

# SWiFT Testing Overview

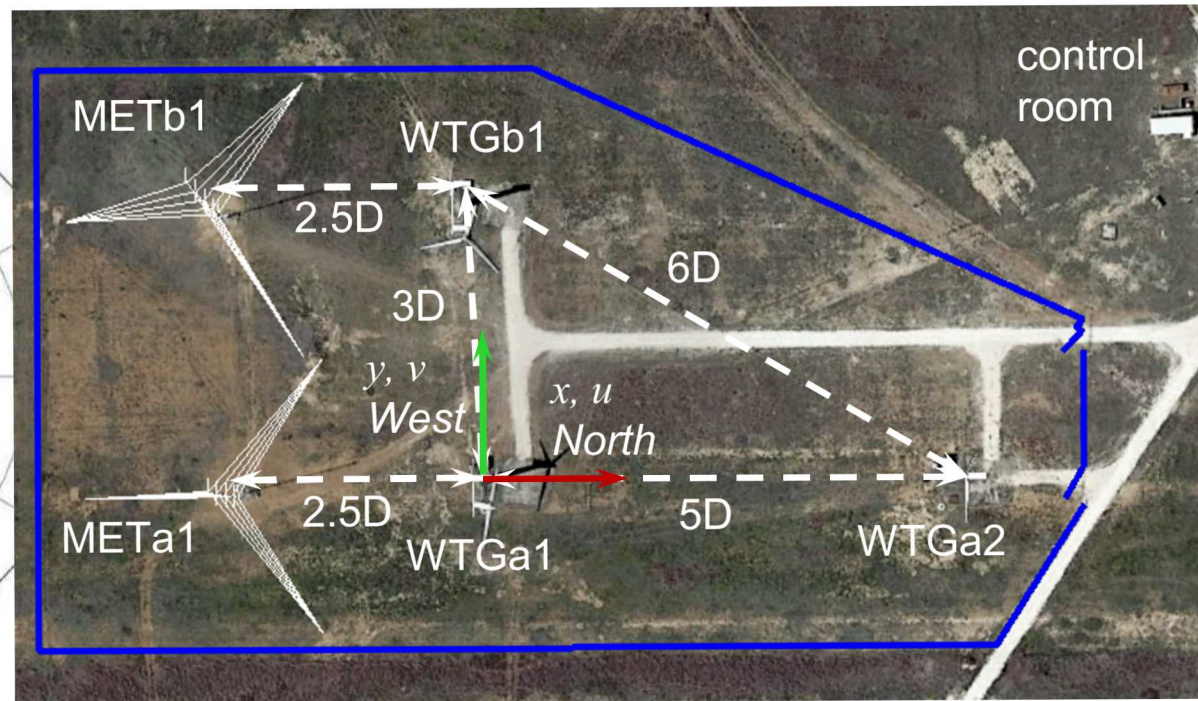
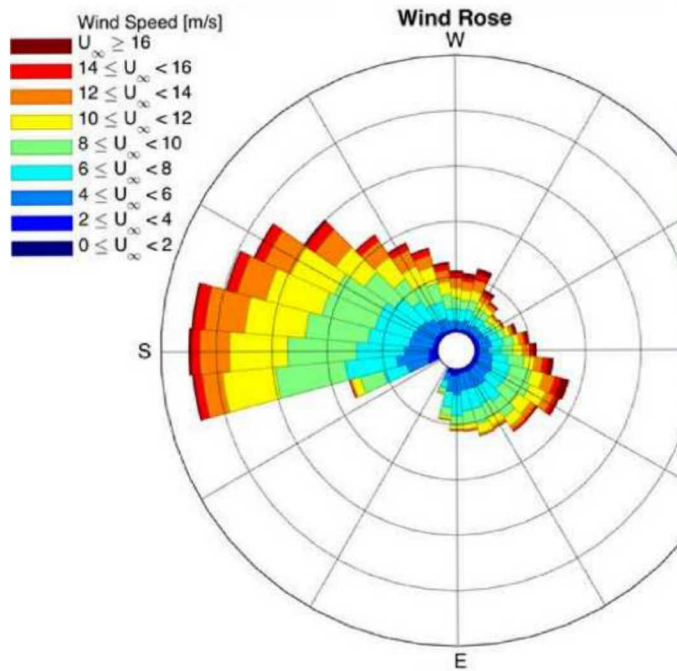
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# Overview

