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Sandia Wake Imaging System Field Test Report: 2015 Deployment at the Scaled Wind Farm Technology (SWiFT) Facility

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Prepared by
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ABSTRACT

This report presents the objectives, configuration, procedures, reporting, roles, and responsibilities and subsequent results for the field demonstration of the Sandia Wake Imaging System (SWIS) at the Sandia Scaled Wind Farm Technology (SWiFT) facility near Lubbock, Texas in June and July 2015.

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NOMENCLATURE

SNL	Sandia National Laboratories
CZED	Critical Zone Exposure Distance
FAA	Federal Aviation Administration
TWD	Technical Work Document
LCA	Laser Control Area
SWiFT	Scaled Wind Farm Technology
SWIS	Sandia Wake Imaging System
NOHD	Nominal Ocular Hazard Distance
NHZ	Nominal Hazard Zone
TWD	Technical Work Document

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1. INTRODUCTION

The Sandia Wake Imaging System (SWIS) has been under development at Sandia National Laboratories since May 2012. The hardware has been demonstrated at both a lab-scale in 2013 and a sub-scale outdoor test at Sandia in 2014 to reduce technical risk and refine the system design. The next stage in proving the system capabilities was to deploy the system at the Scaled Wind Farm Technology (SWiFT) facility where it is intended to measure the inflow and near wake velocity profiles of the research turbines. The SWIS uses a method called Doppler Global Velocimetry (DGV) where laser light is scattered off aerosol particles that trace the flow velocity, shifting the laser-light to higher or lower frequencies. This frequency shift is recorded by specialized cameras and the data are processed to produce instantaneous images of the flow velocity. This field demonstration at SWiFT is the first demonstration of this flow diagnostic method outdoors at large scale (3.5 m by 3.5 m viewing area). The results of this test will be used to refine the system in preparation for future use at SWiFT as a unique flow diagnostic tool.

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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 were required to be completed while secondary objectives were only to be pursued 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: To demonstrate safe concurrent operation of the laser and aerosol systems outdoors at the SWiFT facility.
Success Criteria: A documented velocity image of a flowfield at the SWiFT facility and field test report.
Result: Hours of concurrent system operation have been recorded without incident.
Secondary Test Objective(s) – May be completed after primary test objective is complete
STO1: Verify velocity flow image
Success Criteria: Time-averaged sonic anemometer and SWIS velocity data of a flowfield
Result: Sonic anemometer data was acquired simultaneous to the SWIS data for the entire test period. The sonic was spatially near the laser sheet, and therefor in a similar flow field. Time averaged data was overlaid for analysis purposes and is presented in this report.
STO2: Verify design of aerosol system
Success Criteria: Collect aerosol concentration measurements at target area to verify design equations at estimated target concentrations.
Result: Particle concentration measurements were collected near the laser sheet for the test period, both native background aerosols and aerosols generated by the test. This data is sufficient to confirm aerosol system performance and needed improvements.
STO3: Verify system sensitivity under two different pixel binning configurations of the receiver cameras.
Success Criteria: Velocity images acquired at two different pixel binning configurations.
Result: 4 and 8 pixel binning data were collected to confirm noise reduction potential.

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3. ROLES AND RESPONSIBILITIES

A minimum of 6 personnel were required to conduct testing activities according to the responsibilities described in Table 2:

- 1 SWiFT Site Supervisor
- 1 Test Controller
- 1 Laser and Data Acquisition Operator
- 1 Aerosol Operator (and boom lift operator)
- 2 Visual Observers

Table 2. Roles and Responsibilities

Title	Responsibilities
SWiFT Site Supervisor	• Approves daily test activities • Secures physical access to site during testing • Coordinates deliveries of equipment and supplies • Coordinates with Reese Technology Center • Monitors site conditions, including weather and wind speed.
Test Controller	• Primary testing point of contact for external and internal communication needs • Manages start and stop operations • Reviews pre-test checklist • Conducts team briefings • Must be laser operator
Laser Operators	• Controls the operation of the laser • Performs laser and optical system alignment
Deputy Laser Safety Officer	• Conducts laser hazard calculations to determine maximum permissible exposure and establish nominal hazard zones
Aerosol Operators	• Controls the operation of the aerosol generation system
Visual Observers	• Visual observation of the airspace above the test area to watch for wildlife, aircraft, and other objects in the airspace that may cross the laser sheet • Control and confirmation of laser shutoff in case of spotted object • Two visual observers will be active at all times the laser is outside of the transportainer
Data Acquisition Operator	• Oversees data collection and evaluation towards test objectives including SWiFT data • Ensure completion of other reporting requirements (Section 9)
Equipment Configuration Lead	• Ensures delivery and placement of transportainer • Ensures delivery and placement of receiver (Ares) van • Ensures delivery and placement of RV
Boom Lift Operator	• Operates the aerial boom lift

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4. UNIQUE HAZARDS

The following table (Table 3) provides a high-level summary of major hazards that were unique to this test. Further information on hazards and controls for this test are provided in Refs. 2 and 3 with the general SWiFT site hazards listed in Ref. 1.

Table 3. Unique Hazards

Hazard	Description
Laser Radiation	The laser system propagates a Class 4 frequency doubled Q-switched Nd:YAG laser with 532 nm wavelength. The laser system presents significant ocular hazards to laser operators and other personnel present in the laser control area (LCA). Class 4 laser systems present significant hazards to eyes and skin from the direct beam exposure, specular reflections, and sometimes from diffuse reflections. Class 4 lasers also represent potential fire hazards. Collateral hazards associated with laser use may include high voltage, extreme temperatures, and radiation hazards.
Pressurized Fluids	A potassium chloride (KCl) aqueous solution will be supplied through a high flow liquid pressure pump to aerosolizing nozzles at a pressure not to exceed 20 psi. The air supply to the nozzle interface will be supplied via a high volume air compressor. The air pressure on the system will not exceed 85 psi.
Arial Lifting	The aerosol emission system and the laser alignment activities will require the operation of a telescoping boom lift to raise equipment to heights up to approximately 20 meters. This presents a hazard of falling items from height. There is also a wind speed limit to operation that must be observed.

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5. SCHEDULE

The test campaign occurred from June 29th to July 17th 2015 during weekdays and during the daytime. Active testing time was dictated by weather conditions and system performance. Any restricted dates or times as determined by impacted stakeholders were noted by the Test Controller and incorporated into the daily briefings.

Table 4. Test Schedule

Dates (2015)	Description
June 29nd – July 2nd	Aerosol system setup and testing, delivery of boom truck, RV mobile office, generator for aerosol, water tank, water, and air compressor and air tanks.
July 6th – July 10th	Laser system setup and alignment. Delivery of Transportainer, generator, Ares van.
July 13th – July 17th	Primary testing window. Completed all testing by July 16th.
July 20th – July 24th	Alternative testing window – not used.

