SAND2015-0395PE

Exceptional service in the national interest

Sandia National Laboratories

Atmospheric Instrumentation at SWiFT and the Surrounding Area

Presenter: David Maniaci

1/26/2015

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

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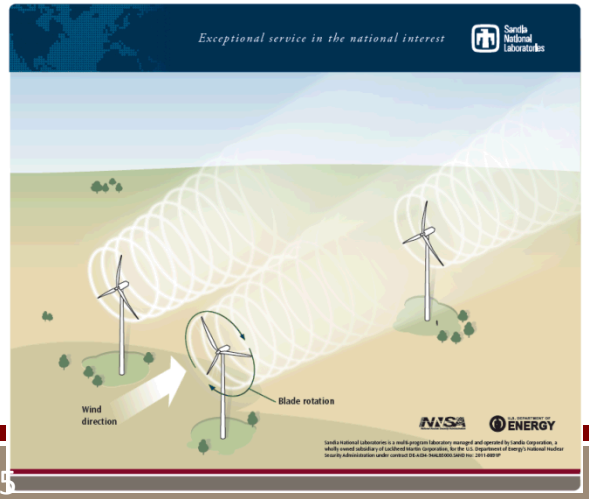
SWiFT Facility

DOE/SNL Scaled Wind Farm Technology (SWiFT) facility hosted by Texas Tech University (TTU)

SWiFT exists to:

- Reduce turbine-turbine interaction and wind plant underperformance
- Public, open-source validation data
- Advance wind turbine technology



Facilities:

- Three variable-speed variable-pitch modified wind turbines with full power conversion and extensive sensor suite
- Two heavily instrumented inflow anemometer towers
- Site-wide time-synchronized data collection

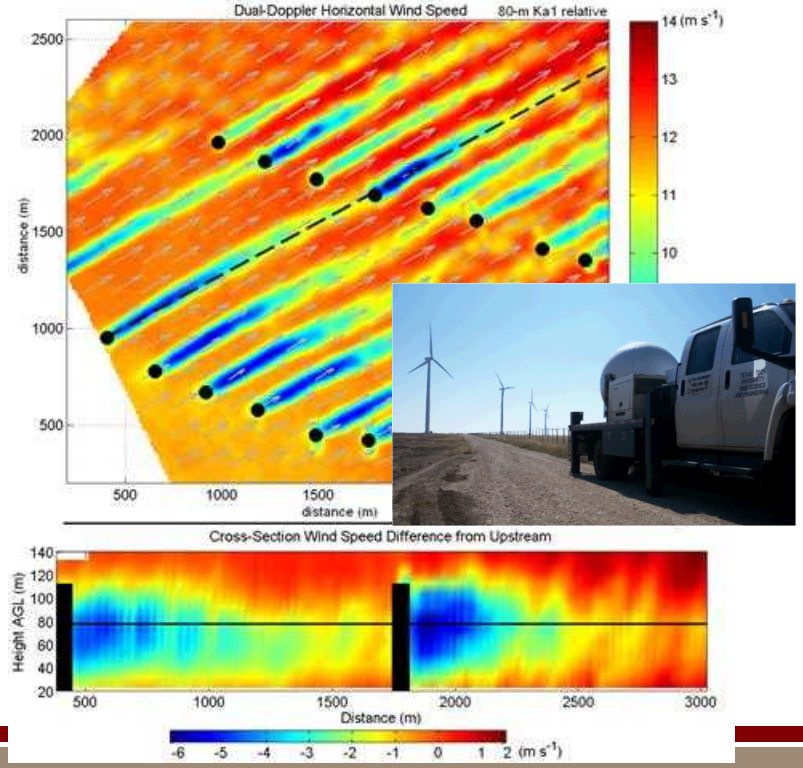
DOE/SNL/TTU Partnership

National Wind Institute (NWI) at Texas Tech University (TTU)

- Operates, maintains, and/or partners with other entities to support research quality measurement facilities at the Reese Technology Center (RTC) field site west of Lubbock, TX.