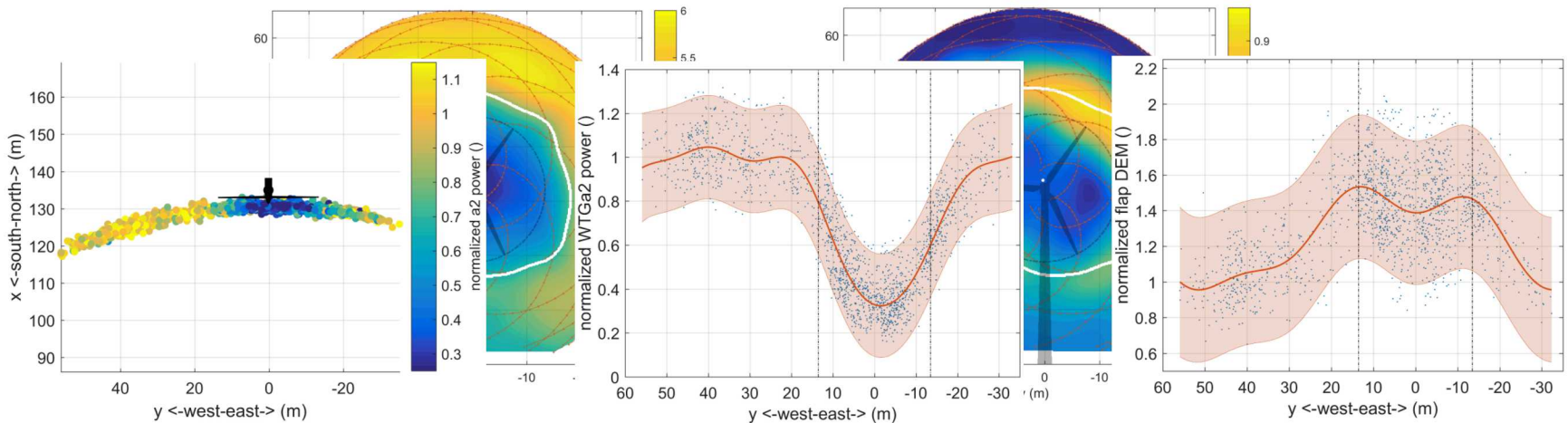
- SWiFT facility created to:
  - Measure wind plant flows and turbine-turbine interactions
  - Perform prototype testing of innovative rotor technology
- Wake steering experiment sought to quantify wake deflection vs. yaw offset and the corresponding effects on a two-turbine system
  - Characterize wake shape, velocity deficit, turbulence, and dynamics under various conditions



