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Pentalum SpiDAR Deployment at the SWiFT Facility FY19

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ABSTRACT

The Texas Tech University (TTU) research group is actively studying wind turbine wake development, as part of developing innovative wake control strategies to improve the performance of wind farms. The team has a set of eight ground lidars to perform field measurements at the Sandia National Laboratories SWiFT site.

This document describes tests details including configurations, timeframe, hardware, and the required collaboration from the Sandia team. This test plan will facilitate the coordination between both TTU and the Sandia team in terms of site accessibility, staff training, and data sharing to meet the specific objectives of the tests.

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ACRONYMS AND DEFINITIONS

Abbreviation	Definition
SNL	Sandia National Laboratories
DOE	Department of Energy
TWD	Technical Work Document
SWiFT	Scaled Wind Farm Technology
TTU	Texas Tech University

APPROVALS

The following test plan may not be implemented until the following individuals approve by signing and dating below.

Approved by: _____ Date: _____

Dave Mitchell, SWiFT Site Supervisor

Approved by: _____ Date: _____

Tim Riley, SWiFT Program Lead

Approved by: _____ Date: _____

Brian Naughton, Sandia Technical Liaison

Approved by: _____ Date: _____

Brandon Davis, 8821 ES&H Lead

Approved by: _____ Date: _____

Suhas Pol, Project PI

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1. INTRODUCTION

The TTU research group is actively studying wind turbine wake development, as part of developing innovative wake control strategies to improve the performance of wind farms. The team has a set of eight ground lidars (Pentalum SpiDAR, recently acquired by NRG Systems) to perform field measurements of the wind velocity at the Sandia SWiFT site.

This document describes test details including configurations, timeframe, hardware, and the required collaboration from the Sandia team. This test plan will facilitate the coordination between both TTU and the Sandia team in terms of site accessibility, staff training, and data sharing to meet the specific objectives of the tests.

2. TEST OBJECTIVES AND SUCCESS CRITERIA

The following table summarizes the primary and secondary test objectives for the test plan along with the criteria used to evaluate the success of the test in achieving the objectives. Primary objectives are required to be completed while secondary objectives are only to be prioritized after successful completion of the primary objectives.

Table 1. Test objectives and success criteria

Primary Test Objective(s) – Must be completed for a successful test	
PTO1 (Phase 1):	SWiFT inflow characterization
Success Criteria:	All SpiDARs obtain data at higher than 80% data availability rate for a period of at least one month.
Secondary Test Objective(s) – May be completed after primary test objective is complete	
STO1:	Data binning across stability, and wind direction conditions
Success Criteria:	Characterization of streamwise and lateral velocity in-homogeneity, and wind shear and veer.
Primary Test Objective(s) – Must be completed for a successful test	
PTO2 (Phase 2):	Ground-based Lidar wake detection
Success Criteria:	All SpiDARs obtain data at higher than 80% data rate for a period of at least one month when WTGa1 is operational.
Secondary Test Objective(s) – May be completed after primary test objective is complete	
STO2:	Data binning across stability, wind direction, and yaw error conditions
Success Criteria	Quantification of in- and out-of-wake velocity difference.
Primary Test Objective(s) – Must be completed for a successful test	
PTO3 (Phase 3):	Scaled-wake and regular rotor wake comparison
Success Criteria:	All SpiDARs obtain data at higher than 80% data rate for a period of at least one month when WTGa1 and WTGb1 are operational.
Secondary Test Objective(s) – May be completed after primary test objective is complete	
STO3:	Data binning across stability, wind direction, and yaw error conditions
Success Criteria:	Quantification of scaled-wake and regular wake velocity, velocity gradient, and estimated circulation difference.