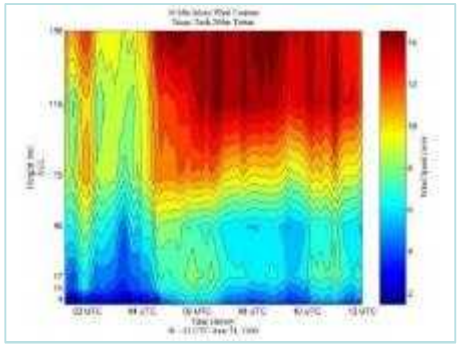
Distributed Wind Resource Assessment

2x mobile Doppler research radars

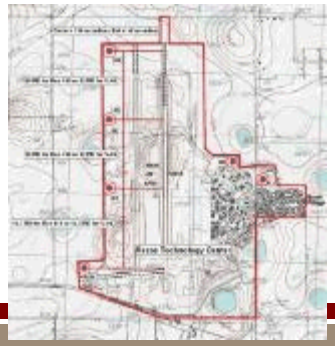


Large-scale Test Infrastructure

200 meter anemometer tower

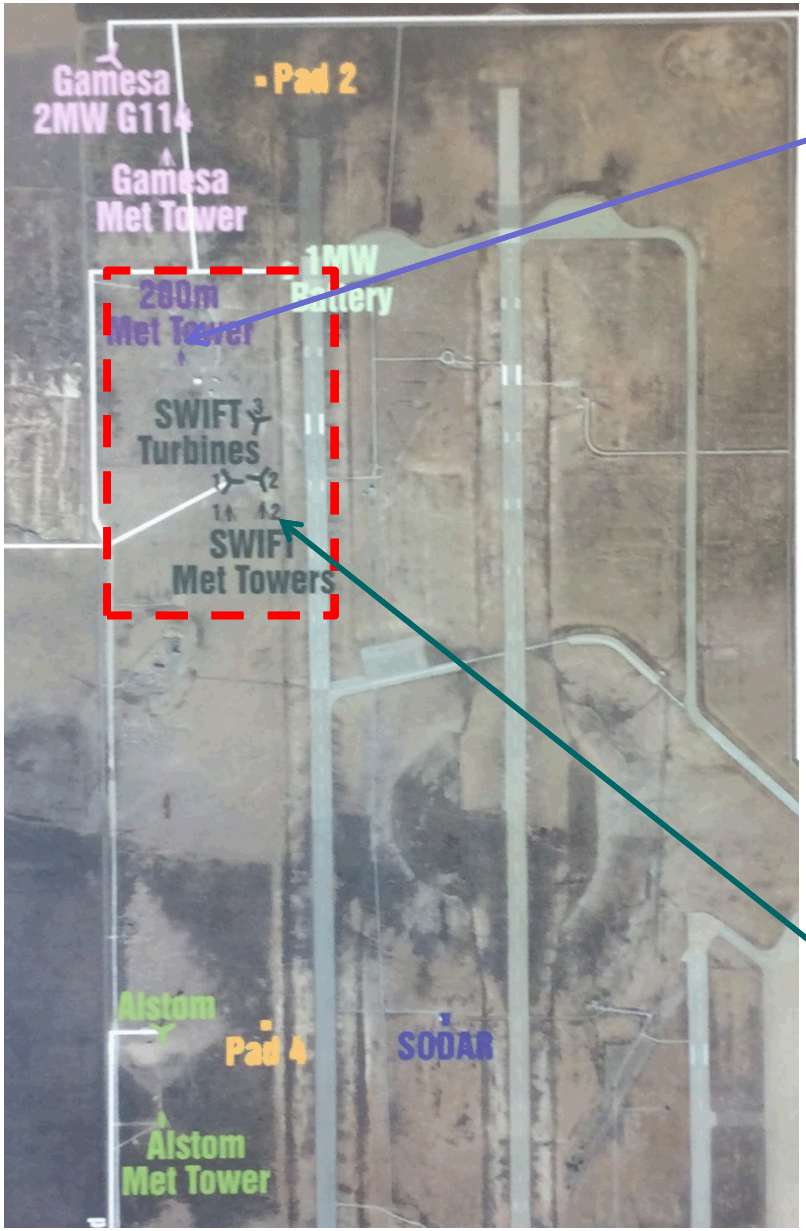


MW Wind Turbines



Reese Technology Center

Sandia National Laboratories



200m
MET Tower

58.5m MET Towers

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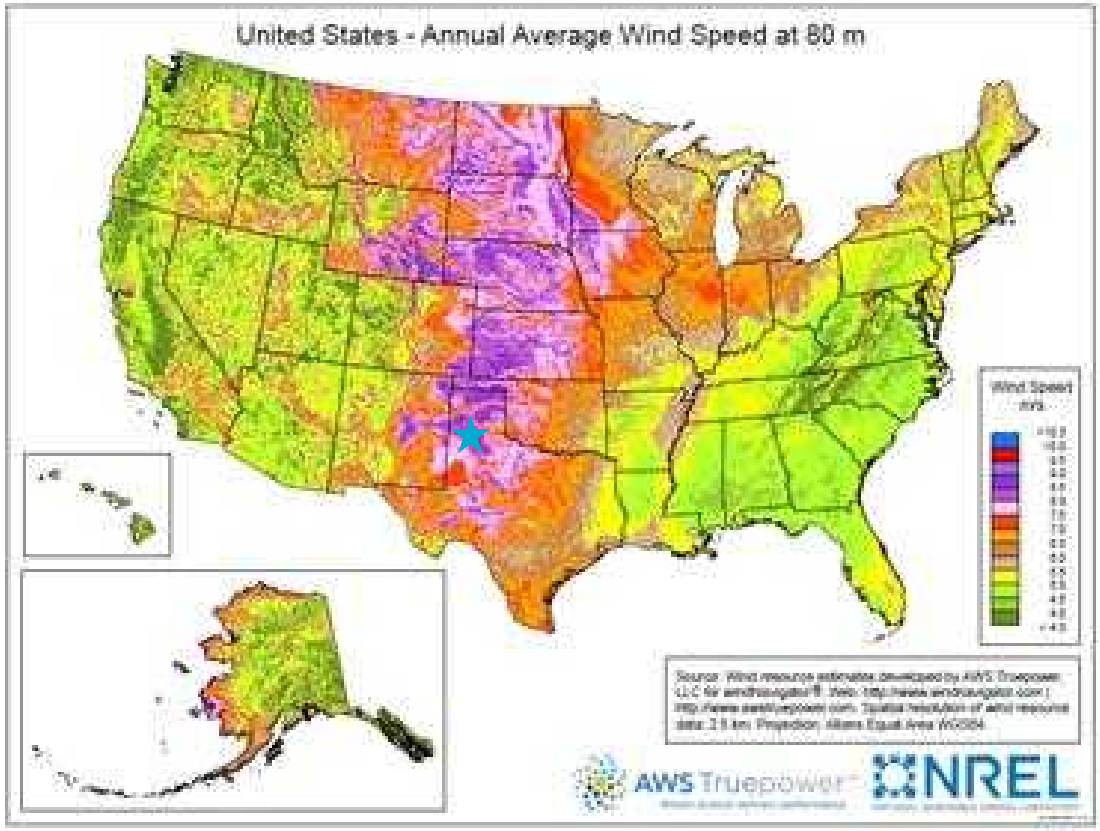
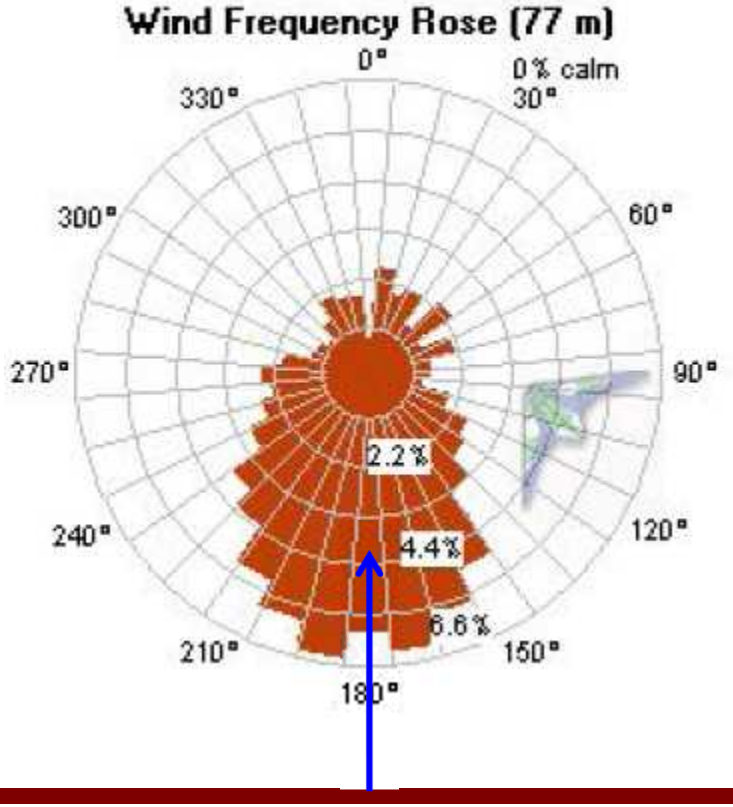
Location and Resource



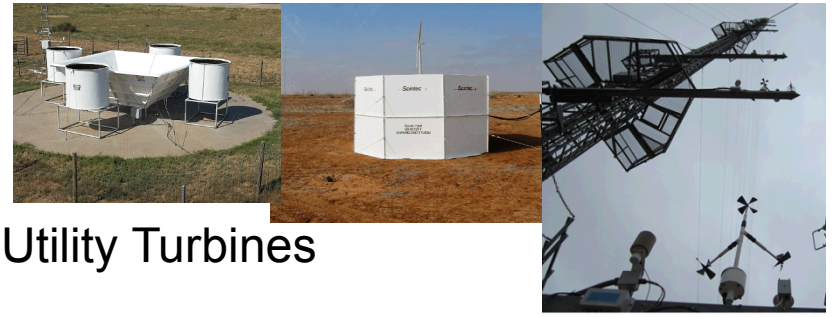
- 7.5 m/s at 50 m, Class 5 Wind Site
- Consistent South Wind, 180.5° Average



TEXAS TECH UNIVERSITY.

NWI/TTU/RTC Capabilities

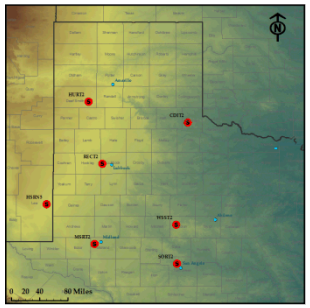
National Wind Institute (NWI) at Texas Tech University (TTU)

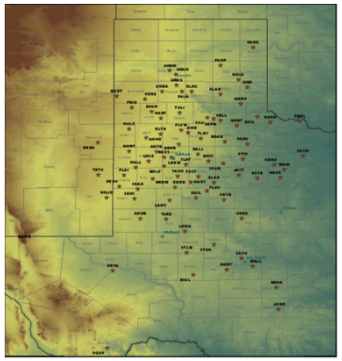


Reese Technology Center

- Radar Profiler
- SODAR
- MET Towers: 200m, SWiFT 2x60m, Utility Turbines

NWI SODAR Network





West Texas MesoNet

- 10m MET towers

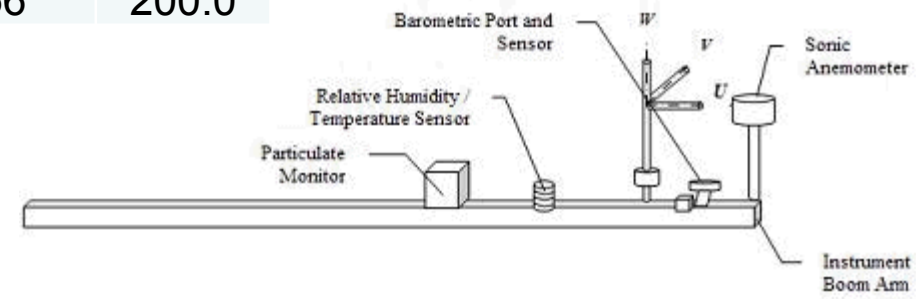
TTUKa Mobile Doppler Radar

TTU 200m Meteorological Tower

Several years of historical data have been logged at 50-hz.

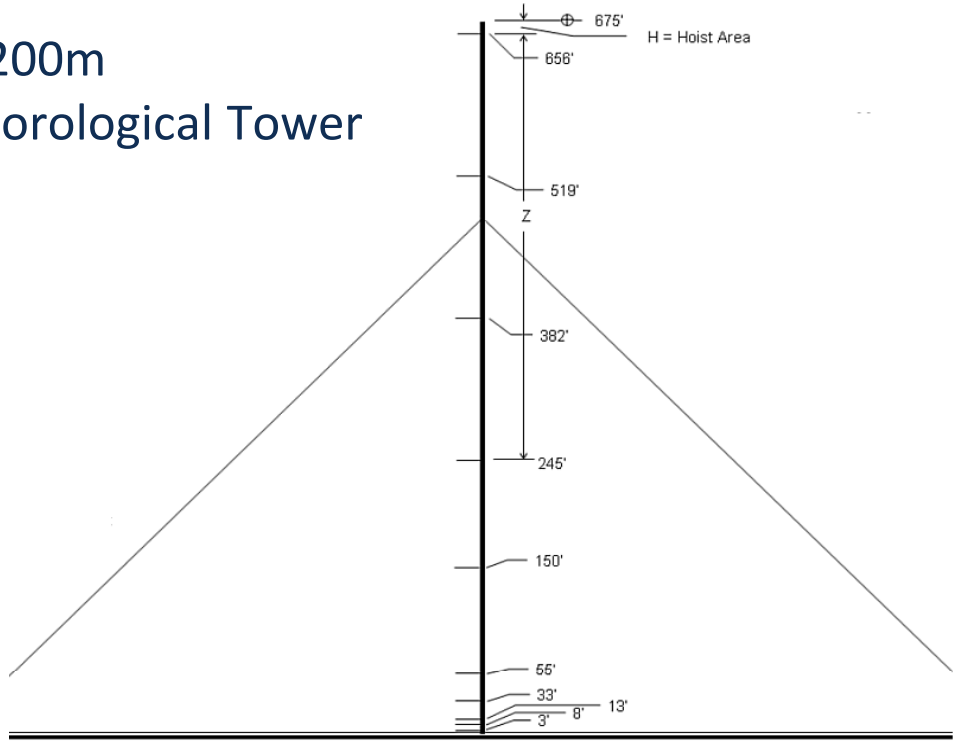
TTU Sensor Heights	
[ft]	[m]
3	0.9
8	2.4
13	4.0
33	10.1
55	16.8
155	47.3
245	74.7
382	116.5
519	158.2
656	200.0

Sensor Package at [4, 200]m
033T Sonic U-arm
033T Sonic V-arm
033T Sonic W-arm
033T Sonic Temperature
033T Temp
033T Relative Humidity
033T Bar. Pres. (61302V)HR
033T U-arm (propeller style)
033T V-arm (propeller style)
033T W-arm (propeller style)