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6. CONFIGURATION

6.1. Definition of Test Area and Conditions

Test Area and Configuration

The Sandia Wake Imaging System (SWIS) components were situated at the SWiFT site according to the schematic in Figure 1 and the photo in Figure 2. Generally, there was an aerosol generation system connected to a boom lift positioned between the two existing met towers and raised to a height of approximately 15 meters. The transportainer, containing the laser, was located between SNL 1 and Vestas 1 turbines on a trailer. Farther downwind (27 m to the North) was the receiver van containing the cameras, iodine cell, and optics. These are the three primary pieces of equipment that comprise the Sandia Wake Imaging System. Additional equipment such as a generator, a water tank, and an air compressor supported the aerosol system, while a generator positioned near the transportainer, powered both the transportainer (laser) and receiver van. A mobile met tower, located near the imaging area of the cameras, recorded secondary sonic anemometer data, while an RV camper positioned by the receiver van served as an office, light workspace, and data processing area.

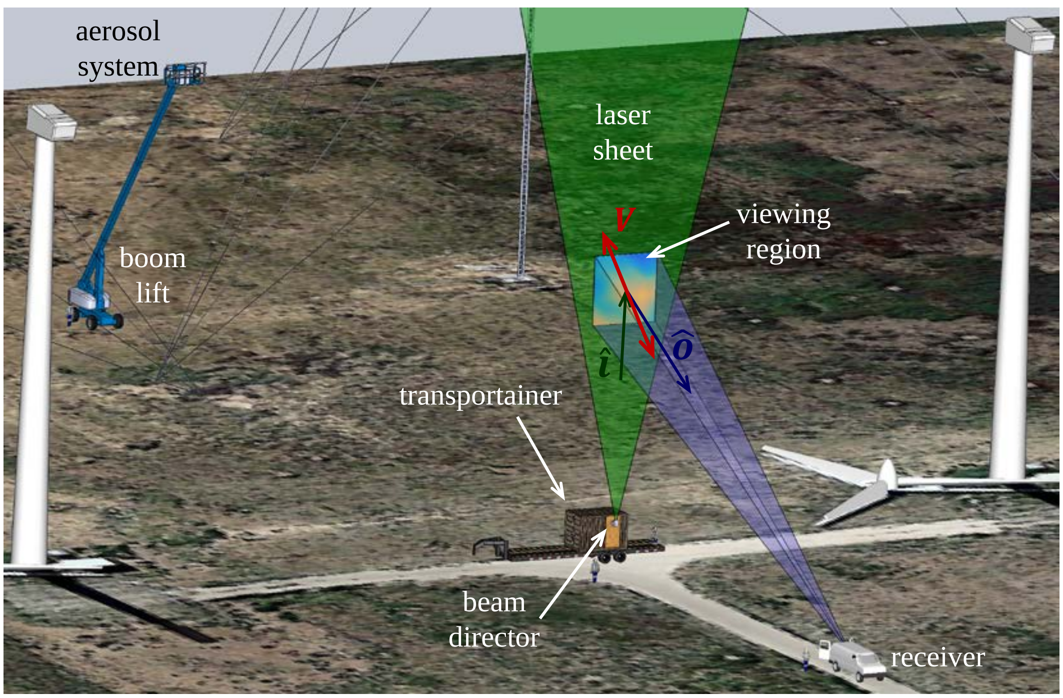

Figure 1. As planned SWIS deployment configuration at the SWiFT facility. The aerosol system, transportainer/laser system and receiver systems are aligned south to north between the Sandia and Vestas turbines.

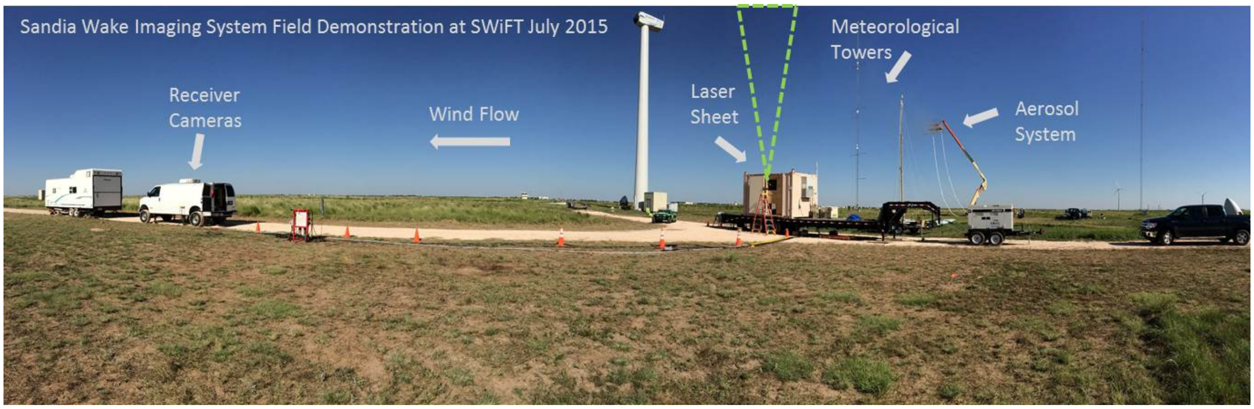

Figure 2. SWIS system components as deployed at the SWiFT facility in July 2015.

<u>Laser Control Area</u>

The laser was emitted from the transportainer in the form of a sheet with a 14 degree divergence (half-angle). Laser hazard calculations performed for safety and for the application process with the Federal Aviation Agency (FAA) identify a hazard cone that originates near the top of the transportainer (approximately 3 m from the ground) and extends approximately 1000 m above ground with a radius of 530 m. The hazard area is projected onto the test site as shown in Figures 3 and 4. A test control area was established around the test site by the SWiFT Site Supervisor to prevent unauthorized personnel from entering the area while testing is underway. On a few mornings there was a conflict with other users of the Reese Technology Center working within the exclusion zone, but it only delayed operations by 30 minutes to an hour.