3. ROLES AND RESPONSIBILITIES

Describe all the roles and responsibilities of the personnel that will be involved in all stages of the test plan

Table 2. Roles and Responsibilities

Title	Name(s)	Responsibilities
Principal Investigator, Research assistant professor	• Suhas Pol	• PI and TTU team field supervisor
Graduate research assistant (or postdoc) and undergraduate researcher	• Tassia Pereira • Ricardo Castillo • Nicholas Ward • Jennifer Puac	• Experimental setup • Data collection and analysis • Reporting
SWiFT Site Supervisor	• Dave Mitchell	• Provide physical access to SpiDARs • Communicate SWiFT site status to Project PI • Site safety
Forklift Operator / Pickup Driver	• Dave Mitchell • Miguel Hernandez	• Operate the forklift to move the SpiDAR units from a truck bed to the ground when repositioning
SWiFT Program Lead	• Tim Riley	• Coordinate, and prioritize SWiFT site activities
Sandia Technical Liaison	• Brian Naughton • Tommy Herges • Chris Kelley	• Provide SWiFT instrumentation data (QA/QC) to PI • Coordinate with NRT experiment
Forklift Operator	• Dave Mitchell • Miguel Hernandez	• Rigging and lifting of the SpiDAR units from the pickup bed to the ground.

4. UNIQUE HAZARDS

The following table provides a high-level summary of major hazards that are unique to this test. Further information on hazards and controls for this test are provided in the safety documents if necessary.

Table 3. Unique Hazards

Hazard	Description
Laser use	Class 1M laser (see manual in Ref. 4). No specific PPE required. Class 1M laser systems are not regulated by Sandia. The SpiDAR manual and this test plan will be available in a binder in the control building during the test.

5. SCHEDULE

The major phases of the experiment are provided in the table below:

Table 4. Test Schedule

Dates	Description
Once approved, 1 to 3 months.	**Phase 1:** Place the SpiDARs according to the configuration shown in figure 1. Met tower guy wire locations were considered to finalize SpiDAR locations.
Upon WTGa1 installation to WTGb1 installation (or at least 1 month)	**Phase 2:** The SpiDARs will be placed in an east-west row at 2D (54 m) north of WTGa1 turbine to characterize its wake. The configuration of the SpiDARs is shown in figure 2.
Upon installation of WTGb1 to 3 months	**Phase 3:** The SpiDARs will be placed in two east-west rows at 2D (54 m) north of WTGa1 and WTGb1 turbines respectively to characterize and compare their wakes. The configuration of the SpiDARs is shown in figure 3.

6. CONFIGURATION

This section describes the physical configuration of the experiment including the equipment, services, materials

6.1. Definition of test area and conditions

6.1.1. Test area and configuration

The test configuration for each phase is shown in the schematics below. Each phase has a unique location for each SpiDAR lidar units. It should be noted that 7 lidar units will be utilized in phase 1 and 8 lidar units will be utilized in phases 2 and 3. Wiring paths may change for each phase and should be developed in consultation with the SWiFT Site Supervisor prior to changes.