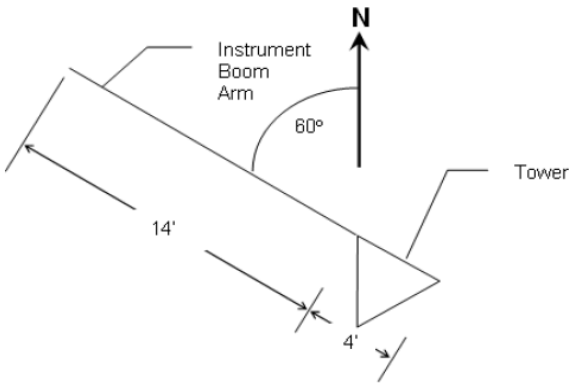


http://www.depts.ttu.edu/nwi/facilities/200-m-tower.php

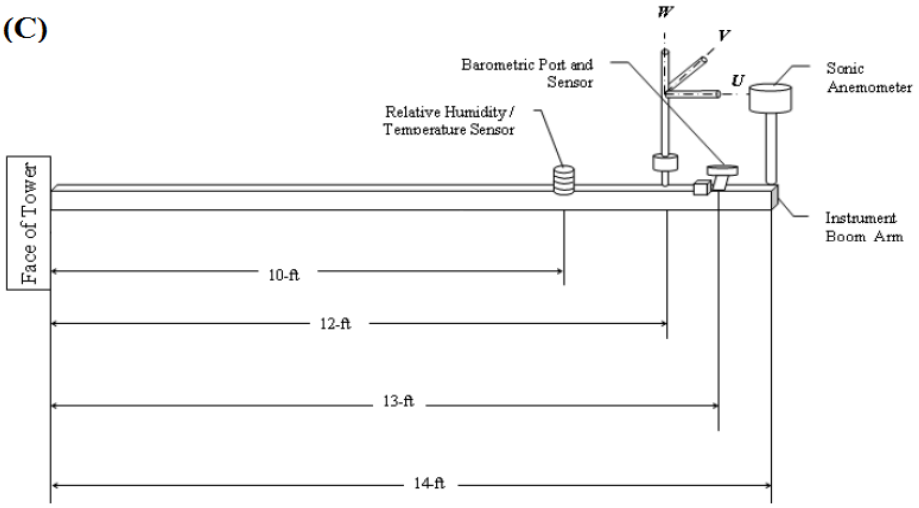
TTU 200m Meteorological Tower



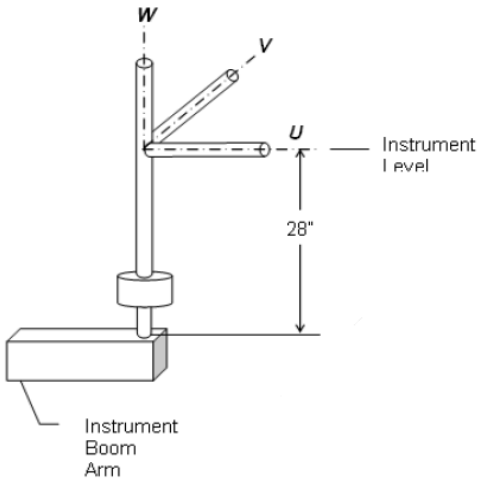
(B)



(C)



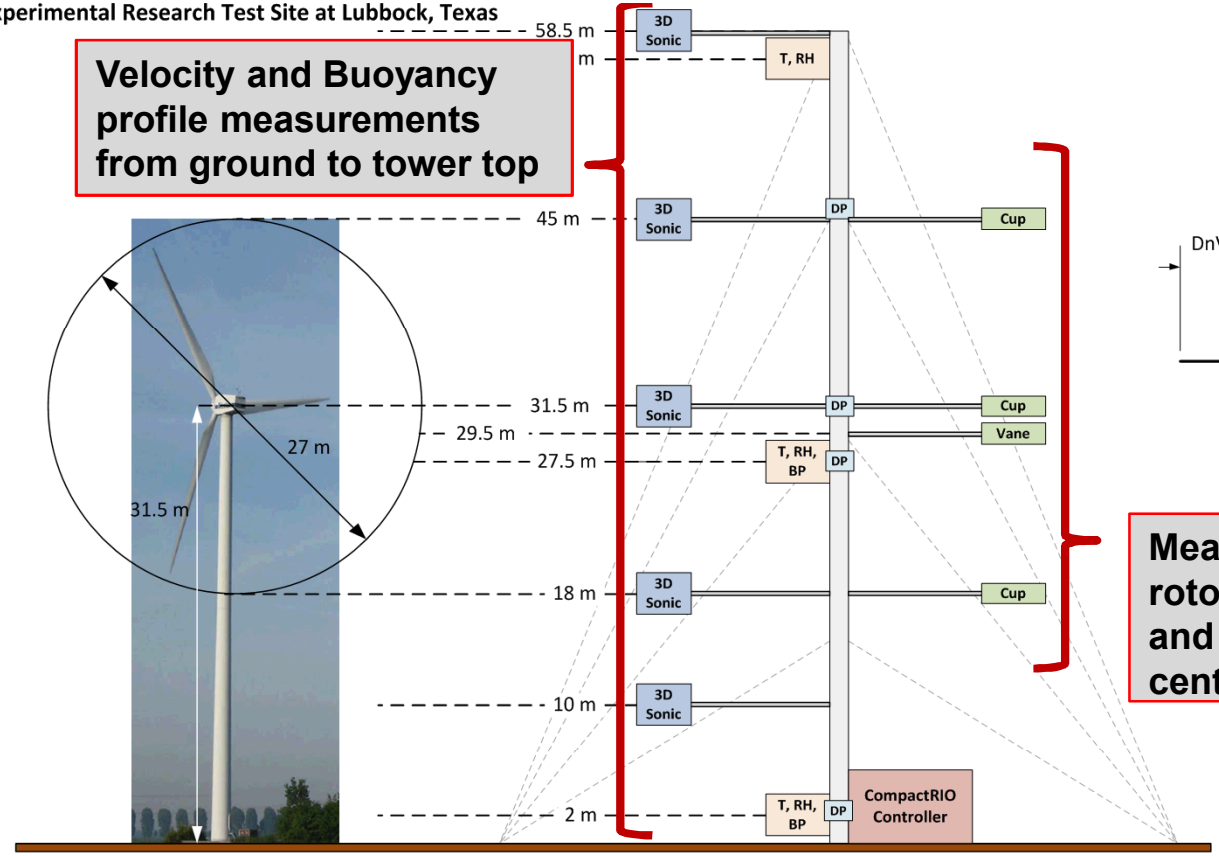
(D)

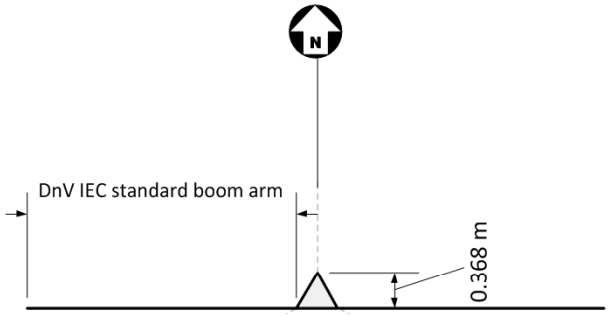


SWiFT MET Mast Configuration

Experimental Research Test Site at Lubbock, Texas

Velocity and Buoyancy profile measurements from ground to tower top





Measurements across the rotor disk with velocity and direction at rotor center

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

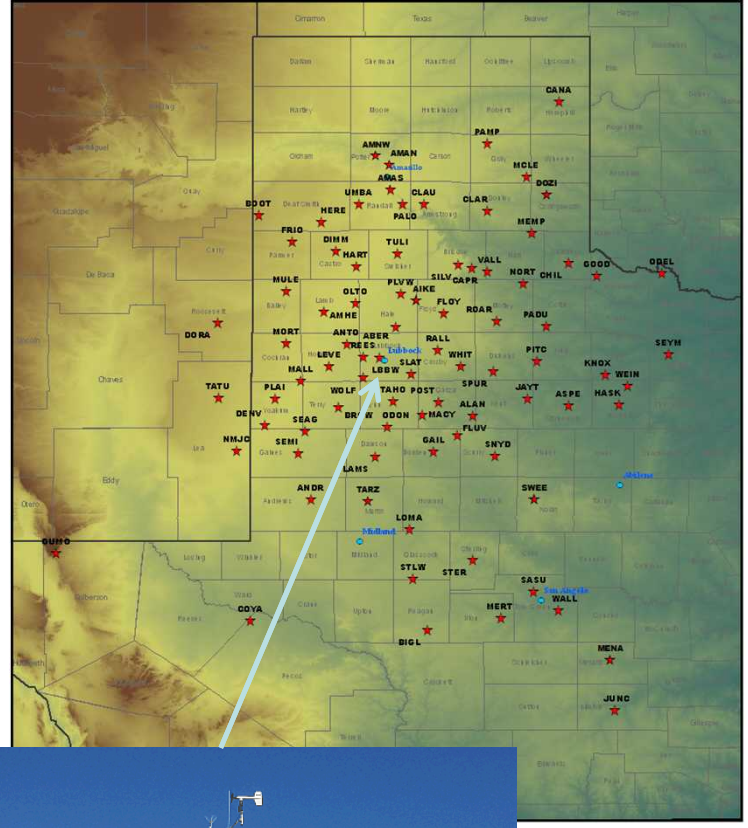
Met mast heights*

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

TTU West Texas Mesonet

Network of 10m meteorological surface observation stations.