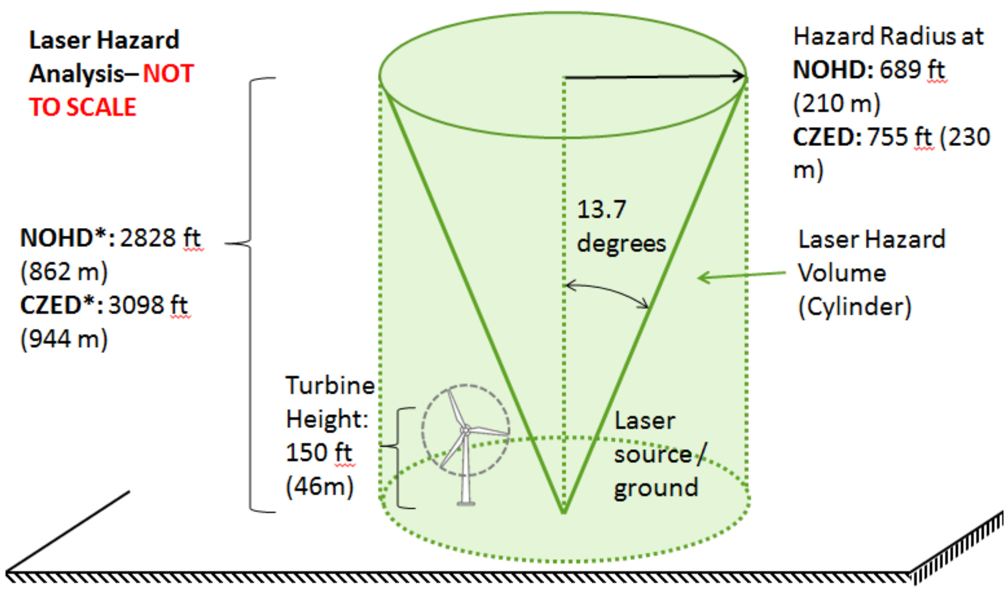

Figure 3. Size and location of the FAA Critical Zone Exposure Distance (CZED) as calculated for the Sandia Wake Imaging System laser sheet. The radius is 230 m at a height of 944 m above ground. This region is the hazard volume to observe for potential object inference.

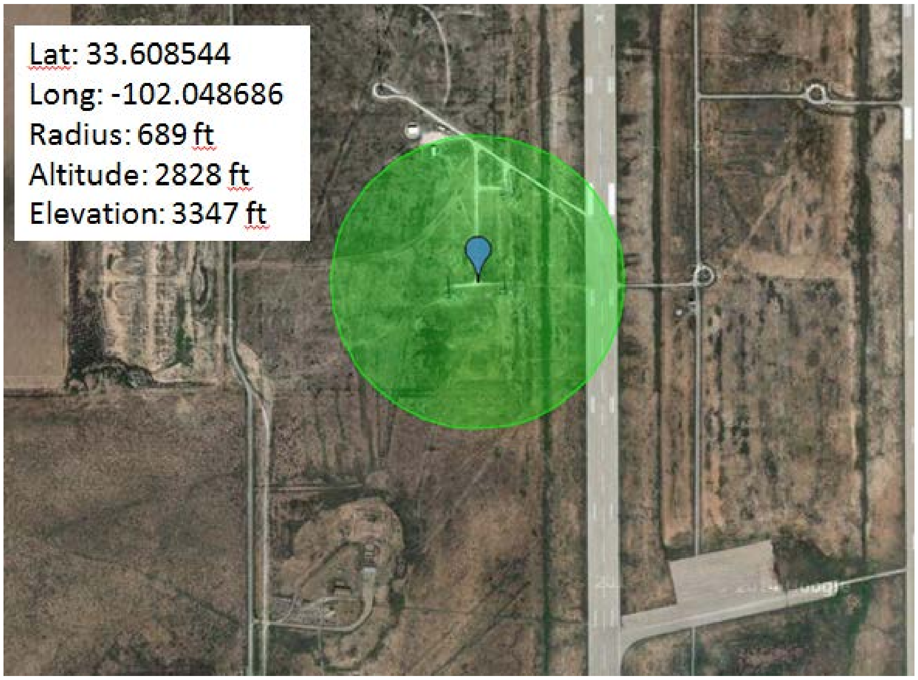

Figure 4. Size and location of the FAA Critical Zone Exposure Distance (CZED) as viewed from above on the SWiFT site.

Site Conditions

All activities took place only during daylight hours and under safe environmental conditions per current SWiFT facility guidelines (Ref. 1) and within equipment operational windows. Generally this includes wind speeds below 20 m/s (45 mph), no lightning, or extreme weather. Testing also ceased during precipitation events which only occurred during system setup and configuration.

The system was configured to work best in wind coming directly out of the south, as is most common at the site. The primary testing week had very consistent winds from the south, with slight easterly and westerly components shifting throughout the day.

6.2. Equipment, Facilities, and Materials

The following is a list of major equipment, facilities, and materials required for the test activities along with the supplier as indicated in the parentheses.

Equipment

- Transportainer on trailer contained the laser and emission optics (SWIS)

  Transportainer was locked during non-test hours and only accessible by a qualified laser operator during testing (see roles and responsibilities). The internal area of the transportainer was considered within the laser control area.

- 65-foot telescoping boom truck (rental)

  The boom lift was used for laser alignment and aerosol emission activities. During both uses personnel were not in the bucket and the boom was operated from the ground by qualified personnel.

- Aerosol emitter frame (SWIS)

  The aerosol emitter consisted of a custom frame, tubing, and emitter nozzles that was secured to the boom lift and raised up to 15 meters above ground during operation.
- High volume water pump (SWIS)

  The water pump supplied the water/potassium chloride solution to the nozzle system.
- Water tank (SWIS)

  A trailer-mounted 1000 gal water tank was located next to the boom truck to supply water to the aerosol emitters.
- Diesel air compressor (rental)

  Compressed air was mixed with the aqueous salt solution at the emitter nozzles to form aerosols.
- Diesel-powered generator (rental)

  A smaller generator supplied aerosol system power needs.
- Diesel-powered generator (rental)

  A larger generator supplied to transportainer, camper, and Ares van
- Receiver Van (SWIS)

  The van is customized for remote optics testing.
- RV mobile office (SWIS)

  The RV provided pace for light work, breaks, data analysis, and test observation.
- 10-meter mobile met tower trailer (Texas Tech University equipment)

  A small tower on a trailer was used to mount an aerosol particle sizer and a sonic anemometer (both supplied by the SWIS)
- 2-way communication Radios (4 provided by SWIS, 6 provided by SWiFT)

<u>Materials</u>

- Potassium chloride (SWIS)

  The aerosol system used potassium chloride (KCl) dissolved in water as a solution emitted from nozzles to create an aerosol. The KCl was stored in the RV or control building located at SWiFT with proper signage.
- Diesel (SWIS)

  Fuel that powered the generators. Diesel was supplied about once per day, and on the weekends as well.
- Water (SWIS)

  The aerosol system required water to create the aerosol solution. The water was provided by a tank located nearby the system. 600 gallons of water were acquired from a hydrant at the Reese Technology center as needed. (SWIS)

Power

- Diesel-powered generators supplied power to the aerosol system compressor, transportainer laser, hardware systems, and cooling systems, in addition to the receiver van cooling and hardware systems. The receiver van and transportainer required 24-hour power for climate control and system stability. (rental)
- Diesel for the generators was stored in an approved tank located in a government truck bed. (SWIS)
- Power cables ran along the surface of the ground between the generator and the transportainer, van, and camper. (SWIS)

Data

- Ethernet cables were connected between the transportainer and the Ares van and ran along the ground. (SWIS)
- SNL Met tower 1

  Data was acquired for current wind speed and direction as well as archived for later analysis. (SWiFT)

Structures

- The control building was used as an office by the field test staff as needed. (SWiFT)

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7. PROCEDURES

This section will present the major test procedures that were used to achieve the test objectives. Details regarding specific steps related to safety are referred to the SWIS Technical Work Document in Ref. 2. Daily briefings were conducted by the Test Controller prior to the commencement of test activities using pre-test checklists.

