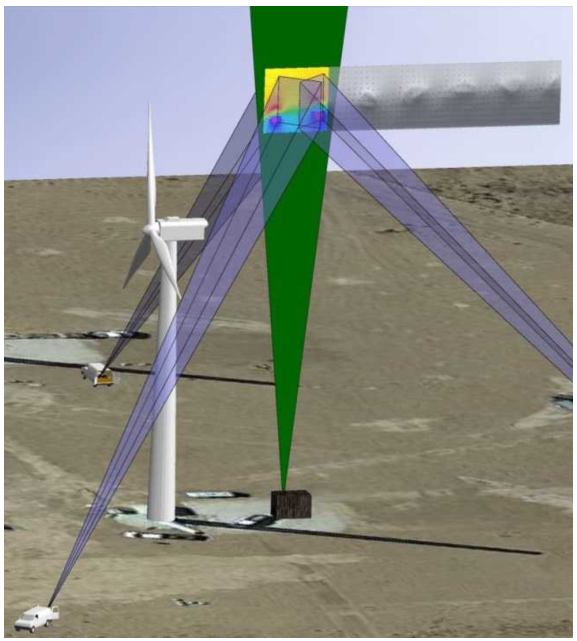
SWiFT Integrated Experimental Planning

Sandia National Laboratories

Regional Atmosphere, Mesoscale Forcing's

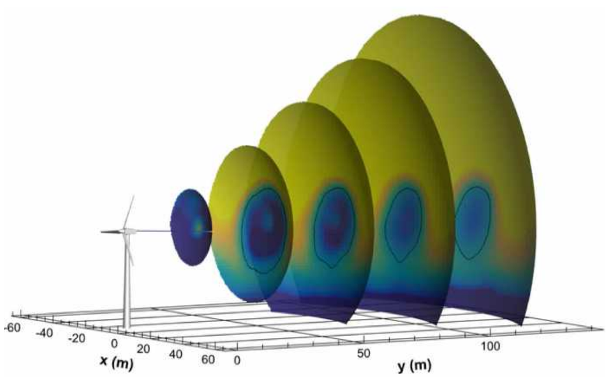


Atmospheric Boundary Layer



Wake Flow Structures

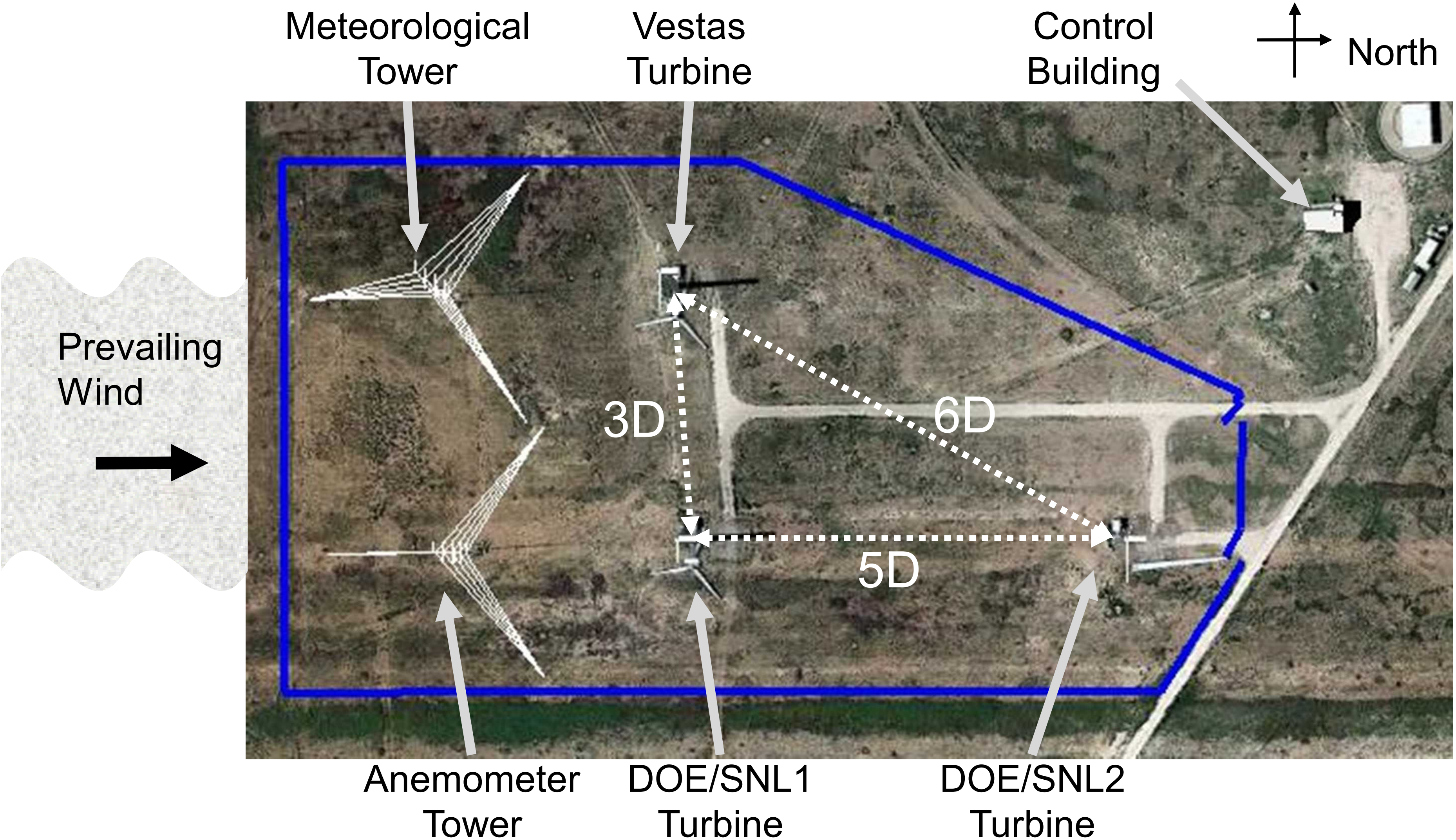
Wind Farm Flow



Thank you

BACKUP SLIDES

Layout


Meteorological Tower
Vestas Turbine
Control Building
North