- 84 individual surface stations
- First station deployed at RTC in 2000
- Measurements:
  - Wind speed and direction (2m, 6m, 10m)
  - Temperature (2m, 9m)
  - Relative humidity (1.5m)
  - Barometric pressure
  - Accumulated Rainfall
  - Incoming solar radiation
  - Soil temperature and moisture



www.mesonet.ttu.edu

NWI SODAR Network and WTM Radar Profiler

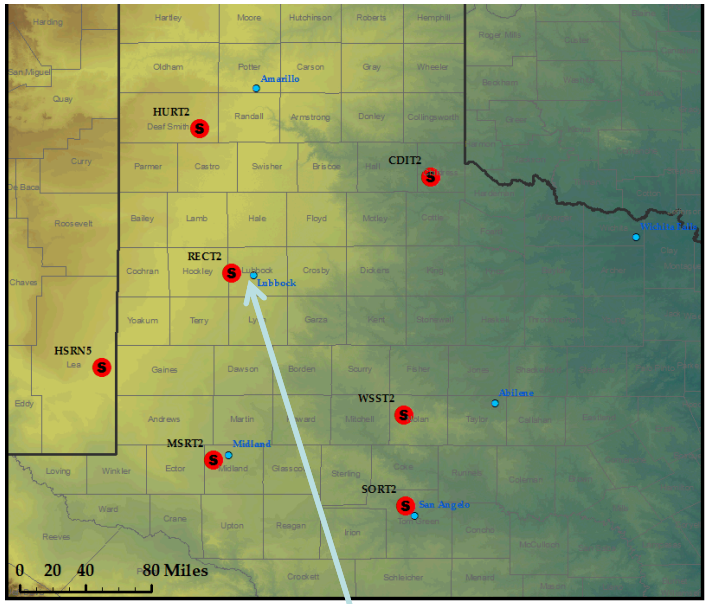
Regional SODAR Network

- Seven systems:
  - Six SCINTEC MFAS flat panel array systems
  - One ART VT-1 mobile system

Reese Technology Center

- SODAR:
  - SCINTEC MFAS
  - 30m-320m vertical profile at 10m bins
  - Wind speed and direction stored at 10 minute intervals

- Radar Profiler
  - Vaisala LAP-3000 boundary layer radar profiler
  - 150m – 6000m AGL
  - Wind speed, wind direction, and temperature profiles every 20 minutes



TTUKa Mobile Doppler Radars

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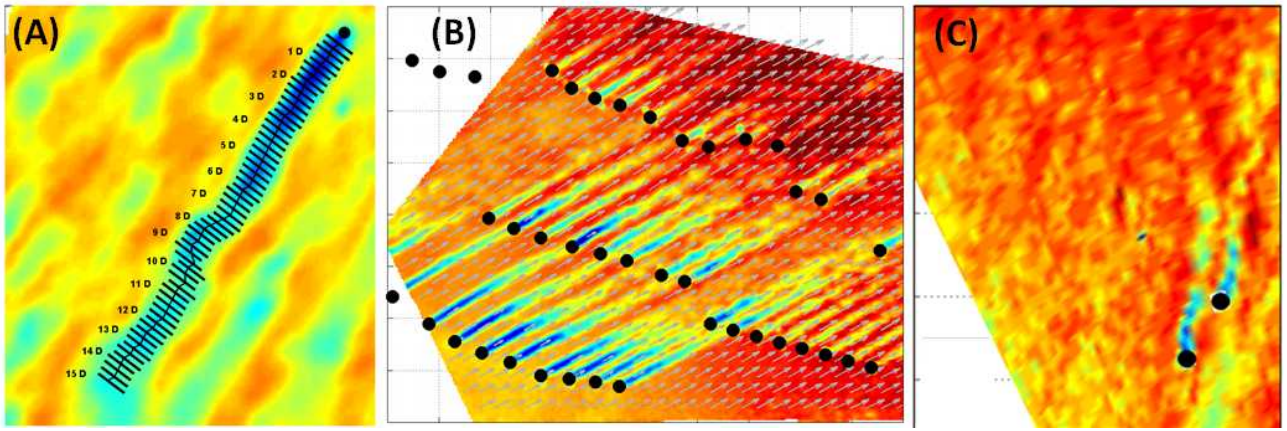
Two custom Ka-band mobile Doppler radars

- Half-power beamwidth of 0.33˚
- Along-beam range gate spacing of 9-15 m
- Operational range of 10-30km
- Velocity accuracy of 0.03 m/s



TTUKa complex flows data showing:
(A) dual-Doppler synthesis of the Alstom turbine wake
(B) dual-Doppler wind speed from a wind plant
(C) single-Doppler representation of the wakes at the SWiFT facility.

TTU/RTC Other Measurements

Alstrom Turbine Site
- 1.67 MW turbine and 80 m certification meteorological tower

Gamesa Turbine Site
- G114 2.0 MW turbine and supporting meteorological tower deployed at RTC

Sounding Facility
- Vaisala DigiCORA III sounding system

Lightning Mapping Array

Portable StickNet Tower Array

SWiFT Integrated Experiment Planning

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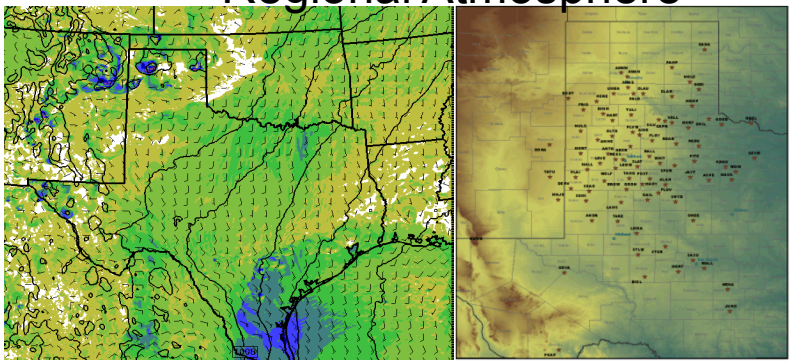
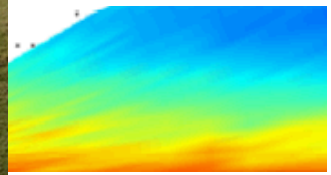
Regional Atmosphere

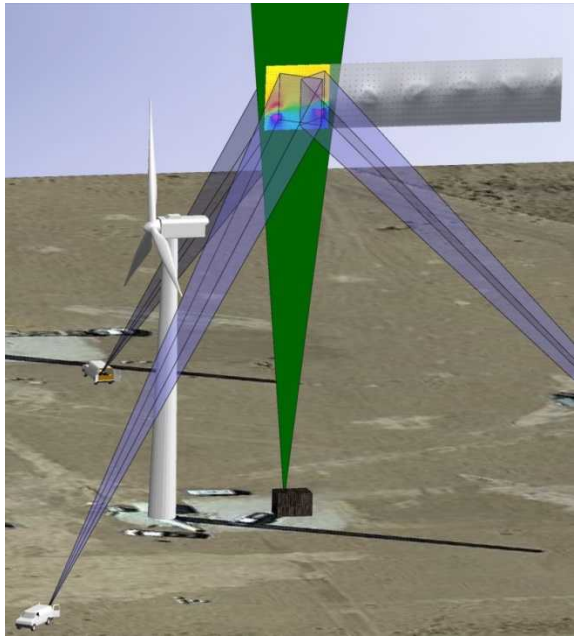


Atmospheric Boundary Layer

Wind Farm Flow



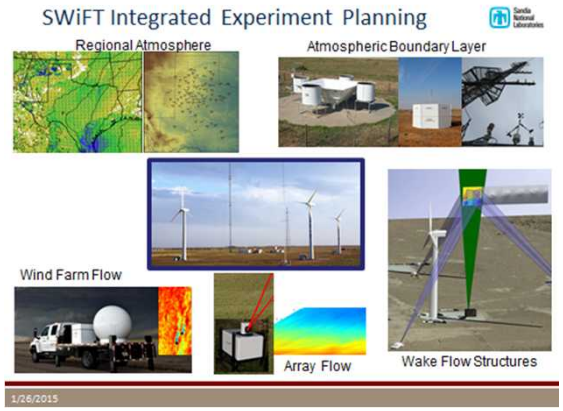
Array Flow



Wake Flow Structures

Questions

- Currently planning on performing validation experiments at SWiFT on the wind plant scale based on local measurements
- Regional meteorological measurements are available
  - What measurements should be captured during SWiFT experiments that would be useful to the Meso-Micro efforts?
- Are there near term efforts planned that would rely on the SWiFT/TTU data? (ie. That would require resource allocation in the next 1-2 years.)



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Thank you!

Back-Up Slides

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SWiFT Meteorological Measurements