7.1. Pre-test Approvals

Prior to any testing activities, a letter of non-objection for the test period was obtained from the Federal Aviation Administration Air Traffic Organization Central Service Center located in Fort Worth, Texas.

The Air Force Space Command Laser Clearinghouse was consulted prior to laser activity. System details were reviewed by the Clearinghouse and a full waiver was issued to use the system anytime due to the laser system propagation not impacting satellite systems.

A formal Test Plan was delivered to the SWiFT Facility Lead, SWiFT Site Supervisor, Wind Energy Technologies Department Manager, Texas Tech University Liaison, and Reese Technology Center Liaison for approval to ensure there were no conflicts with other planned activities.

7.2. Setup

Equipment listed in Section 7.2 was delivered to the site by Sandia personnel, Texas Tech University staff, and rental companies. The equipment remained on site until testing was completed. Equipment was setup in the configuration displayed in Figure 1. All personnel visits and equipment deliveries were coordinated with the SWiFT Site Supervisor.

7.3. Aerosol System Testing

Prior to the deployment of the full SWIS, the aerosol system was set up and tested to confirm operational parameters and gather basic aerosol dispersion and concentration data in the SWiFT inflow environment. This activity involved the aerosol generator equipment and a boom lift but no laser, and therefore only required an aerosol operator, boom lift operator, and a data acquisition operator. Further detail can be found in Ref. 3.

7.4. Laser Alignment

The Test Controller called the local Lubbock Preston Smith International Terminal Radar Approach Control (LBB TRACON) for daily notification 30 minutes prior to any outdoor laser operation. A list of cellular numbers were given to LBB TRACON in case of emergency including the Test Controller's cellular number and the SWiFT Site Supervisor's cellular number. LBB TRACON was also notified upon completion of daily laser activity.

After delivery and setup of the laser system, the laser system required alignment of the laser beam and sheet prior to any testing activities. The purpose of alignment was to ensure the orientation and power of the laser sheet was within the allowable limits established by the FAA and Air Force Space Command Laser Clearinghouse. Laser alignment was conducted by the Test Controller with the support of Qualified Laser Operators, Visual Observers and a boom lift operator.

The equipment configuration for laser alignment included a target attached to the bottom of a boom lift located above the transportainer as shown in Figure 5. The target was made of wood to produce a diffuse laser reflection (reflected in broad angles by the surface or medium).

(a) **(b)**

Figure 5. Diagram of outdoor vertical alignment procedure. (a) a laser plumb bob is used to orient the center target above the center of the laser beam. (b) the low power laser sheet reflects off the targets to confirm orientation prior to full power operation.

The Visual Observers were always present during outdoor laser alignment to ensure that aircraft, wildlife, and debris did not enter the laser hazard area as established in discussions with the FAA. The hazard area was described to the Visual Observers based upon the FAA application.

Sandia Wake Imaging System Activity at the Scaled Wind Farm Technology Facility TWD, describes the laser alignment procedure in greater detail (Ref. 2).

7.5. Testing and Data Collection

The Test Controller called the local Lubbock Preston Smith International Terminal Radar Approach Control (LBB TRACON) for daily notification 30 minutes prior to any outdoor laser operation (806-766-6503 or 806-766-6505). The Test Controller’s cellular number was given to

LBB TRACON in case of emergency. LBB TRACON was also notified upon completion of daily laser activity.

Full system testing required a minimum of 6 test personnel with roles as described in Section 4 of this report. Testing included the simultaneous operation of the aerosol system, the laser system, and the receiver system. The aerosol system required an operator while the laser and receiver systems were operated simultaneously by the Laser Operator. In addition, two Visual Observers were required for laser operation, a Test Controller to oversee the testing operation, and the SWiFT Site Supervisor to control physical access to the site. The personnel were generally situated as shown in Figure 6.

