SAND2015-8969C

Sandia Wake Imaging System (SWIS)

Overview and Field Demonstration

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Brian Naughton

Tommy Herges

Wind Energy Technologies, Org 6121

Sandia National Laboratories

Exceptional service in the national interest

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Team Members

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6121 Wind Energy Technologies

- Brian Naughton
- Tommy Herges
- David Maniaci

5783 Optics and Sensor Engineering

- Dave Bossert

1118 Laser, Optics & Remote Sensing

- Crystal Glen
- Randy Schmitt
- Alice Sobczak
- Mark Johnson

6633 Contraband Detection

- Andres Sanchez

Outline

- Project Overview and History
- July 2015 SWiFT Field Test
- Safety Case
- Next Steps

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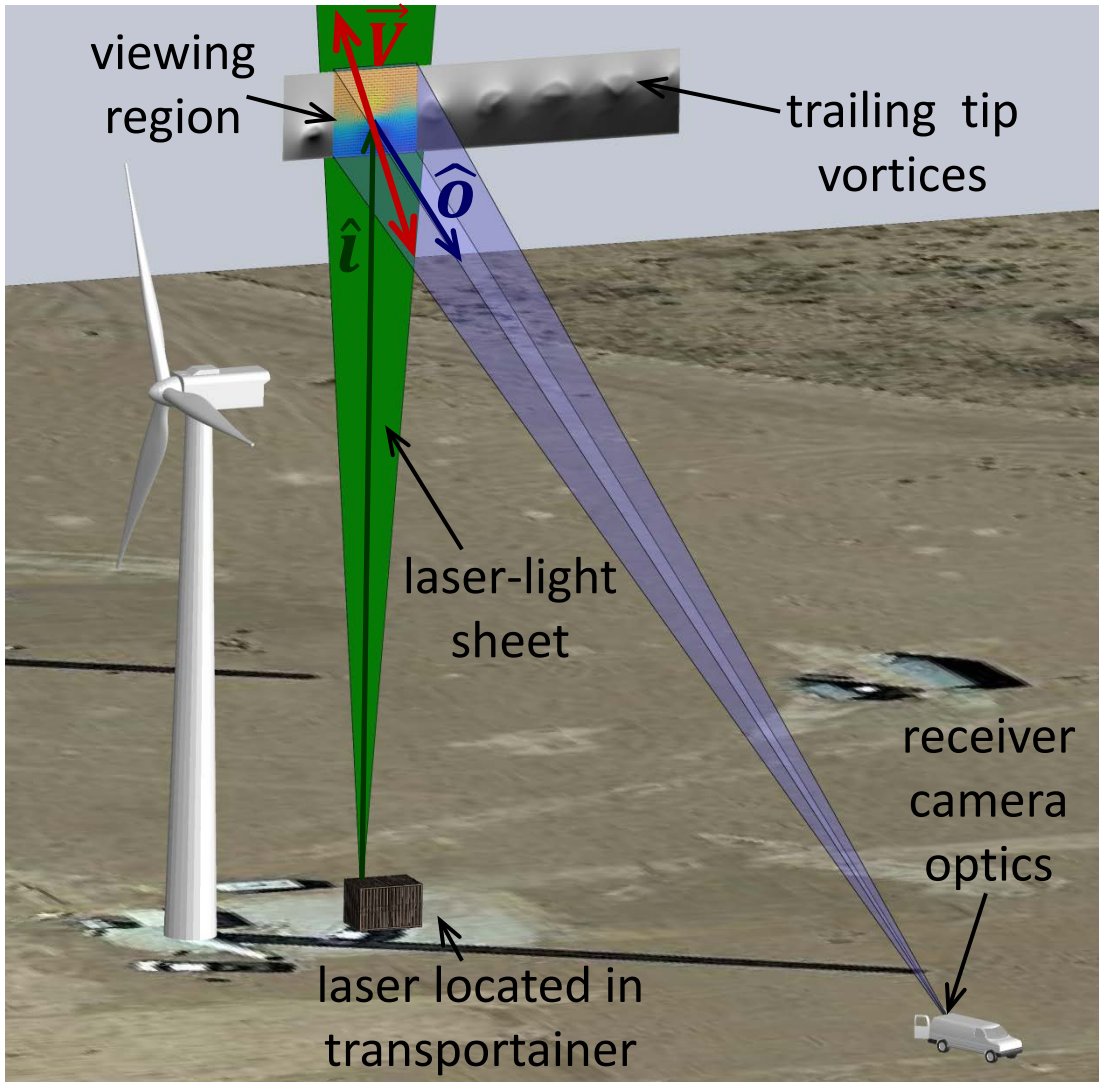
Project Overview and History