Brandon Ennis

SNL Wind Energy Technologies Department

1/26/2015

U.S. DEPARTMENT OF ENERGY

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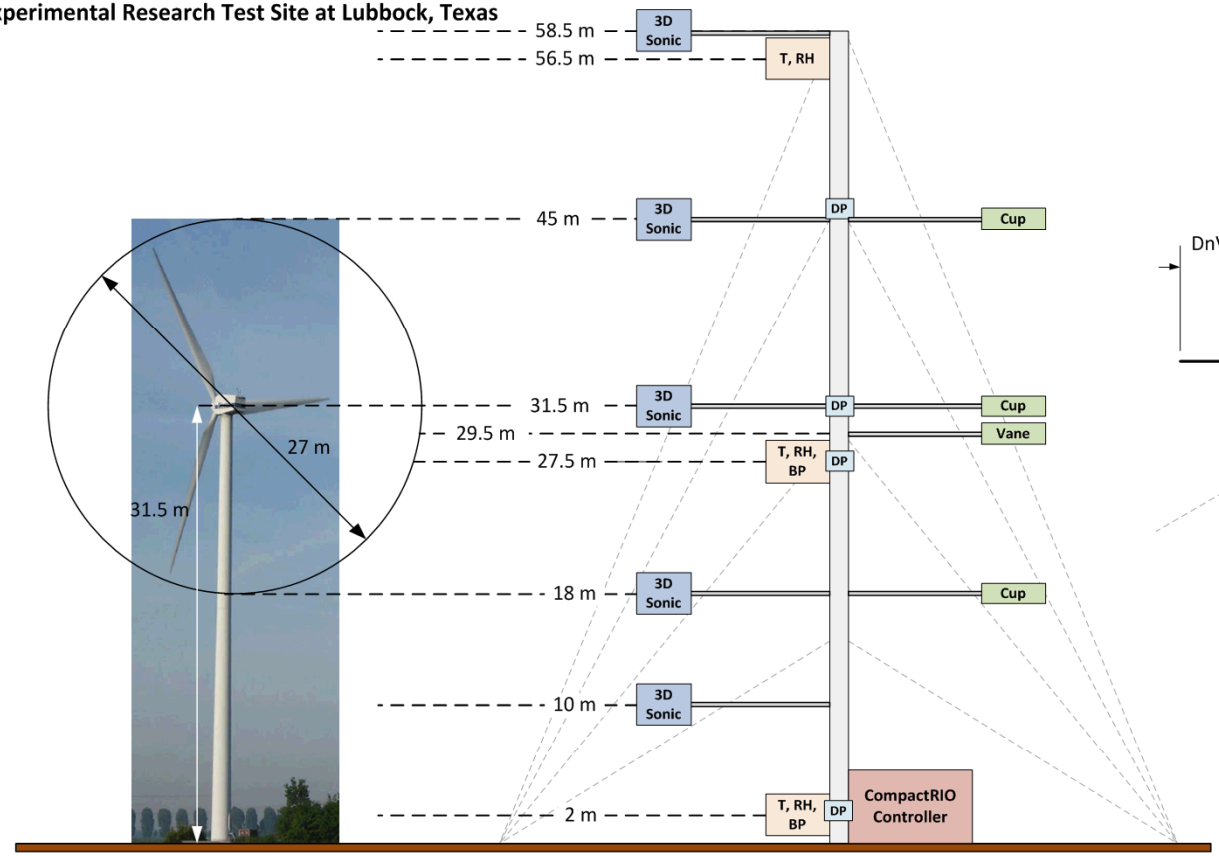
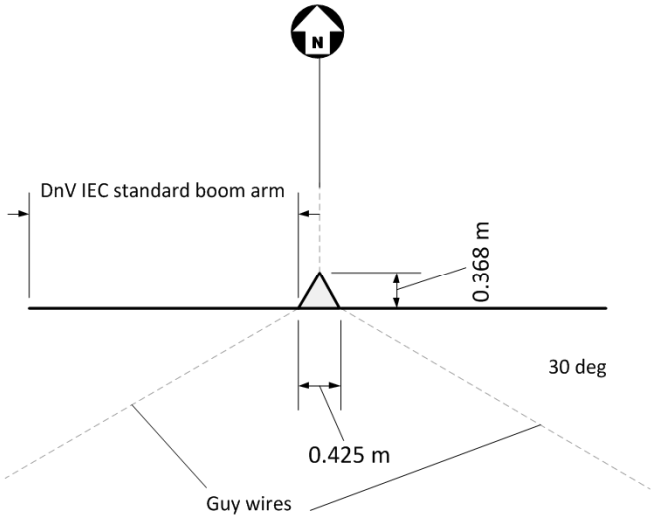
Met Mast Configuration

Experimental Research Test Site at Lubbock, Texas





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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

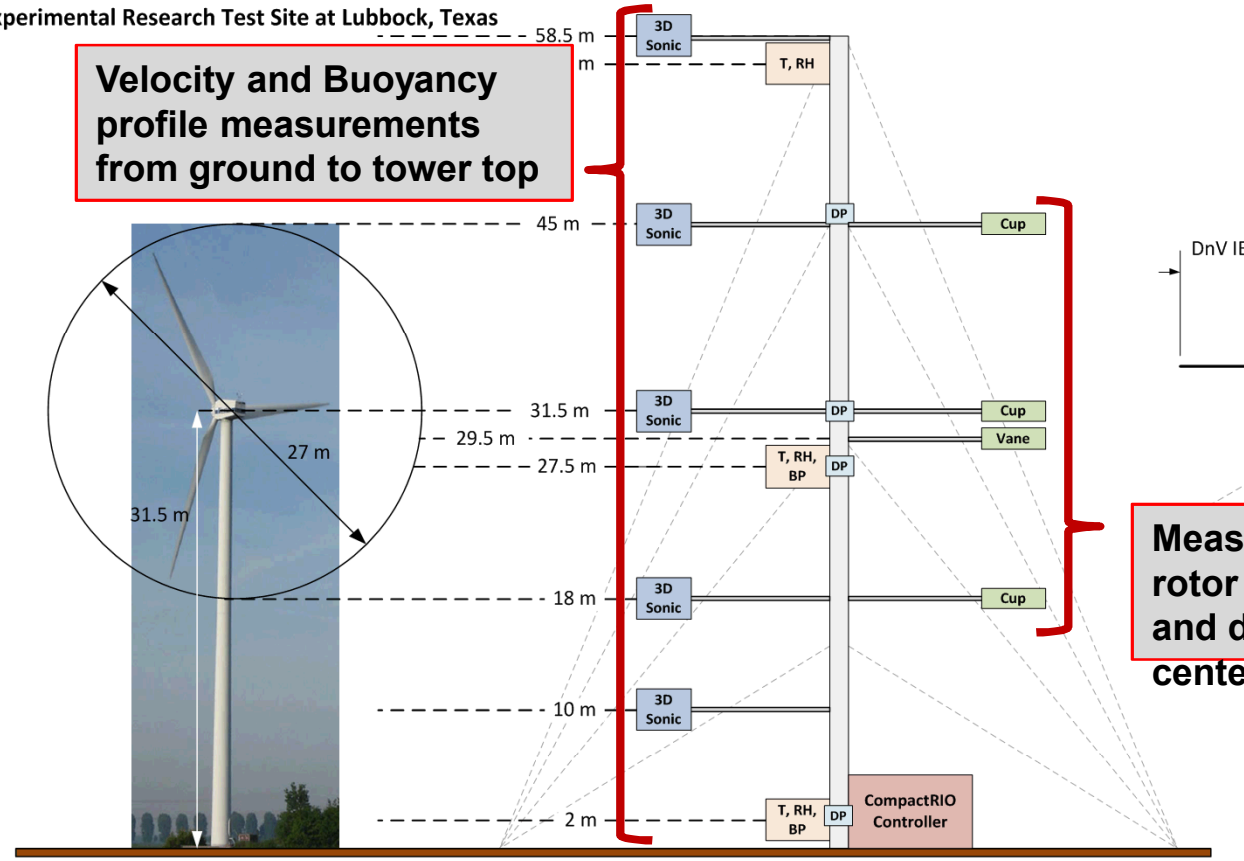
Vestas®

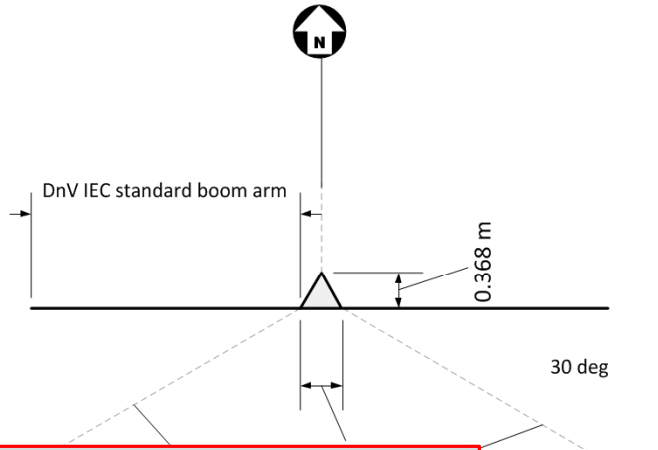
**Boom arms not drawn to scale*

Met Mast Configuration

Experimental Research Test Site at Lubbock, Texas

Velocity and Buoyancy profile measurements from ground to tower top





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Guy wires
Radius 47.5m

57.91 m
45.11 m
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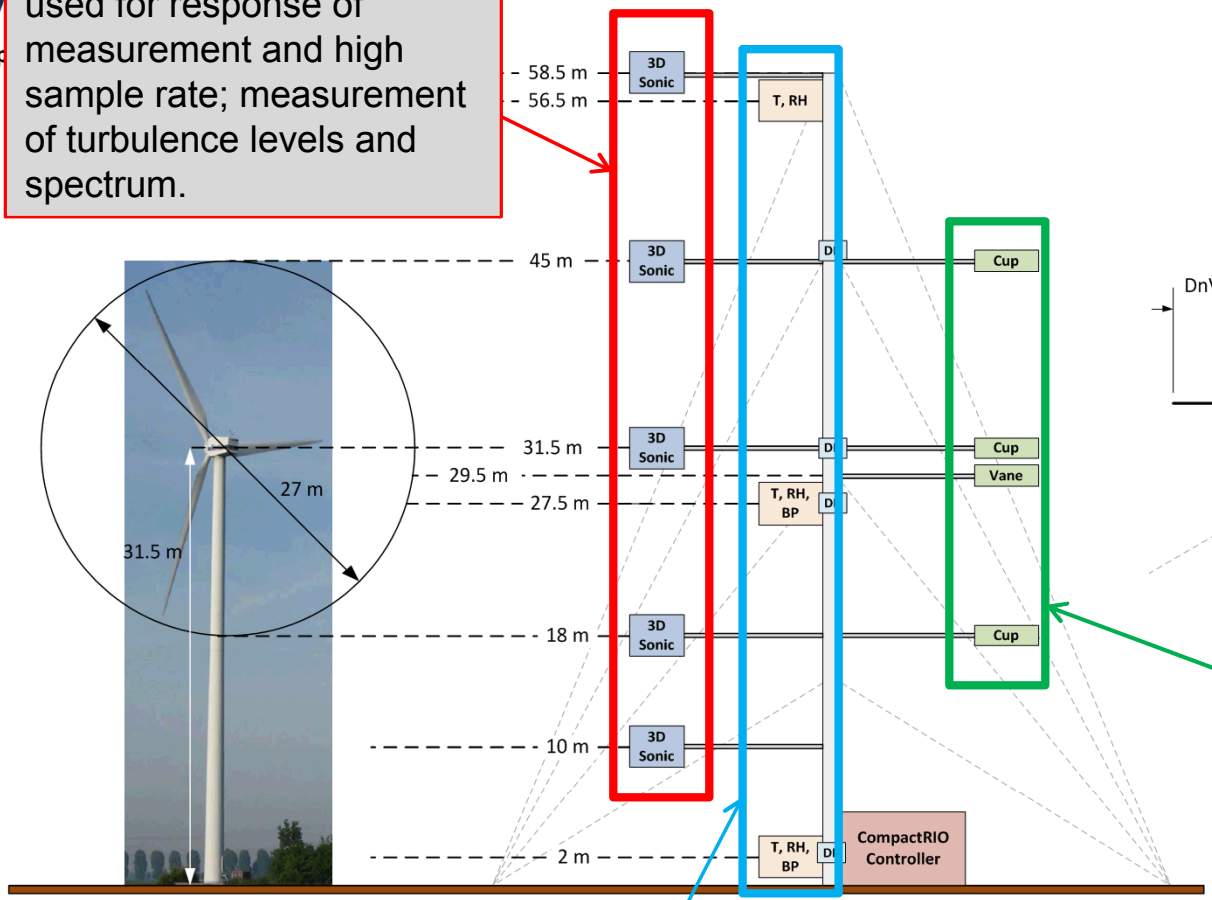
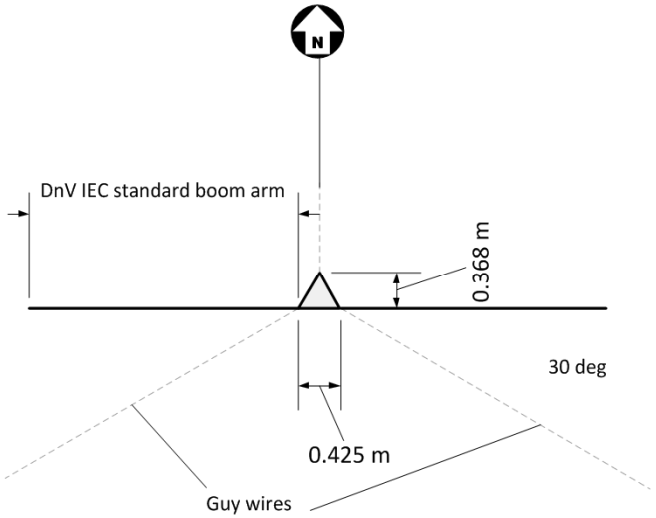
14.63 m