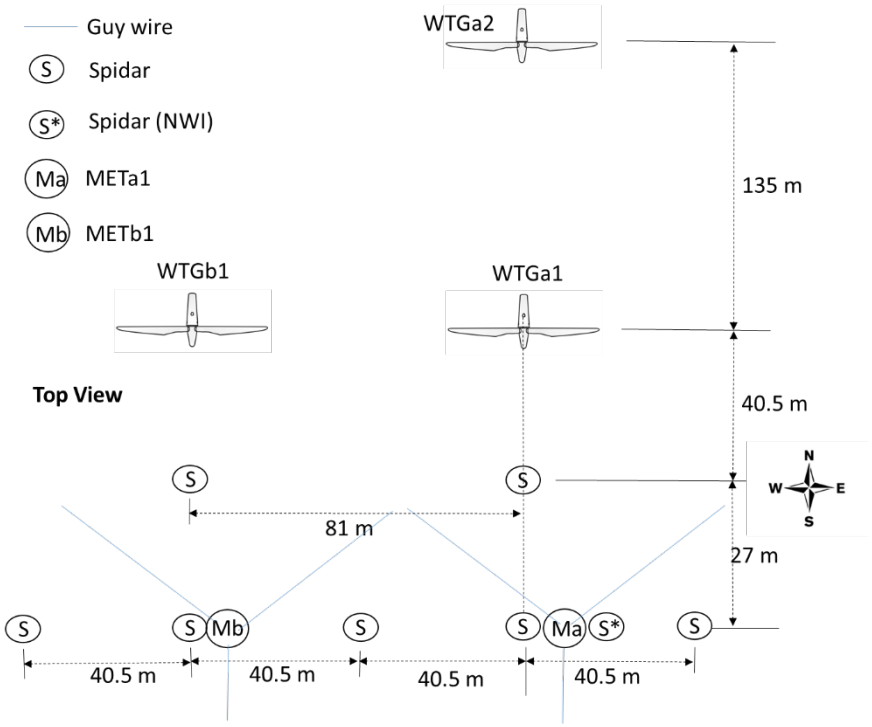

Figure 1. Phase 1 test configuration. Note: Figure not to scale.

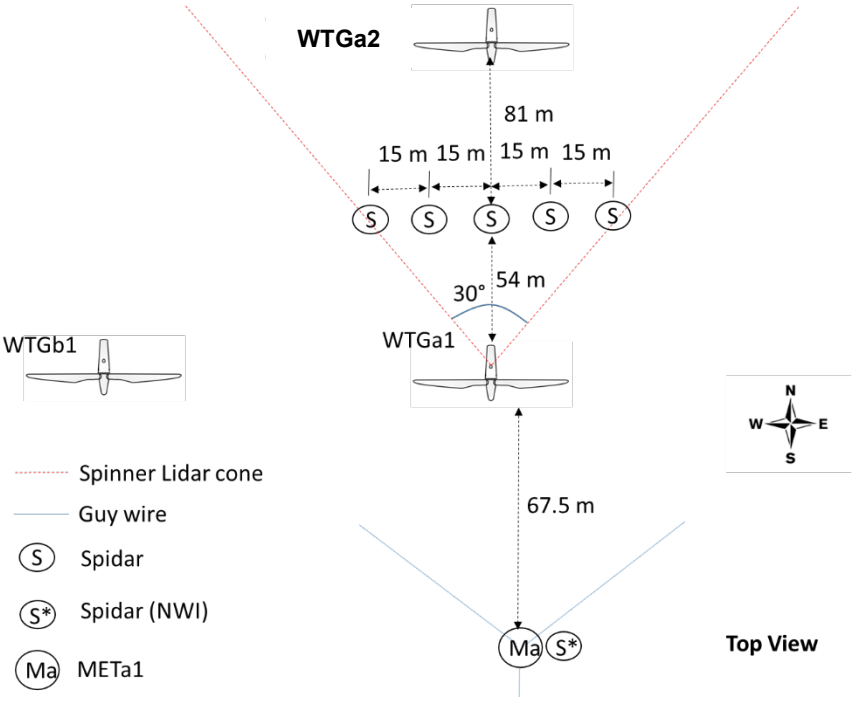

Figure 2. Phase 2 test configuration. Note: Figure not to scale.