Sandia Wake Imaging System (SWIS)

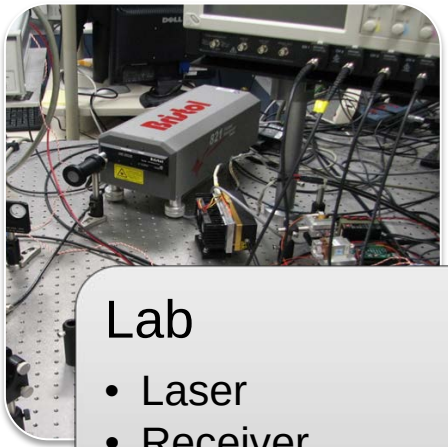


- Position of laser and camera dictates the measured velocity component
- Measure velocity component along bisector angle between observation and incident vectors, $(\hat{o} - \hat{i})$
- Additional velocity components measured with additional observation angles

Doppler frequency shift equation:

$$\Delta f_D = \frac{1}{\lambda}(\hat{o} - \hat{i}) \cdot \boldsymbol{V}$$

Project Development

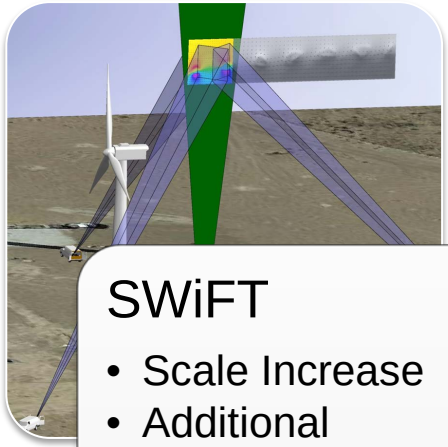


Lab

- Laser
- Receiver
- Iodine Cell
- Image Processing
- 15 cm × 15 cm

TA3 Sprung

- Aerosol
- System Sensitivity
- Measurement Uncertainty
- 2 m × 2 m



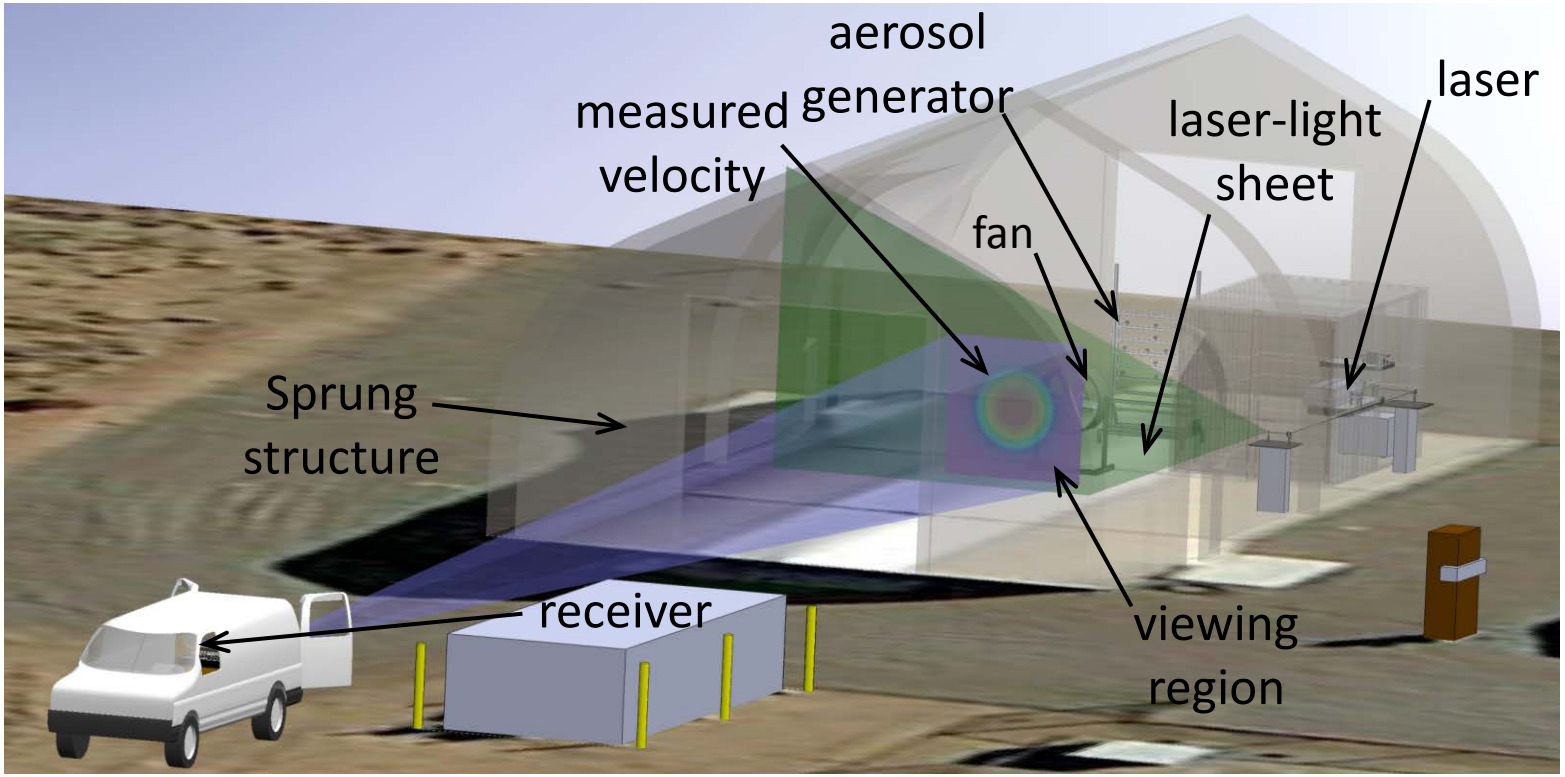
SWiFT

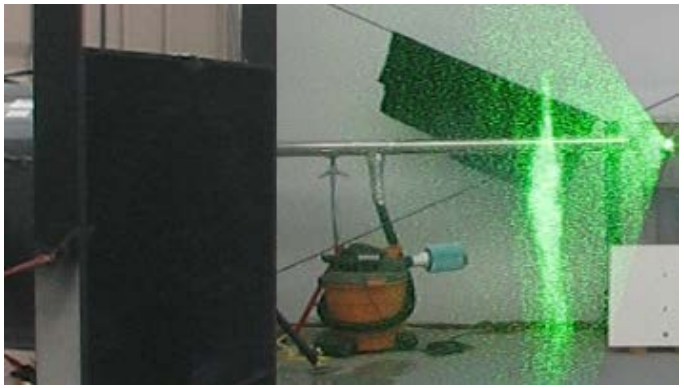
- Scale Increase
- Additional Velocity Components
- Outdoor Aerosol System
- 5 m × 5 m

Risk reduction approach:

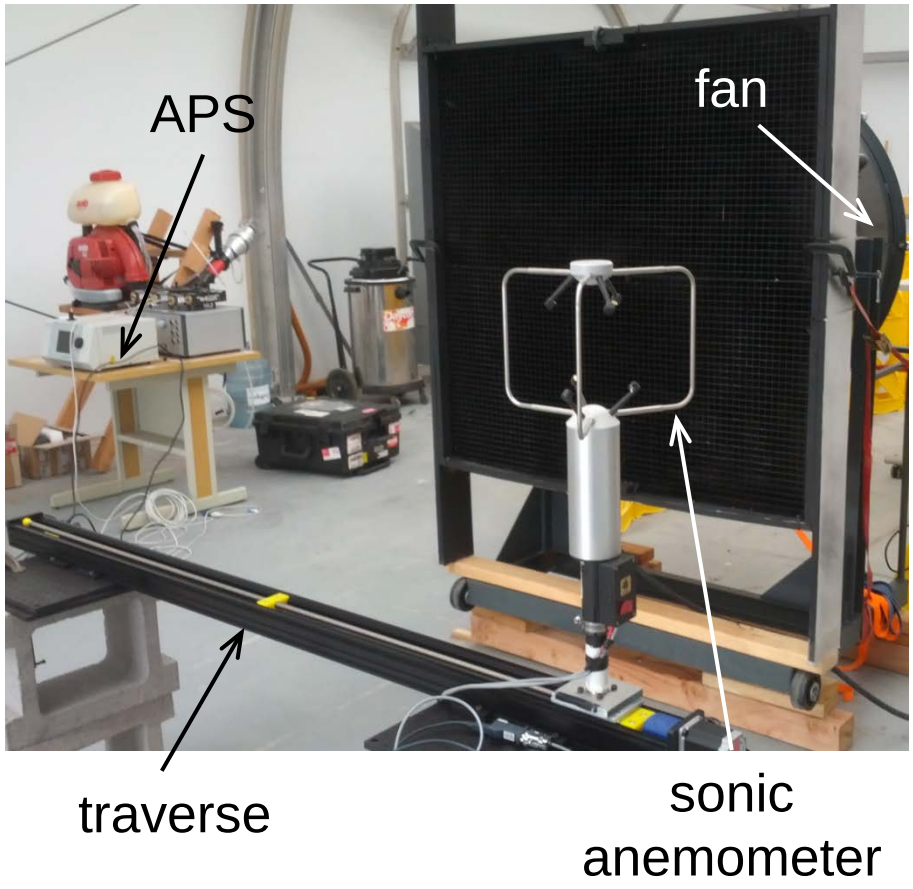
- Demonstrate simplest possible system
- Address make-or-break components
- Build up from lab to field-test to SWiFT experiments
- Identify and resolve ES&H issues early
- Leverage deep expertise, equipment, and facilities at Sandia to save time and money