Vestas®

**Boom arms not drawn to scale*

(5) Sonic Anemometers used for response of measurement and high sample rate; measurement of turbulence levels and spectrum.





(3) Standard Anemometer Measurements Cup anemometers for correlation to sonic across rotor disk (current IEC standard) with wind vane at rotor center

(3) Atmospheric measurement locations Temperature, Relative Humidity, and Pressure to measure temperature and density profiles

Met mast sens

3D Sonic: ATI SAT
Cup: Thies W
Vane: Thies W
T: 592 Me
BP: 092 Me
RH: 593 Me
DP: ATI PAD

Met mast heights*

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Guy wires
Radius 47.5m

57.91 m
45.11 m
29.87 m
14.63 m

*Boom arms not drawn to scale

Tower Top Sensors

Measurement Type:	*Height (m)*	*Sensor Model*
Sonic Anemometer	58.5	Applied Technologies, SATI-3A
Temperature	56.5	Met One, Model #592
Relative Humidity	56.5	Met One, Model #593
Barometric Pressure	56.5	Met One, Model #092

Rotor Top Sensors

Measurement Type:	*Height (m)*	*Sensor Model*
Sonic Anemometer	45	Applied Technologies, SATI-3A
Cup Anemometer	45	Thies 4.3351.00.161

Hub Height Sensors

Measurement Type:	*Height (m)*	*Sensor Model*
Sonic Anemometer	31.5	Applied Technologies, SATI-3A
Cup Anemometer	31.5	Thies 4.3351.00.161
Wind Vane	29.5	Thies 4.3150.10.161
Temperature	27.5	Met One, Model #592
Relative Humidity	27.5	Met One, Model #593
Barometric Pressure	27.5	Met One, Model #092

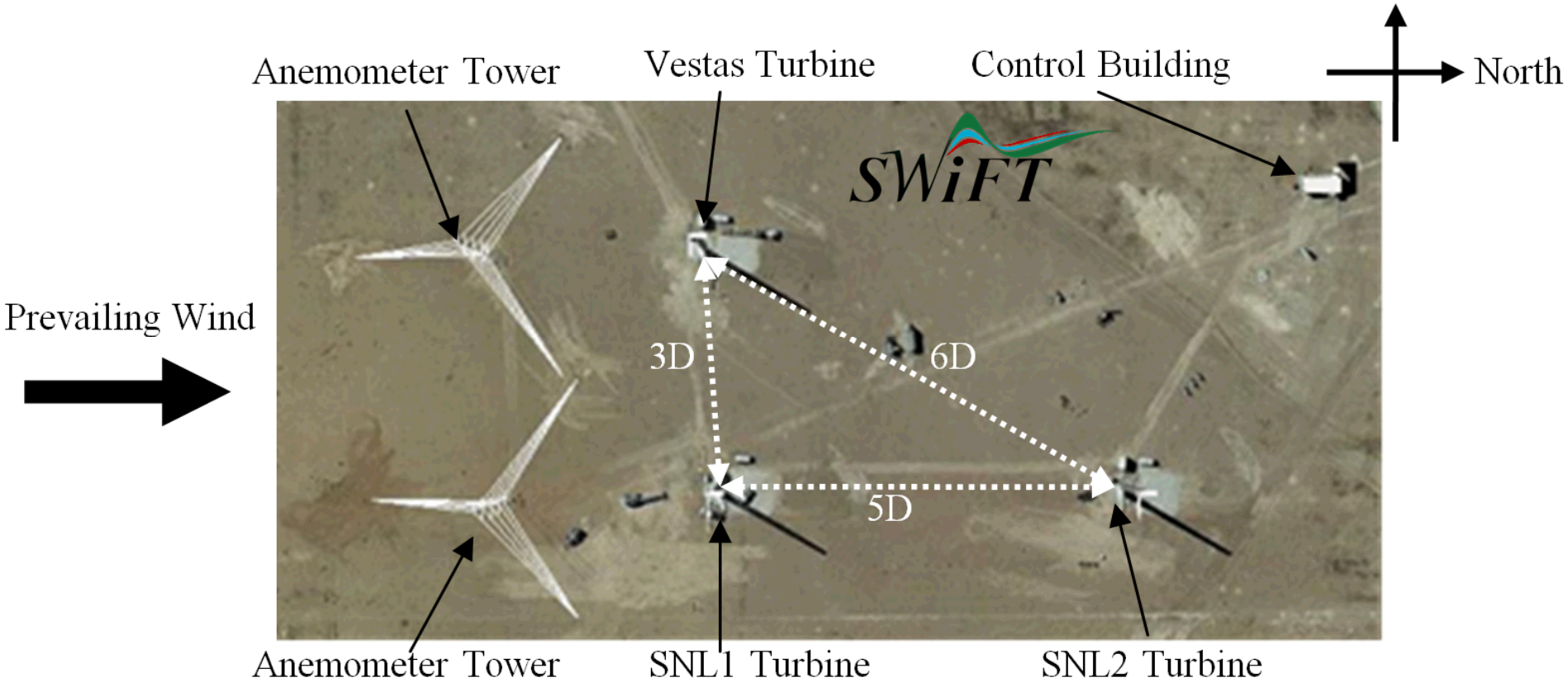
Rotor Bottom Sensors

Measurement Type:	*Height (m)*	*Sensor Model*
Sonic Anemometer	18	Applied Technologies, SATI-3A
Cup Anemometer	18	Thies 4.3351.00.161

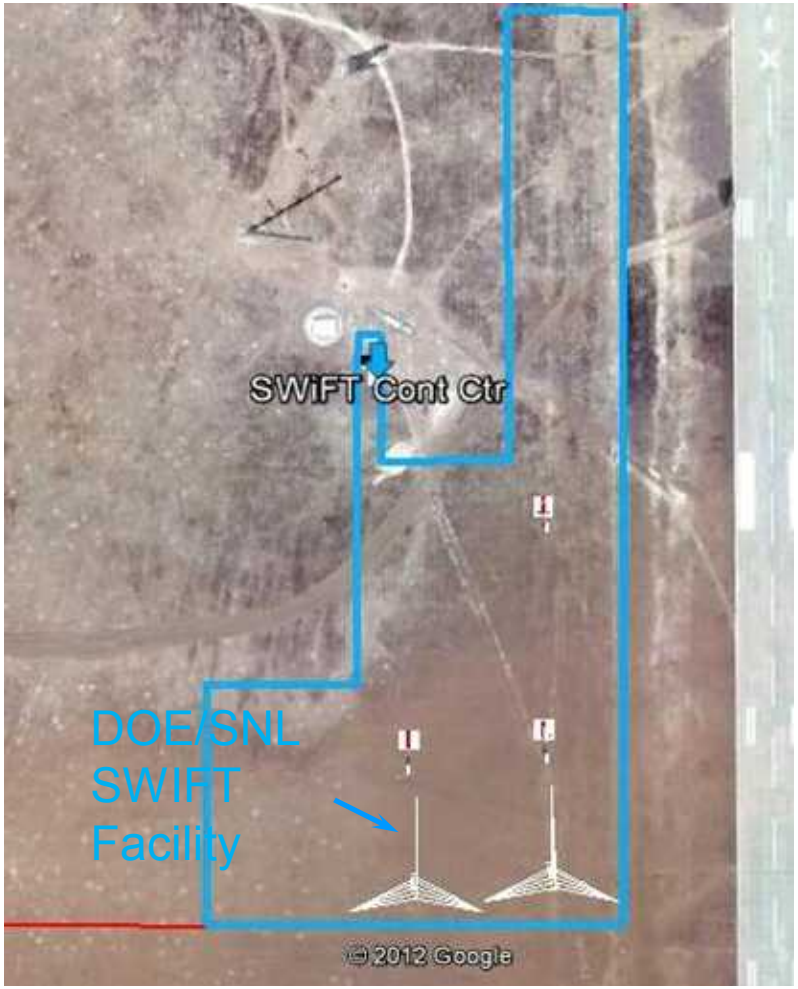
Tower Bottom Sensors

Measurement Type:	*Height (m)*	*Sensor Model*
Sonic Anemometer	10	Applied Technologies, SATI-3A
Temperature	2	Met One, Model #592
Relative Humidity	2	Met One, Model #593
Barometric Pressure	2	Met One, Model #092