# Overview

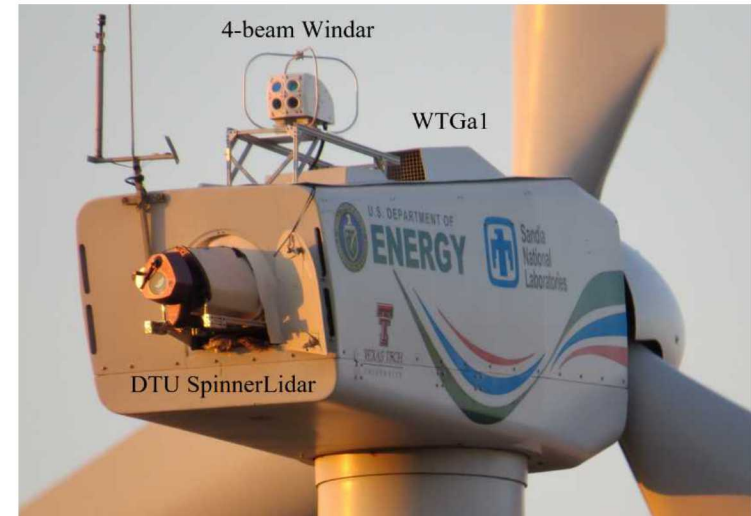
## Observations

- Wake deflected  $\approx 10\text{m}$  for 25 deg yaw offset for V27 Ct
- Wake behavior very dependent on inflow characteristics
- Wake can be defined from lidar turbulence estimates
- Rotor integral aerodynamic properties can be estimated from lidar wake measurements
- Yaw offset reduced power, increased/decreased fatigue loads dependent on shear and veer conditions
- Downstream turbine power increased with less wake impingement
- Partial waked case has higher fatigue loads than fully waked case.



# Overview

- Instrumentation:
  - Two highly instrumented, modified V27
  - Met tower to characterize inflow
  - DTU SpinnerLidar for wake characterization
  - Blade root edge and flap strain measurements
  - 4-beam Windar measurements of wake
  - All sensor channels GPS timestamped



- References

- Herges T G, Maniaci D C, Naughton B T, Mikkelsen T, and Sjolholm M, 2017, High resolution wind turbine wake measurements with a scanning lidar, *Journal of Physics: Conference Series*, 854
- Ennis B L, White J R, and Paquette J A, 2018, Wind turbine blade load characterization under yaw offset at the SWiFT facility, Torque 2018.
- Herges T G, Berg J C, Bryant J T, White J R, Paquette J A, and Naughton B T, 2018, Detailed analysis of a waked turbine using a high-resolution scanning lidar, Torque 2018.
- Kelley C L, Herges T G, Martinez L A, and Mikkelsen T, 2018, Wind turbine aerodynamic measurements using a scanning lidar, Torque 2018.

# Missing Pieces and Lessons Learned

- During wake steering experiment we found the following:
  - Onboard turbine wind direction sensor very inaccurate
  - Operating at a steady, intentional yaw offset with low yaw duty cycle was challenging
  - Sonic anemometer data drop out
  - Calibration of sonic anemometer wind direction
  - Time synchronization was essential
  - Lubbock has good aerosol seeding for lidar
  - Isolating study of wake challenging with moderate turbulence
  - QA/QC-ing data for distribution requires many man-hours
- If we were to do the experiment again we would:
  - Improve onboard wind direction sensor and compensation
  - Improve site specific controller constants to decrease yawing duty cycle
  - Improve site sonic anemometers
  - Calibrate all sensors pre and post test
  - Assure sensors capable of meeting uncertainty values needed
  - Use 4-beam Windars to measure turbine inflow

# Recommendations for Future Testing

- If we were to execute a new field campaign, we would focus on the following science goals:
  - Asses effect of scale, Reynolds numbers, and associated atmospheric conditions on wake mixing and momentum recovery
    - To answer how array losses vary for different wind turbines and sites
  - Model validation starting with specific physics-based quantities of interest, realistic estimates of their impact, use of simplest model that predicts them, and a sensor set that is capable of measuring the quantities at the required uncertainty level
    - Because computational capability is occupied by both complexity and number of cases simulated. Validating mid-level complexity models are of the highest value to turbine designers
  - Define all conditions and combinations of conditions that need to be measured before the test, along with estimates of the time required to collect the data
    - For thorough experimental planning and cost estimates

# Recommendations for Future Testing

- If a new test were to happen we would suggest
  - Collect more data from blades, included deflections, and surface pressure
  - Combine turbine based high-fidelity lidar measurements with lower fidelity lidar, and full-field radar or lidar systems.