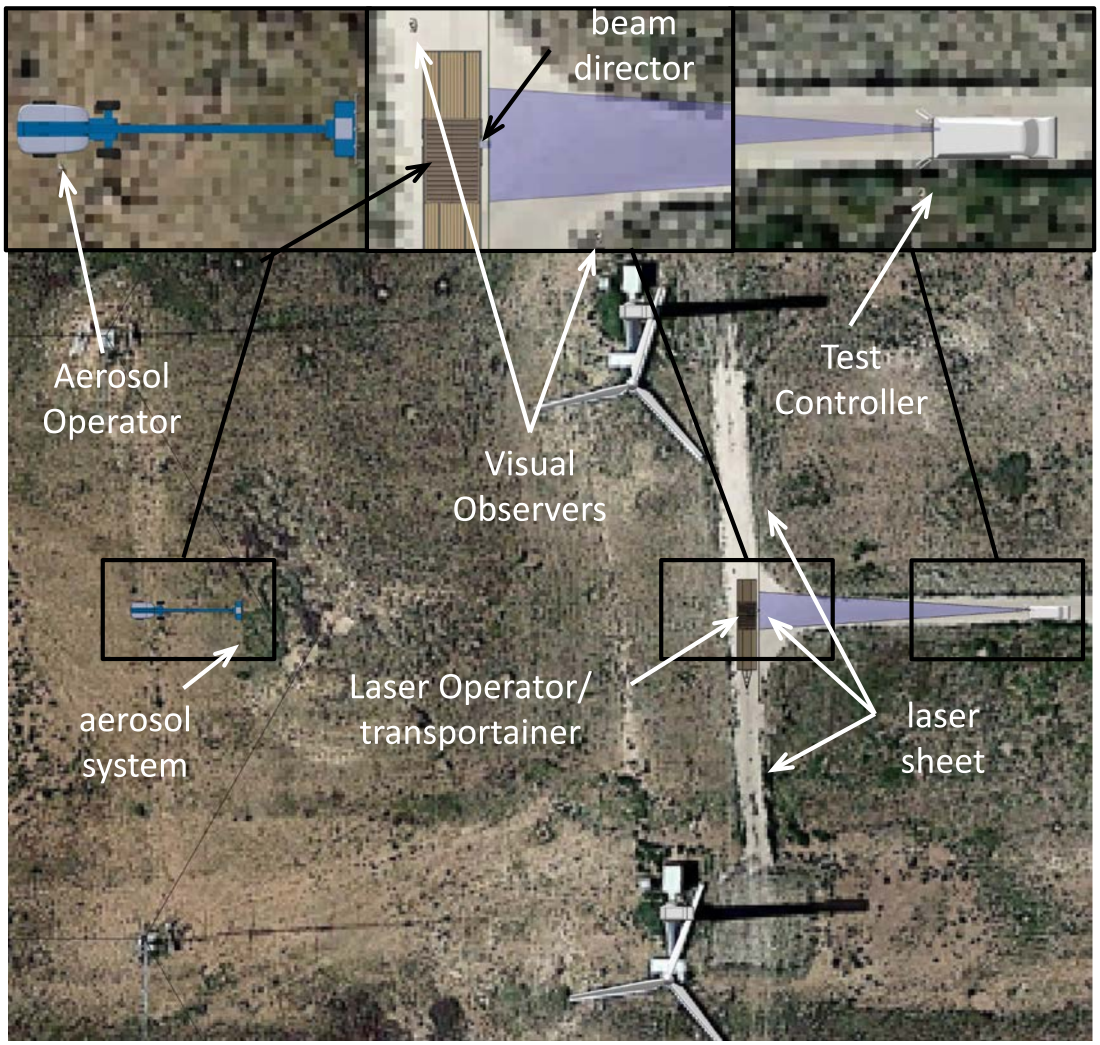

Figure 6: General layout of qualified personnel at SWiFT during general SWIS operation.

SWIS data collection involved the following data sets:

Darkfield Image
Set of images acquired while the laser and aerosol system are off and the camera gate was closed in order to obtain the noise floor of the cameras.

Background Image
Set of images acquired while the laser and aerosol system were off and laser gate was set for normal data collection in order to account for the background sun light. The importance of this data set varied with sun position.

Frequency Background
Set of images acquired with laser and aerosol both in operation. The laser frequency was tuned inside the absorption line. This data set is most effective when acquired during calm, low speed winds. The purpose of the data set was to correct the spatial frequency variation of the laser sheet in the velocity images. It was challenging to find sufficiently low wind speed for this data set. The result is that there is increased uncertainty on the absolute wind speed data collected. Relative changes in velocity can still be evaluated.

Intensity Flatfield
Set of images acquired with laser and aerosol both in operation. The laser frequency was tuned outside the absorption line. This data set was most effective when acquired to similar conditions as the Doppler shift images. The purpose of the data set was to normalize the Doppler shift frequencies to account optical path variations between the signal and reference cameras.

Doppler Shift Image
Set of images acquired with laser and aerosol both in operation. The laser frequency was tuned inside the absorption line. This data set was most effective when acquired during high-speed winds with high turbulence.

SWiFT Met Tower Data
Time stamped met tower data was archived and used for a velocity comparison analysis with the SWIS image data.

Each dataset was collected following the operating procedures detailed in *Sandia Wake Imaging System Activity at the Scaled Wind Farm Technology Facility* (Ref. 2) and *Aerosol Operations at SWiFT* (Ref. 3).

7.6. Teardown

Upon the completion of testing, all equipment and materials were removed from the site and returned to their respective owners. The site was returned to the pre-test state.

8. PRELIMINARY RESULTS

8.1. Aerosol System

The aerosol particles were introduced to increase the signal levels of scattered laser light sensed by the receiver cameras. The aerosol generation system consisted of 20 spray nozzles (4 rows of 5 nozzles) arranged on a 10 ft × 10 ft aluminum frame and connected to the front of the aerial boom lift platform (Figure 7). The spray nozzles produced a mist of potassium chloride (KCl)/water solution. The distance between the aerosol generation system and the measurement region was primarily to allow the dispersion of the aerosol particles to cover the field of view, while also providing sufficient time for the liquid to completely evaporate, leaving small KCl particles entrained in the atmospheric boundary layer. The direction and height of the aerosol system was dependent on wind speed and direction throughout the day.

Figure 7: Aerosol generation system during the SWIS demonstration field test.

The air pressure for the nozzle system was supplied by a diesel air compressor at 65 psi with a liquid flow rate of 3.83 liters per minute (LPM) per nozzle. Optimal salt-water concentration was determined to be 10g/L (KCl/tap water). Electrical power for this system was supplied with a portable diesel electrical generator.

SWIS data was acquired on July 15th and 16th, 2015 using the generated KCl particulates and background (naturally occurring, "native aerosol") particulates, respectively. An aerosol particulate measurements system, or aerodynamic particle sizer (APS), was used to collect particle concentrations during the field test. The APS was placed on top of the transportainer during the measurement period at an approximate height of 5.5 m from the ground. The KCl mist had drying issues due to a higher humidity than anticipated during testing. The drying issue required that the aerosol system be positioned further upstream (approximately 90 m from the measurement area) in order to have dry KCl aerosol particulates downstream at the transportainer. A combination of the increased distance between the aerosol system and the measurement region, the area that the aerosol plume covered, and the meandering of the plume within the atmospheric boundary layer (observed in Figure 7) resulted in a hit (aerosol particulates observed by the receiver) percentage of 24% in the acquired images. The aerosol plume was visually observed to fluctuate the full distance between the turbine towers in a short amount of time (within minutes) with a southerly wind highlighting the challenge of positioning a plume far downwind.

Figures 8 and 9 show the total aerosol particulate concentration sampled by the APS on July 15th (KCl aerosol generation system) and July 16th (background aerosol particulates), respectively.

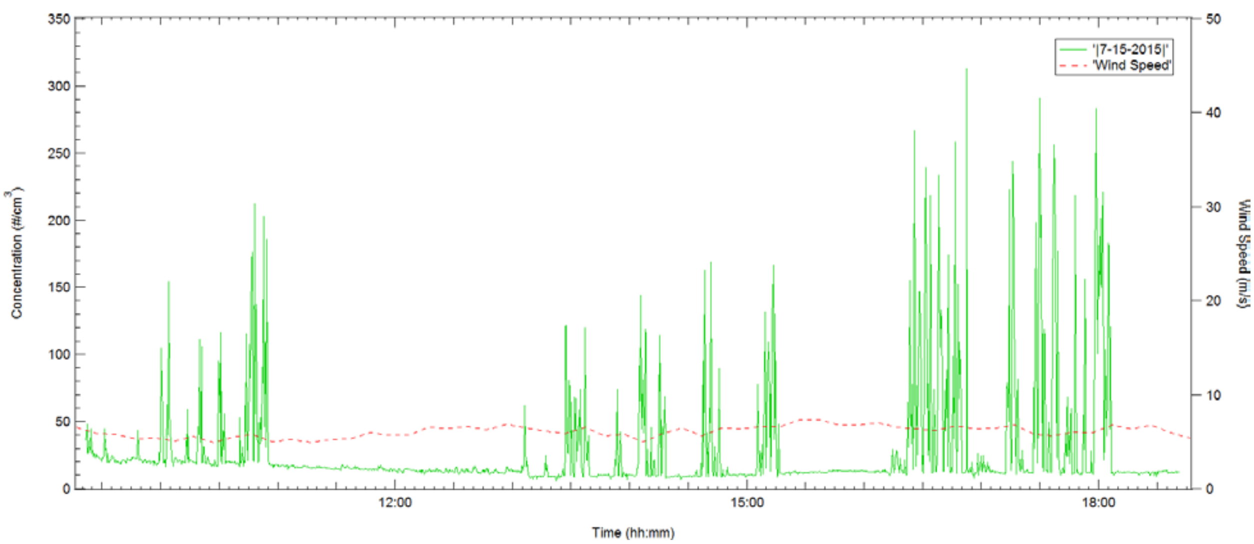

Figure 8: KCl aerosol plume concentration/wind speed vs time on July 15th, 2015.