SWiFT Site Configuration

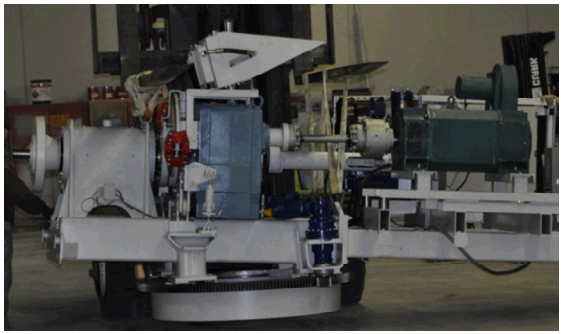


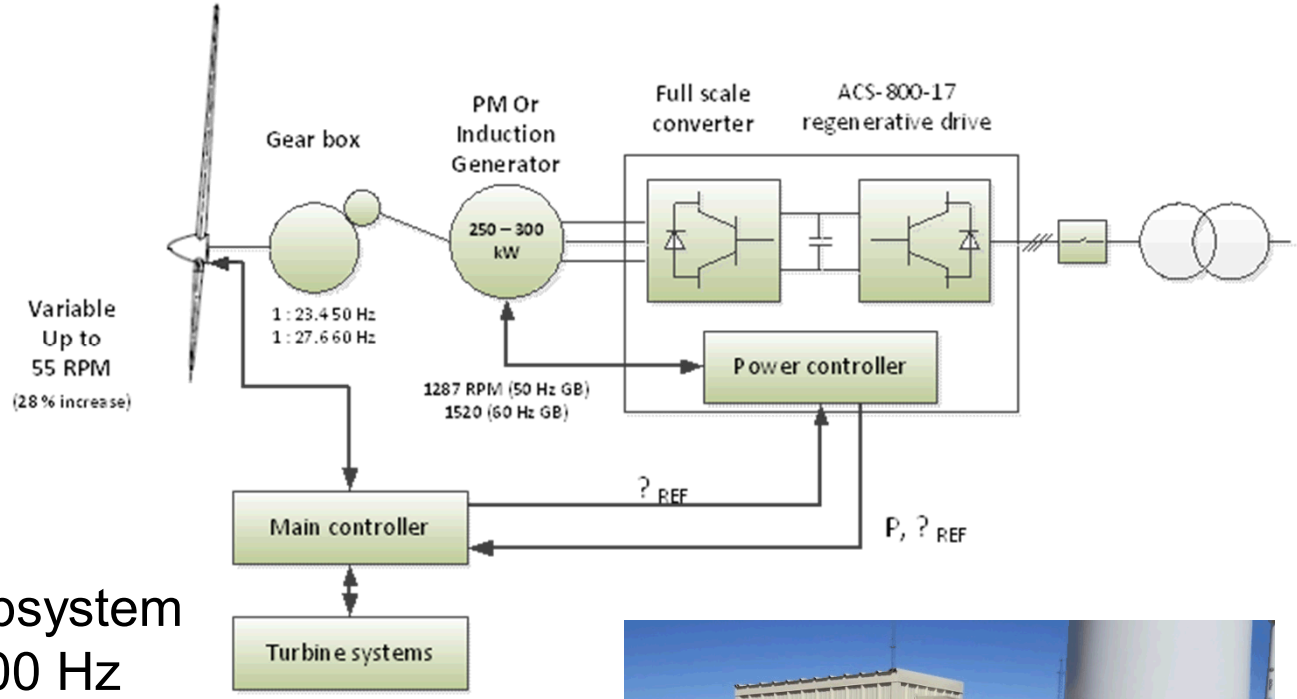
Layout



SWiFT Wind Turbines

Control Software





- Open Source Code
- Modularized by Subsystem
- EtherCAT up to 1000 Hz
- All DAQ signals available for control
- Running on NI Veristand
- Parameterized Variable Speed and Torque Controller
- Maintains all original safety systems and alarms

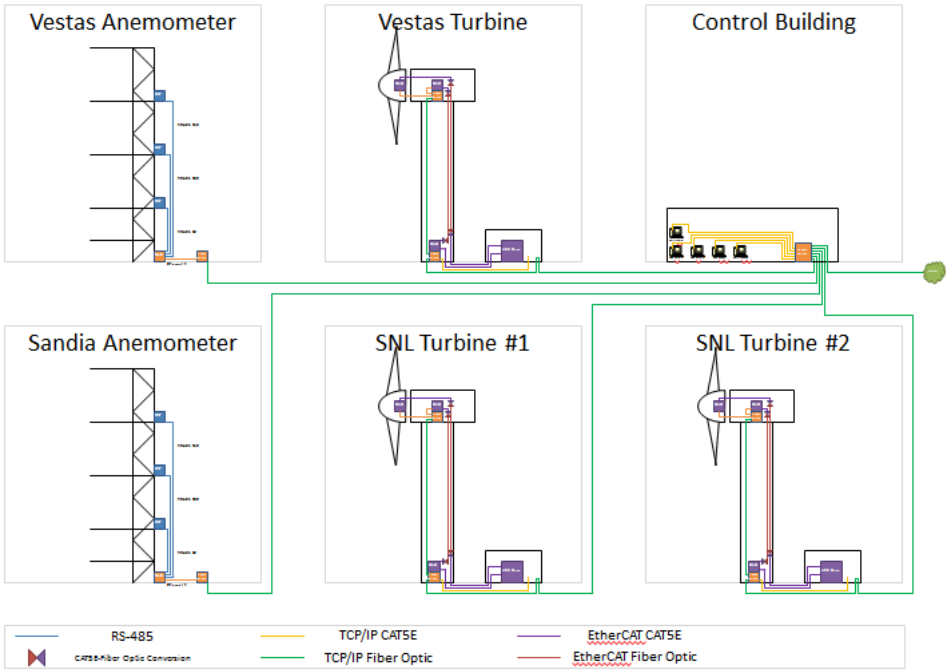
SWiFT Wind Turbines

Hardware

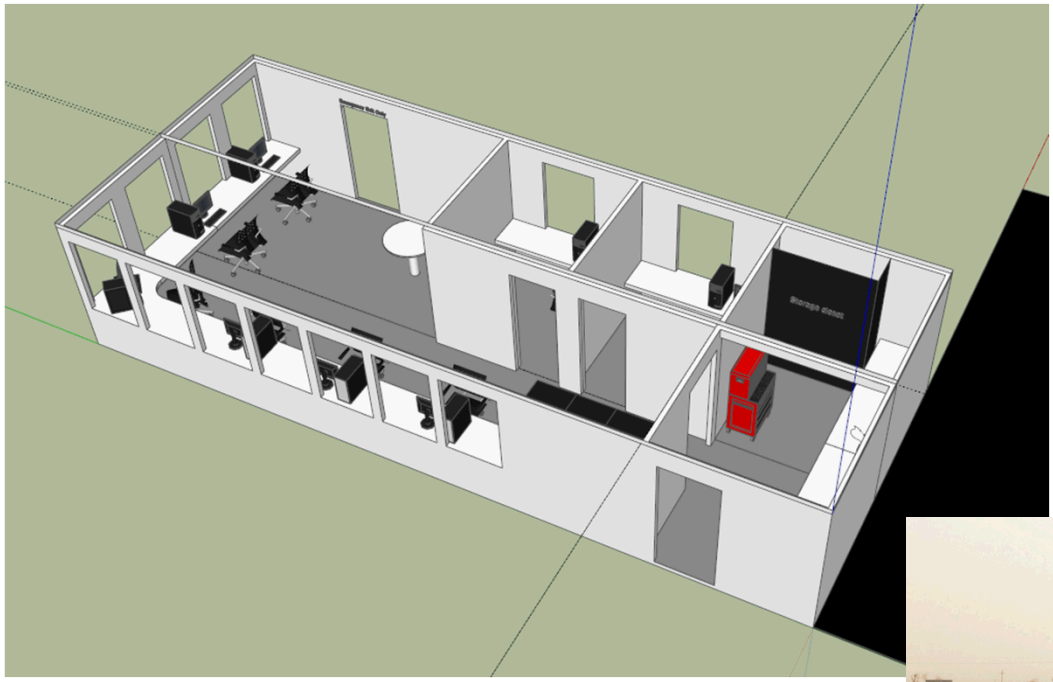
- Collective Pitch System
- 300 kW Variable Speed Generator
- AC-DC-AC Full Scale Convertor
- National Instruments controllers
- Complete turbine / rotor state instrumentation
- Fiber Optic blade sensing system

Networking Infrastructure

- GPS synced measurements
- Up to 1000 Hz
- Currently 500+ channels
- Centrally logged data
- Fiber optic data transfer
- Localized deterministic control loops



Control Building

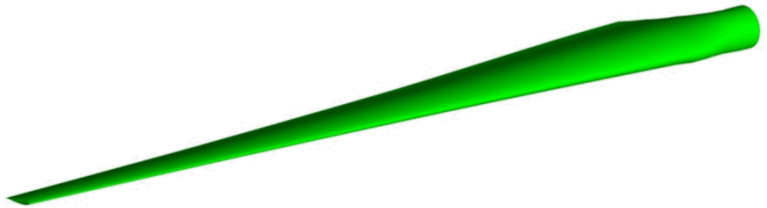


- Central control and operations
- 700 sq. ft. with 2 temporary offices for proprietary work
- Electrical troubleshooting lab