Prevailing Wind
3D
6D
5D
Anemometer Tower
DOE/SNL1 Turbine
DOE/SNL2 Turbine

Sandia National Laboratories

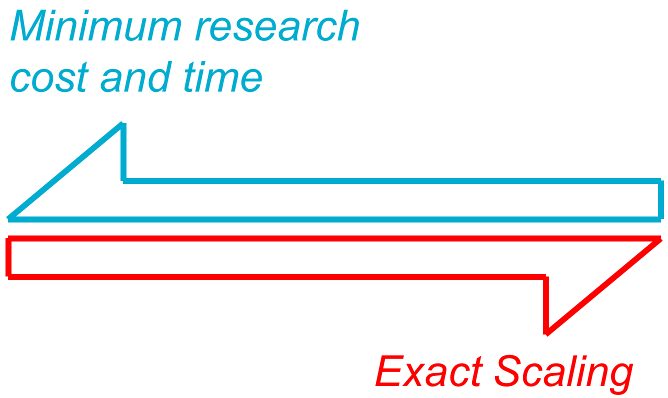
SWiFT Wind Turbines

Hardware

- Collective Pitch System
- 300 kW Variable Speed Generator
- AC-DC-AC Full Scale Convertor
- National Instruments controllers
- Complete turbine / rotor state instrumentation
- Fiber Optic blade sensing system

Why this size?