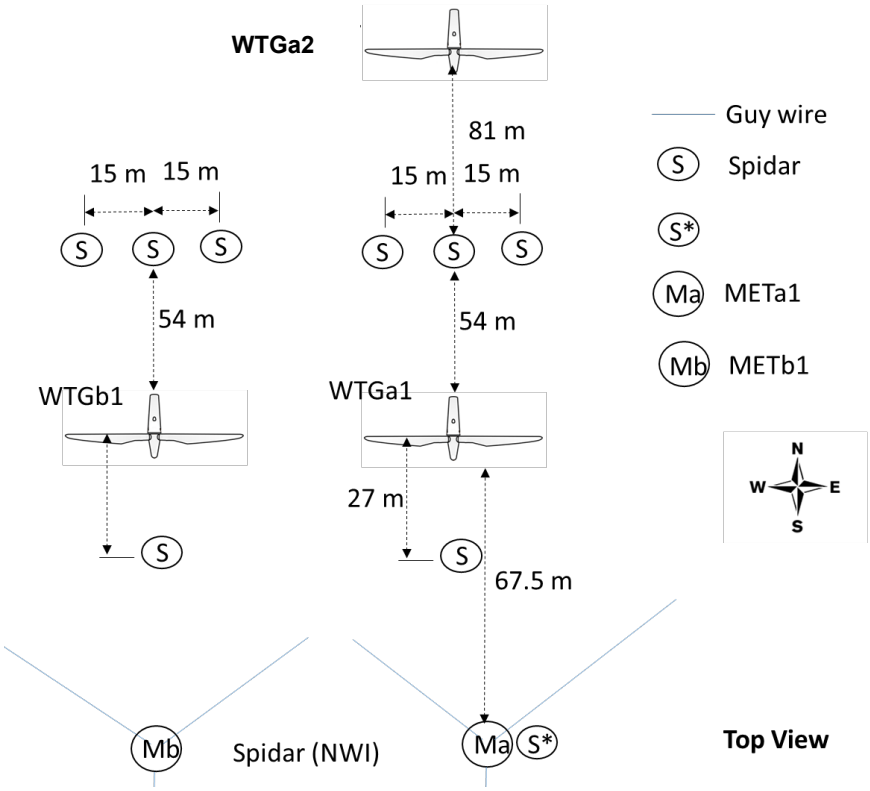

Figure 3. Phase 3 test configuration. Note: Figure not to scale.

6.1.2. Site conditions

6.2. Equipment, facilities, and materials

6.2.1. Equipment (beyond turbines and meteorological towers)

- Ground lidar (Quantity: 8). Supplied by Texas Tech University
  - Manufacturer: Pentalum / NRG Systems
  - Model: SpiDAR
  - Laser: class 1M
  - Power requirement: 35W (up to 250W when heated, activates when temperature is less than 0°C)
  - Further specifications can be found in section 1 of the SpiDAR user manual shown in Ref. 4.

6.2.2. Power

- Extension cords. Supplied by Texas Tech University
  - Outdoor compatible (water proof, rodent proof)
  - Length: 50 ft.
  - Power capacity: 8 x 250W peak, 8 x 35W normal operation
  - 15 A, 125 V, 1875W capacity
- Robust power cable guards if crossing roads. Supplied by Texas Tech University
- Surge protector for each SpiDAR. Supplied by Texas Tech University

7. PROCEDURES

7.1. Setup

Lidar placement: The ground will be mowed where the SpiDARs will be placed along withaccess paths to avoid the likelihood of snakes and other wildlife. The SpiDARs will be delivered to site by a truck. Each SpiDAR weighs approximately 75 kg. Therefore, to put the SpiDAR on the ground, based on previous experience of the TTU and Sandia teams, three people will be required:

- A person with current rigging training will attach lifting straps to the SpiDAR unit and connect them securely to a forklift
- A trained forklift operator will lift the SpiDAR off the truck bed, move it to the planned location and lower it to the ground. Straps will be removed and the forklift moved to a safe location.
- The reverse processed is used when picking up the SpiDAR units and placing them in the truck. Units in the truck shall be secured to avoid movement during transportation.

Once the SpiDAR is on the ground, three people will carry the SpiDAR to its final location by lifting it from its handles. The SpiDAR will be anchored to the ground by inserting an anchor rod through the outer hole of each foot pad (see SpiDAR manual, section 4.5).

Upon installation, the units will be aligned to the wind direction and the precise lidar locations will be measured by Sandia using a total station system.

Electrical cables: Extension cables will be placed in consultation of the SWiFT Site Supervisor for each testing phase. Extension cables will be protected by heavy duty rubber cable protectors anywhere cables must cross roads where vehicles will travel. The routing will minimize road crossing as much as possible.