The average background (native aerosol) concentration for July 15th was calculated at 13.7 #/cm^3. Plume concentrations were dependent on a few factors: wind speed, sampler placement, and solution concentration. It is important to note that the first two plume groups, seen in Figure 8, were disseminated with an approximate salt-water concentration of 11.32 g/L and the last plume group was disseminated with an approximate salt-water concentration of 13.66 g/L using different potassium chloride powders. This difference in solution concentration may account for the slightly higher concentrations in the last plume set. The average wind speed for July 16th was 4.4 m/s at a height of 10 m, while the average background concentration of the native aerosol was 13.16 #/cm^3.

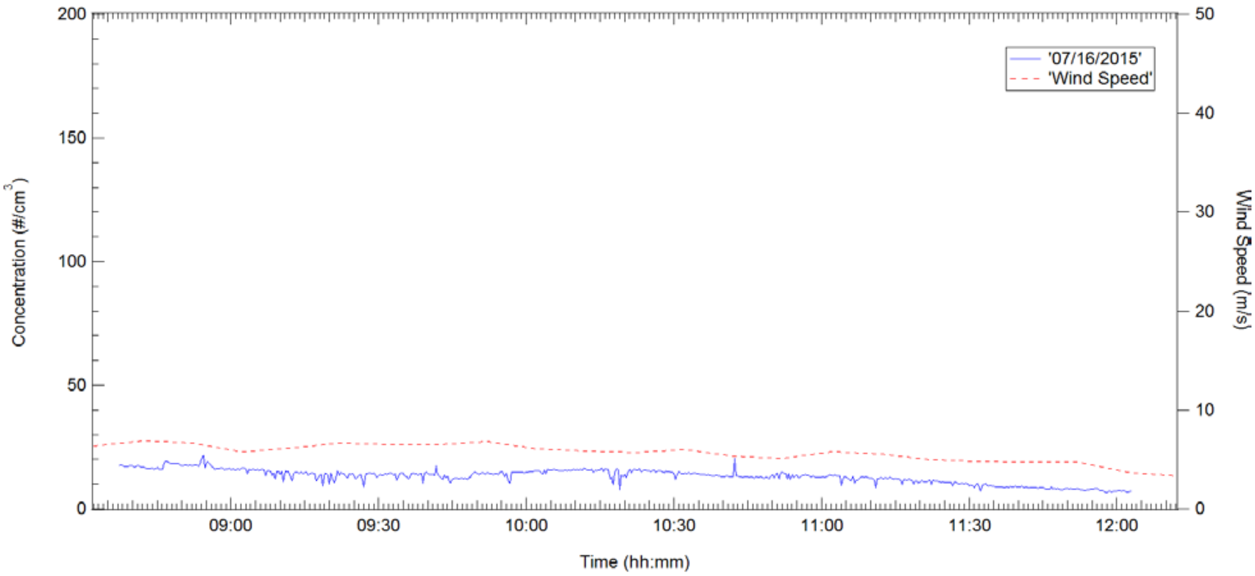

Figure 9: Background aerosol concentration/wind speed vs time on July16th, 2015.

Isokinetic sampling of the aerosol plume would have been preferred for the APS measurements at a position closer to the viewing region due to the variations in the wind speed. Additionally, the concentration measurements of the KCl plume were likely biased to lower levels due to the low hit percentage of the plume at the APS, the long 20 s sample time, and the lower background aerosol concentrations. Figure 10 illustrates a corrected KCl aerosol plume concentration using the APS data scaled by a Gaussian plume model prediction with particle size, density, and evaporation rates as the limited input parameters. Thus, a KCl particle concentration of 2000 #/cm^3 was likely achieved during some of the SWIS measurements (Ref 5).

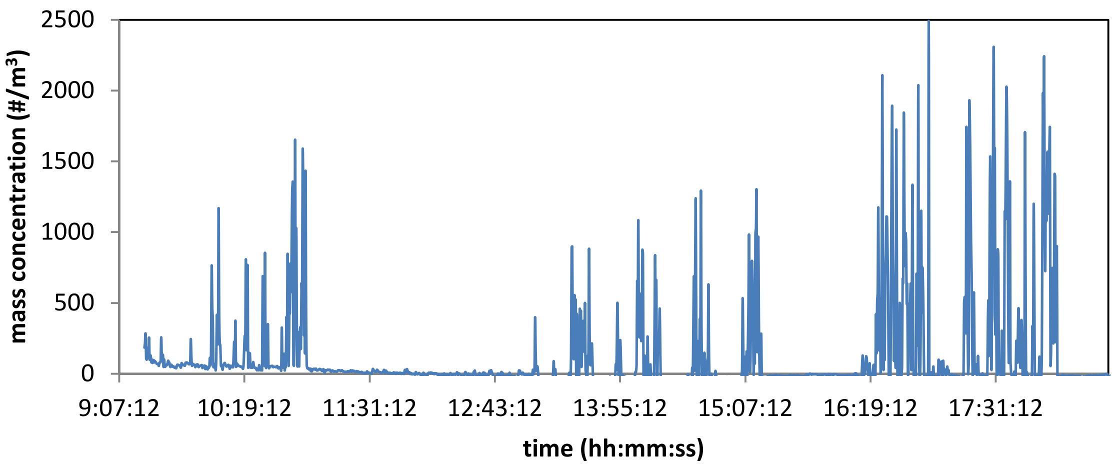

Figure 10: Corrected plume concentration data vs time on July 15th, 2015.

8.2. Velocity Data

Figure 11 shows velocity images acquired using both KCl aerosol generation (Figure 11a) and background aerosols (Figure 11b). With the configuration of the field test, the elevation angle of the receiver is about 17 degrees, and the component of the measured velocity is 58.8% of the streamwise component (southerly), 80.2% of the vertical component, and 3.2% of the component parallel to the laser sheet (easterly). The reduced amount of scatted light acquired only using background aerosols increases the observed velocity noise (Figure 11b). The average velocity images for each case, presented in Figure 12, were used to remove the observed spatial frequency variation in the laser sheet as well as the fringe pattern created from the windows of the iodine cell. The averaged velocity image had to be used because a zero-velocity image could not be acquired due to the wind conditions, thus, the images (Figure 11) and velocity traces (Figure 13) show the velocity change (Δv) relative to the average. A new laser designed specifically for the SWIS and improved iodine cell windows would allow the acquisition of the absolute velocity images without the need of a zero-velocity wind condition.