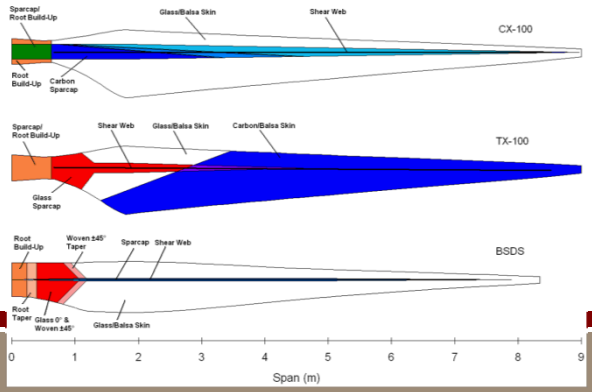
Experimental Preparation Lab

- 4,500 sq. ft. environmentally controlled high-bay experimental rotor preparation
- 1,000 sq. ft. machine shop

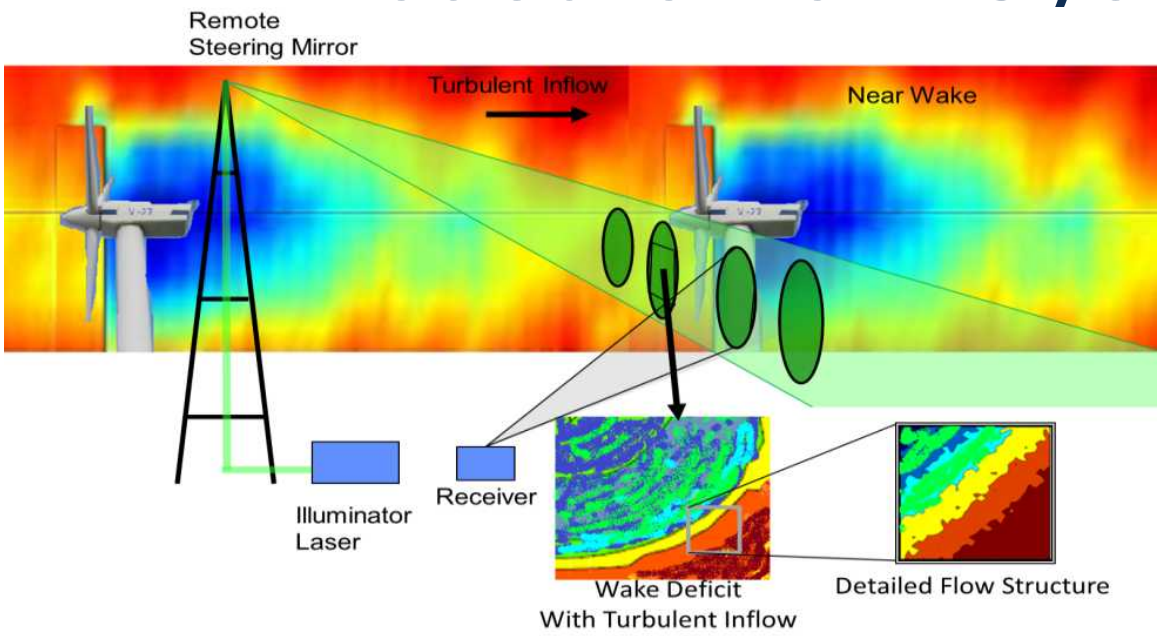
National Rotor Testbed

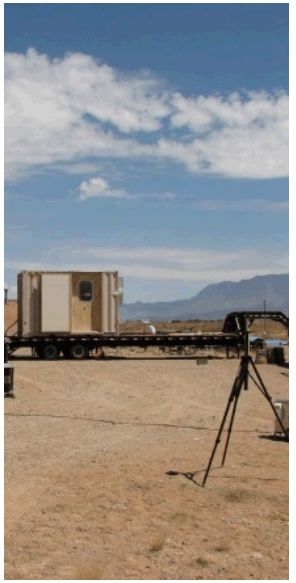


- The National Rotor Testbed is a rotor innovation to enable technology acceleration
- Baseline blades represent functionally scaled-down aerodynamics and structural dynamics of a modern megawatt-scale rotor
- Baseline blade design is public and open
- Enables research in: wake interactions, aero-acoustics, inboard aerodynamics, controls, aeroelastic dynamics



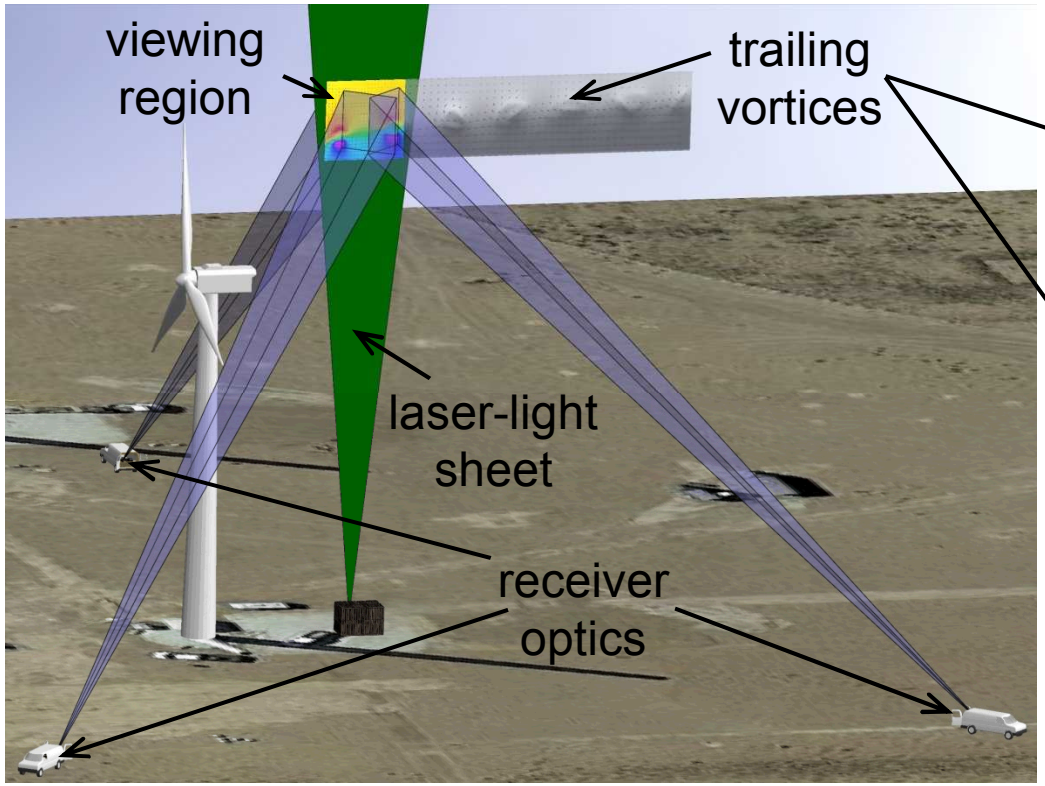
Wake Imaging Measurement System

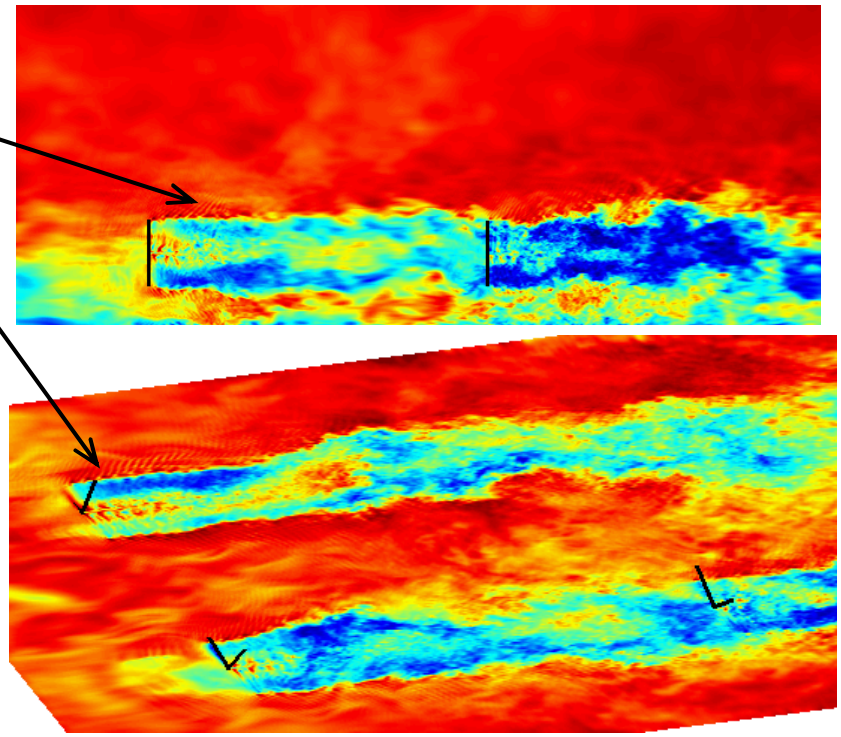




- Capture detailed 3-D flow structures that convect downwind
- High spatial resolution: 16,000 data points per sample
- Imaging allows for fast scanning sufficient to capture sub-rotor scale turbulent flow structures
- Enables direct comparison with high-fidelity and engineering level models

Experiment Planning





UMN Virtual Wind Simulator (VWiS)

- High-fidelity modeling of the SWiFT site will be used to create synthetic flow diagnostic images based on the physics of the wake measurement system
  - Simulations are currently being performed using the UMN VWiS code
  - Results will also be used to determine the most suitable deployment of the aerosol dispersion system