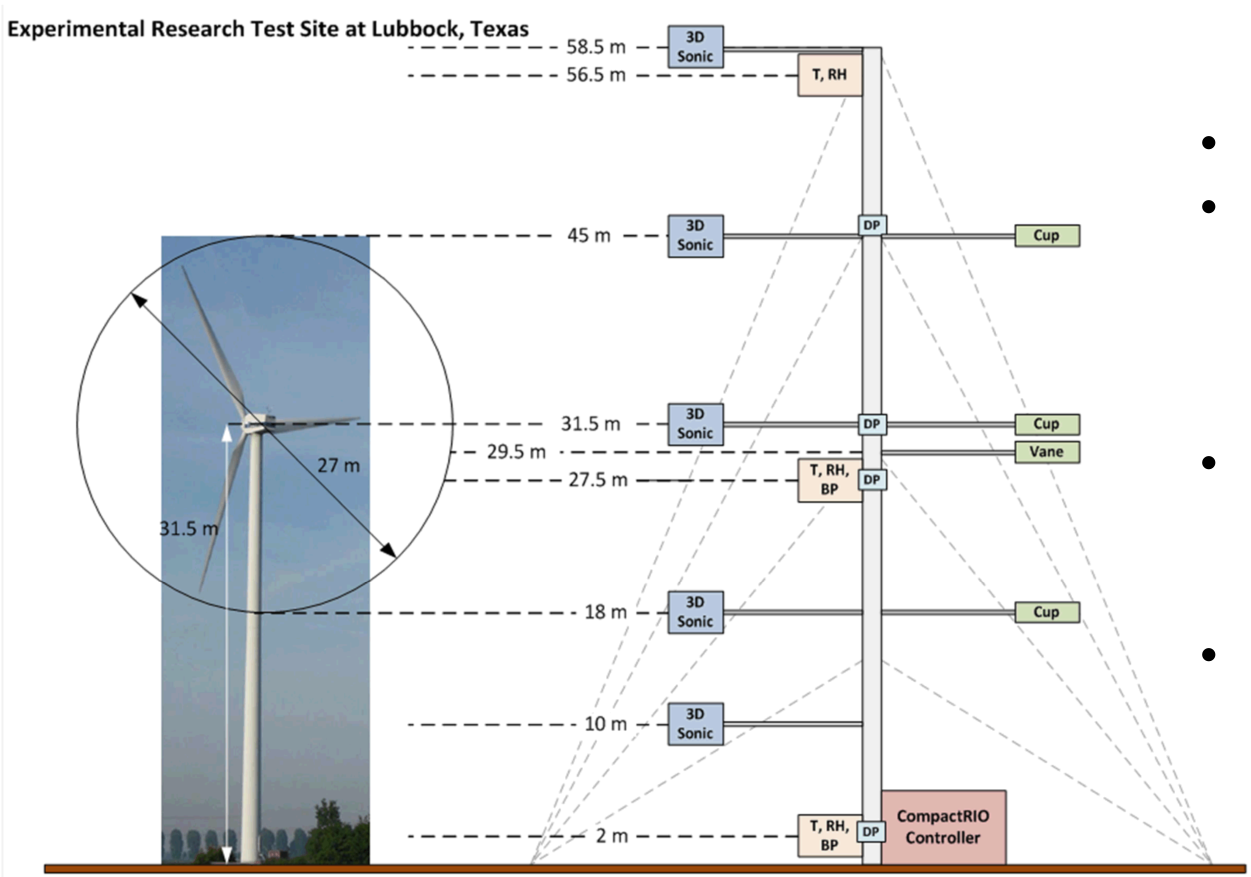
Research-Scale



Megawatt-Scale

- **A cost-efficient size for which research can be directly scaled to larger, more costly and time-consuming sizes.**
- **Requirements:**
  - Operation at Reynolds Number (scaling parameter) between 10^6 and 10^7
  - Tip speeds approaching 80 m/s for acoustics and large rotor projects
  - Variable-speed variable-pitch operation
  - Minimal cost and time associated with research operations
  - Highly reliable turbine
  - Minimal restrictions on publication and intellectual property

SWiFT 58m Meteorological Towers



- Data are logged at 50-hz
- 5 stations with 3-d sonic anemometer measurements; 3 across the rotor disk
- Atmospheric Stability measurement capability being added
- Spatial coherence calculations (towers spaced 80 m)

Met mast sensors

3D Sonic: ATI SATI/3A Sonic Anemometer
Cup: Thies Wind Sensor First Class Advanced (IEC accred)
Vane: Thies Wind Direction Sensor First Class
T: 592 Met One Temperature sensor
BP: 092 Met One Barometric Pressure sensor
RH: 593 Met One Relative Humidity sensor
DP: ATI PAD-401 DataPacker

Met mast heights*

58.5 m: 3D Sonic
56.5 m: T, RH
45 m: 3D Sonic, Cup
31.5 m: 3D Sonic, Cup
29.5 m: 3D Sonic, Vane
27.5 m: T, RH, BP
18 m: 3D Sonic, Cup
10 m: 3D Sonic
2 m: T, RH, BP

Guy wires
Radius 47.5m

57.91 m
45.11 m
29.87 m
14.63 m