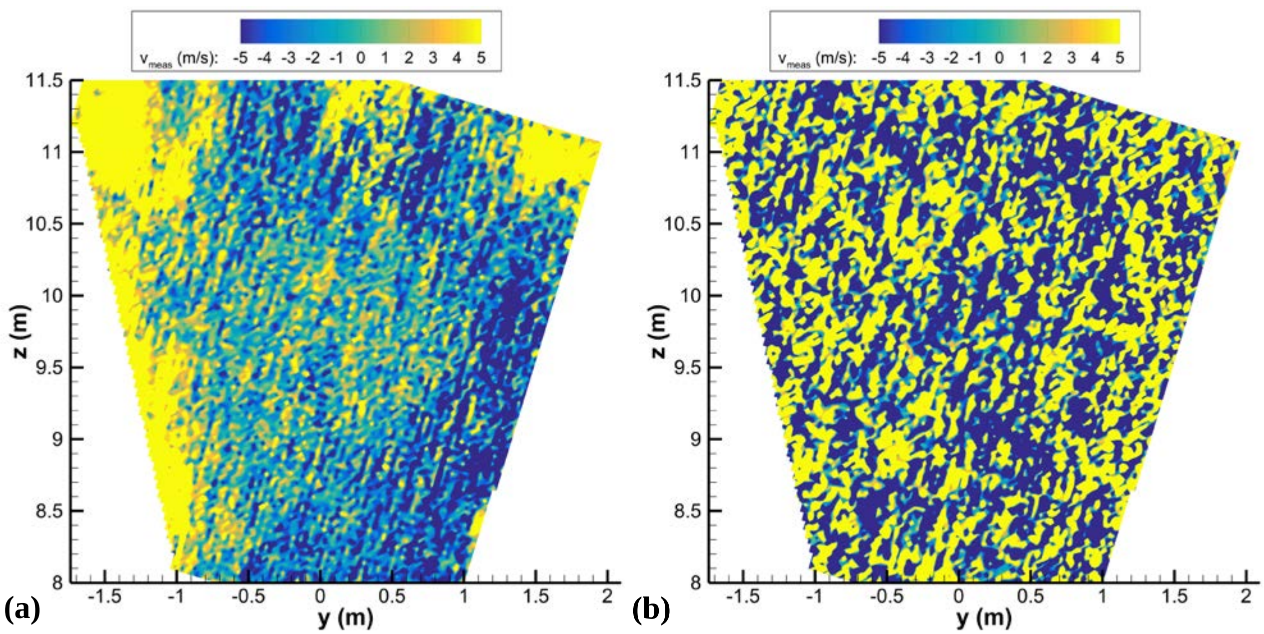

Figure 11: Velocity images acquired by the SWIS: (a) with KCl aerosol generation and (b) background aerosol particulates.

A region of the SWIS velocity data matching the spatial resolution of the mobile met tower sonic anemometer was sampled to produce velocity traces for measurement comparison. These trace comparisons are displayed in Figure 13. The three-component sonic anemometer data has been transformed to match the measured velocity component of the SWIS acquired at the same sample rate (15 Hz). Both velocity traces are processed to display the change in velocity, with the average velocity subtracted. In Figure 11a the SWIS images without the KCl plume have been removed. During KCl operation the sonic anemometer and the SWIS velocity trace standard deviation were $v_{sonic,std}$ = 0.75 m/s and $v_{SWIS,std}$ = 1.75 m/s, respectively. With only background particulates the standard deviation in the SWIS velocity trace increases to $v_{SWIS,std}$ = 4.53 m/s and the sonic anemometer stayed relatively constant at $v_{sonic,std}$ = 0.66 m/s.

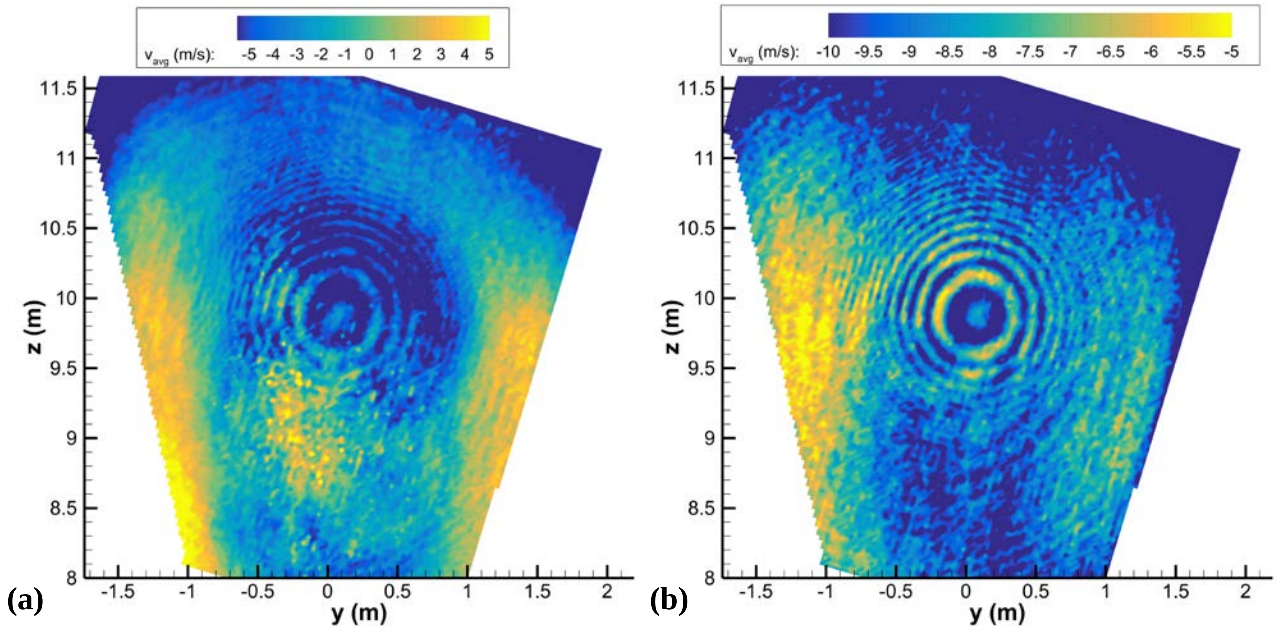

Figure 12: Average velocity images acquired by the SWIS: (a) with KCl aerosol generation and (b) background aerosol particulates.