Access: Daily physical access by TTU staff and students will be required to the SpiDARs until they are fully configured and working. During the data collection stage, weekly access will be required to service the SpiDARs. This will be coordinated through the SWiFT Site Supervisor.

7.2. Testing and data collection

7.2.1. Testing Phases

Phase 1: To completely realize the SWiFT site's broader purpose quantifying horizontal and vertical inflow variability is critical. During phase 1 the SpiDAR lidars will be arranged in 2 parallel east-west rows located close to the southern side of the site. The first row, consisting of 5 SpiDARs, will be located along the east-west line that encompasses the METa1 and METb1 locations, which is 2.5D (67.5 m) south of WTGa1 and WTGb1 turbines. Further the second row of 3 SpiDARs will be located parallel to the first at 1.5D (40.5 m) south of the WTGa1 and WTGb1 turbines. The SpiDAR placement details are outlined in figure 1. It is anticipated that the horizontal and vertical inflow variation, and streamwise flow evolution will be quantified in this configuration. The SpiDARs will be located in phase 1 configuration for a minimum period of 1 month. The measurements and SpiDAR status will be monitored on daily basis (remotely if SpiDAR cellular communication is established). All available data channels of METa1 and METb1 will be used for data comparison. This phase is expected augment previous SWiFT inflow understanding (Ref. 2).

Phase 2: The purpose of phase 2 is to characterize the WTGa1 wake cross-section at 2D (54 m) north (downstream assuming prevailing inflow is from south), as shown in figure 2. Additionally,

phase 2 will also test the SpiDAR's ability to measure wake turbulence. A similar configuration was considered before, with lidars at 4D downstream in the previous study (Ref. 5). It is anticipated that closer location will increase the number of occurrences the wake is captured. The SpiDARs will be located in phase 2 configuration once WTGa1 is operational. The SpiDAR performance and data will be remotely monitored or if needed manually once every week. All available data channels of METa1 and WTGa1 will be utilized for the study.

Phase 3: The purpose of phase 3 is to characterize and compare Vestas V27 OEM rotor and Sandia National Rotor Testbed rotor wakes (regular vs. scaled-wake rotors) comparison placed at WTGa1 and WTGb1 locations respectively. The SpiDARs configuration for this phase is shown in figure 3. The operation and analysis will be similar to phase 2, however it will consider two turbines that would be operational. All available data channels of METa1 and WTGa1 and WTGb1 will be utilized for the study.

7.2.2. Data Acquisition Requirements

Each phase requires a different set of data channels to be acquired from the wind turbines, met towers and lidars as described in the following list:

- METa1 and METb1 sonic anemometers at all heights: this data is required in phase 1, 2 and 3. (provided by Sandia)
- Pentalum SpiDAR: this data is required in phase 1, 2, and 3. (provided by Texas Tech University)
- WTGa1 data is required in phases 2 and 3. (provided by Sandia)
- WTGb1 data is required in phase 3 (provided by Sandia)

7.3. Teardown

Upon the completion of testing, all equipment and materials will be removed from the site and returned to their respective owners. The site will be returned to the pre-test state as much as possible.

8. REPORTING

The reporting requirements are as follows:

- Recording and reporting any safety incidents by SWiFT site supervisor
- Weekly test log summary noting any major configuration changes at the site, weather events, and other activities that may impact data analysis. This report will be completed by the PI.
- A daily test log will be completed by the turbine operator anytime the turbines are operational
- Weekly data packages will be delivered to the PI from Sandia for the data channels identified.
- A final test report at the conclusion of the experiment. Completed by the PI with input and review by Sandia

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[4] Pentalum, SpiDARTM User's Manual, Rev 03, Document Number 60-64000-A, April 2015.

[5] Carsten Westergaard, Suhas Pol, Tassia Pereira, Ricardo Castillo, Pentalum SpiDAR Deployment at SWiFT FY17, SAND2016-12854, Sandia National Laboratories, Albuquerque, NM, January 2016.

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