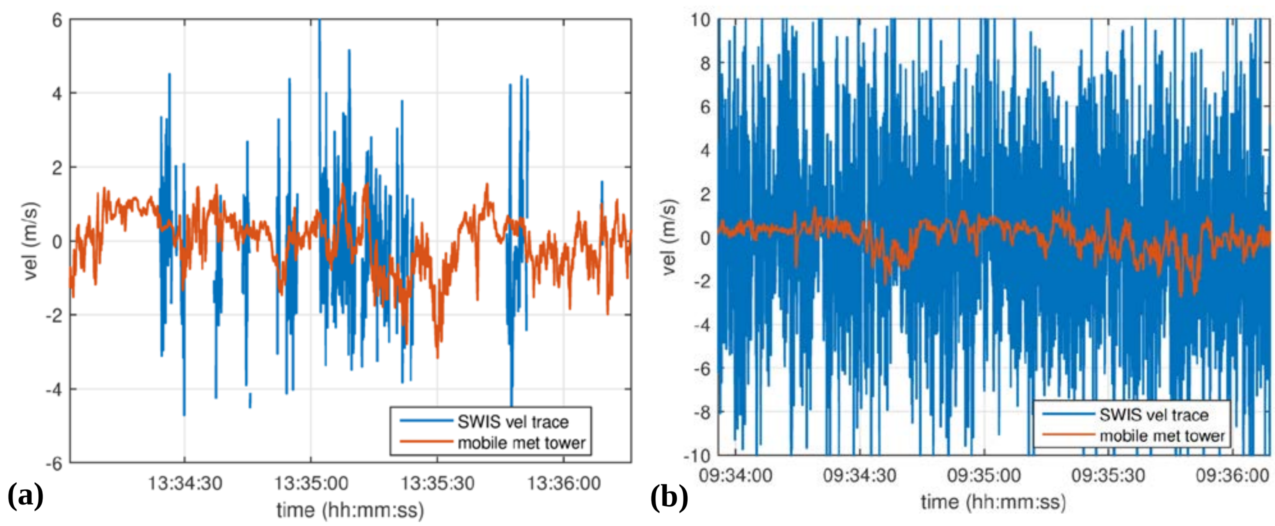

Figure 13: Velocity trace comparison between sample SWIS region and mobile met tower sonic anemometer: (a) with KCl aerosol generation and (b) background aerosol particulates.

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9. REFERENCES

References to related documents such as equipment spec sheets, technical reports, etc. to support more in-depth test plan understanding

1. Jonathan White, *Sandia SWiFT Site Operations Manual - Draft*, Sandia National Laboratories, Albuquerque, NM, July, 2015.
2. Thomas Herges, et al., *Sandia Wake Imaging System Activity at the Scaled Wind Farm Technology Facility – Technical Work Document*, Sandia National Laboratories, Albuquerque, NM, July 2015
3. Crystal Glen, et al., *Aerosol Operations at SWiFT*, OP 6633-12, Sandia National Laboratories, Albuquerque, NM, June 2015
4. David J. Denning, *LAZAP Facility Operating Procedure*, MSTC-OP-14001 Issue D, Sandia National Laboratories, Albuquerque, NM, December 2013
5. Andres Sanchez, Wake Imaging II: Aerosol Experimental Data from Lubbock, TX, Sandia National Laboratories, Albuquerque, NM, August 2015.

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10. APPENDIX A: PRE-TEST CHECKLISTS

The following pages contain checklists used daily both prior to testing and after testing was complete. These forms were printed out, dated, signed and kept in a test log book.

Daily Checklist

The following items will be reviewed daily by the Test Controller or delegate, with all personnel on site prior to any activities:

Date:	Reviewer:
Task	Comments
PRE-TESTING	
1. Review weather forecast with SWiFT Site Supervisor to confirm conditions will be within safe operating limits for equipment and personnel.	
2. Review current test objective(s) and list of activities for the day and confirm completion of specific checklists for those activities. (see additional checklists)	
3. Review and address any safety concerns and highlight significant hazards for day's work activities.	
4. Review roles and responsibilities with personnel and confirm adequate qualifications are met.	
5. Verify that all required and optional PPE has been issued and is functioning correctly.	
POST-TESTING	
6. Confirm all equipment is put into a safe storage mode.	
7. Notify SWiFT Site Manager that operations have ceased for the day.	
8. SWiFT Site Manager reports activity to Reese Technology Center	
9. At end of daily operations, review activities with personnel and note any areas of improvement	

Aerosol System Checklist

The follow items will be reviewed by the Aerosol Operator and Boom Lift Operator daily prior to use of the aerosol generation system:

Date:	Reviewer:
Task	Comments
AEROSOL SYSTEM PRE-TESTING	
1. Boom Lift Operator confirms weather conditions are within the safe operating envelope of the equipment and per the Aerosol Operations at SWiFT OP	
2. Boom Lift Operator confirms safe working order of boom lift and that aerosol generator frame is secure to basket	
3. Aerosol Operator confirms safe working order of water pump, air compressor, hose connections, and nozzles	
4. Boom Lift Operator confirms exclusion area around boom lift is clearly marked and meets distance requirements and that other staff do not enter the exclusion zone	
5. Aerosol Operator confirms all data acquisition systems are properly functioning (APS, sonic anemometer)	
AEROSOL SYSTEM POST-TESTING	
6. At end of testing, lower boom lift to ground, release pressure in water and air tanks, and power down system and generator.	
7. Store KCl in the control building with a chemical safety sign attached to it	
8. Complete Daily Post-testing items	

Laser System Checklist

The follow items will be reviewed by the Laser Operator daily prior to alignment of the laser system:

Date:	Reviewer:
Task	Comments
LASER SYSTEM PRE-TESTING	
1. Confirm order of emergency contact numbers and sufficient cellular signal for a minimum of 2 independent mobile phones.	
2. Test Controller shall call the local Lubbock Preston Smith International Terminal Radar Approach Control (LBB TRACON) for daily notification 30 minutes prior to any outdoor laser operation (806-766-6503 or 806-766-6505). A list of cellular numbers shall be given to LBB TRACON in case of emergency. Ordering of the numbers shall be: Test Controller, Laser Operator, Visual Observer, SWiFT Site Manager.	
3. Test Controller verifies required personnel are present and in position and other personnel have been excluded from the site for the laser activity (alignment or normal testing). If the laser will propagate outdoors, 2 visual observers are required.	
4. For alignment - boom lift operator confirms safe working order of equipment, including the secure attachment of the alignment target, and a properly marked exclusion zone.	
5. Test Controller confirms that generator is working and has sufficient fuel for the day’s activities.	
6. Laser operator confirms laser safety systems are in place, including secure connection of the beam director, operating beam block switches, laser and beam block lights.	
7. Test Controller confirms communication systems are working, including 2-way radios and mobile phones.	
8. Data Acquisition Operator confirms all data systems are properly functioning.	

LASER ALIGNMENT POST-TESTING	
9. Test Controller confirms all equipment is placed in storage mode, including the boom lift and laser system.	
10. Test Controller shall contact LBB TRACON immediately after laser system is powered down for the day.	
11. Test Controller confirms sufficient fuel in generator to power environmental systems until next testing day.	
12. Complete Daily Post-testing Checklist	

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