Sprung Scaling Experiment

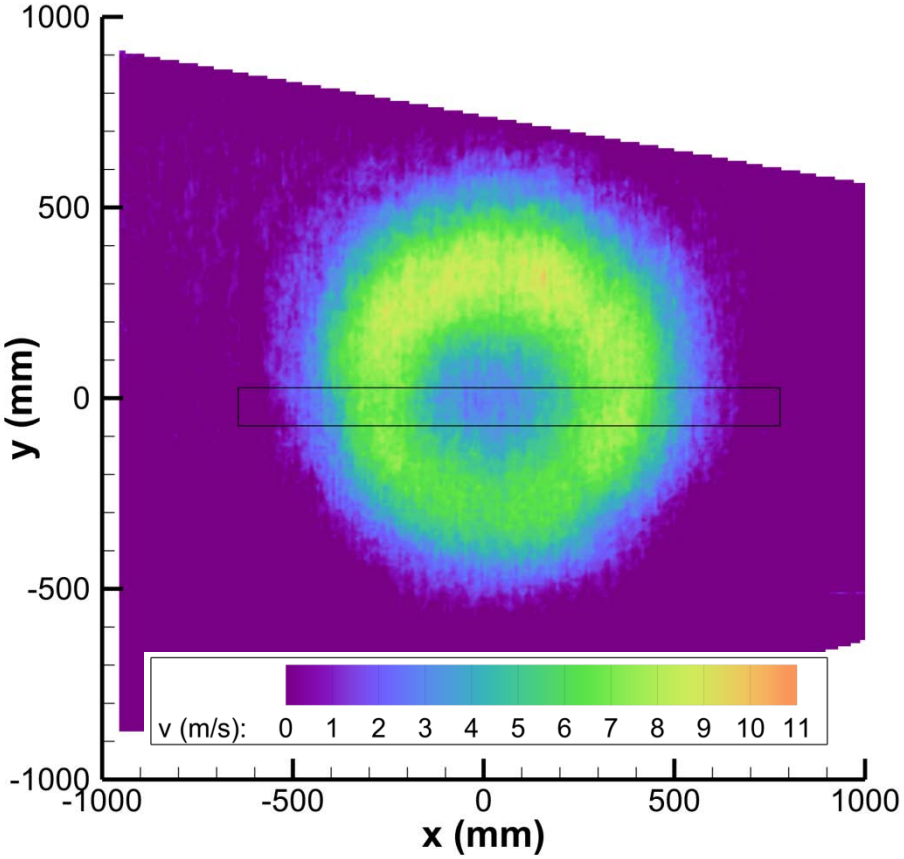


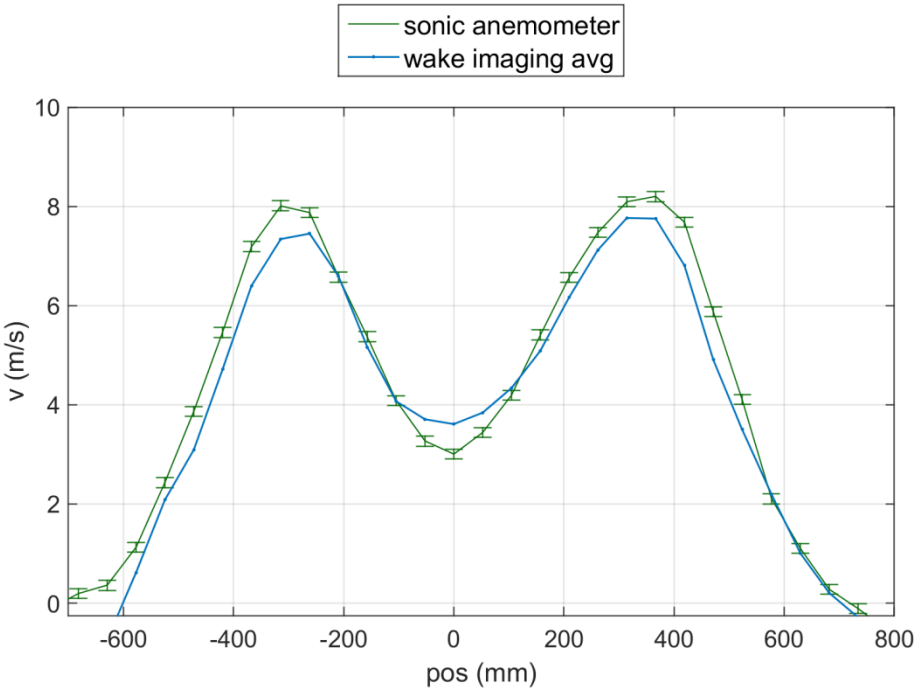


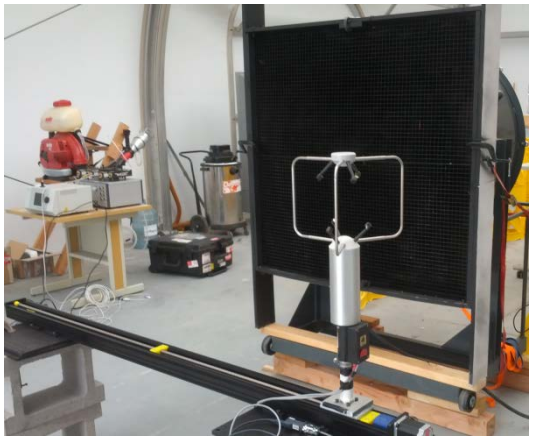
Experimental Configuration



Velocity Measurement Comparison





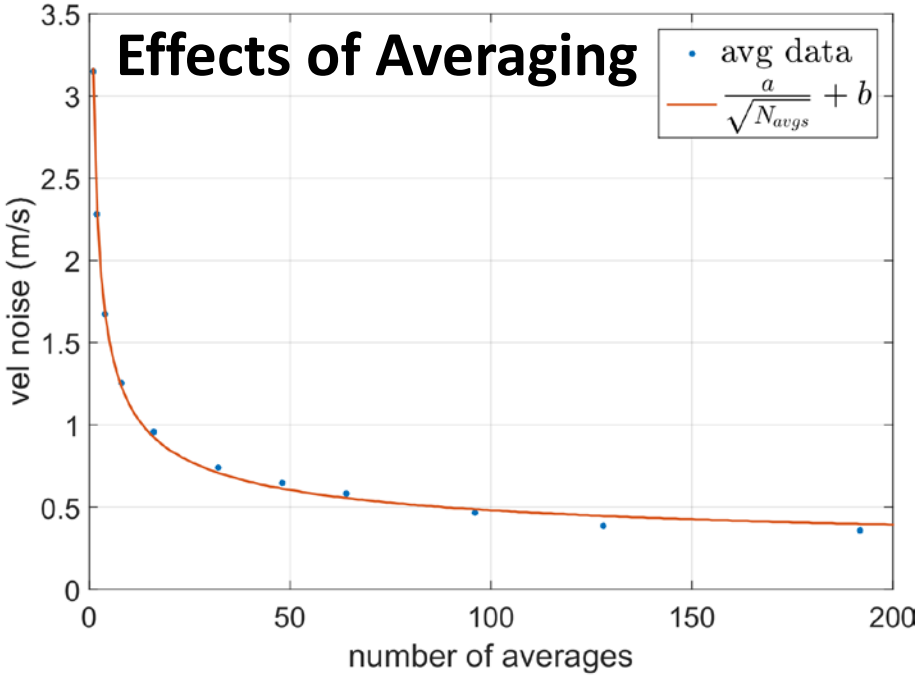


- Independent sonic anemometer data compares well
- Velocity image processed to match sonic anemometer spatial resolution
- Velocity bias exists between different wake imaging system data sets

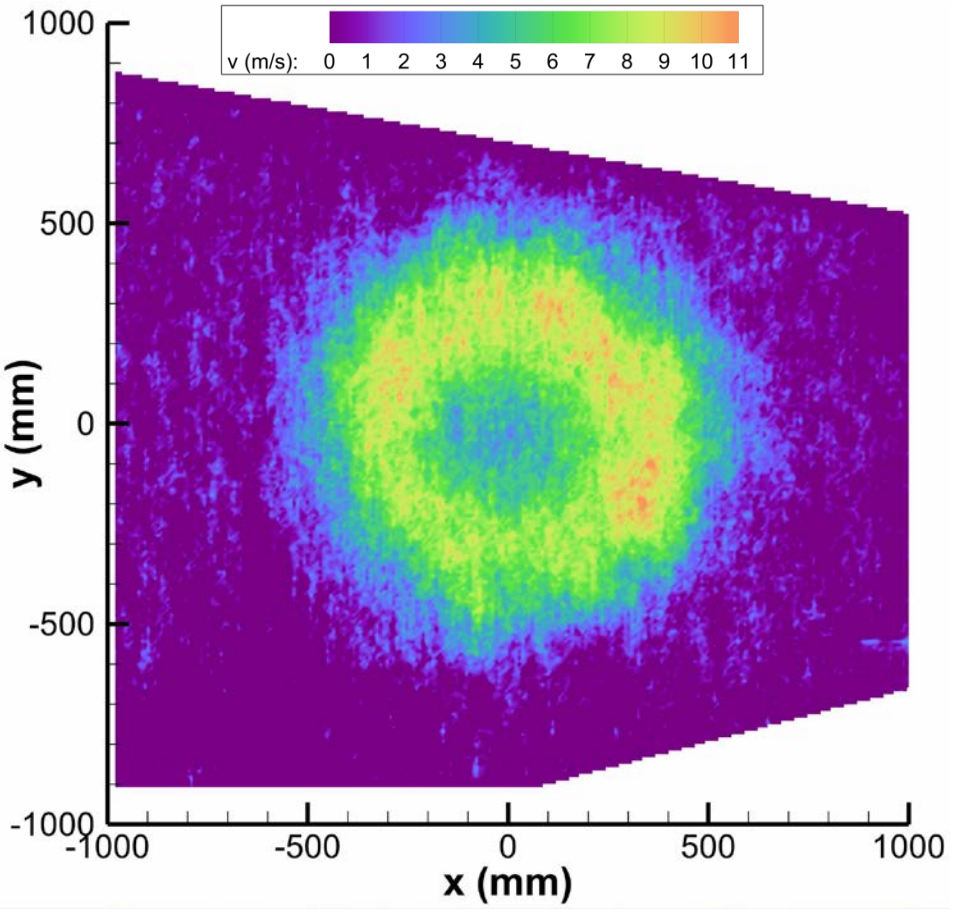
Reducing Noise for SWiFT Deployment

- Increase energy per laser pulse
- Receiver binning (increased signal with reduced spatial resolution)
- Higher particulate concentration
- Larger receiver aperture
- Improved post-processing techniques
  - Averaging
  - Filtering

Effects of Averaging



Post-Processed Instantaneous Image



July 2015 SWiFT Field Test

Test Objectives

Primary test objective

To demonstrate safe, concurrent operation of the laser and aerosol systems outdoors at the SWiFT facility.

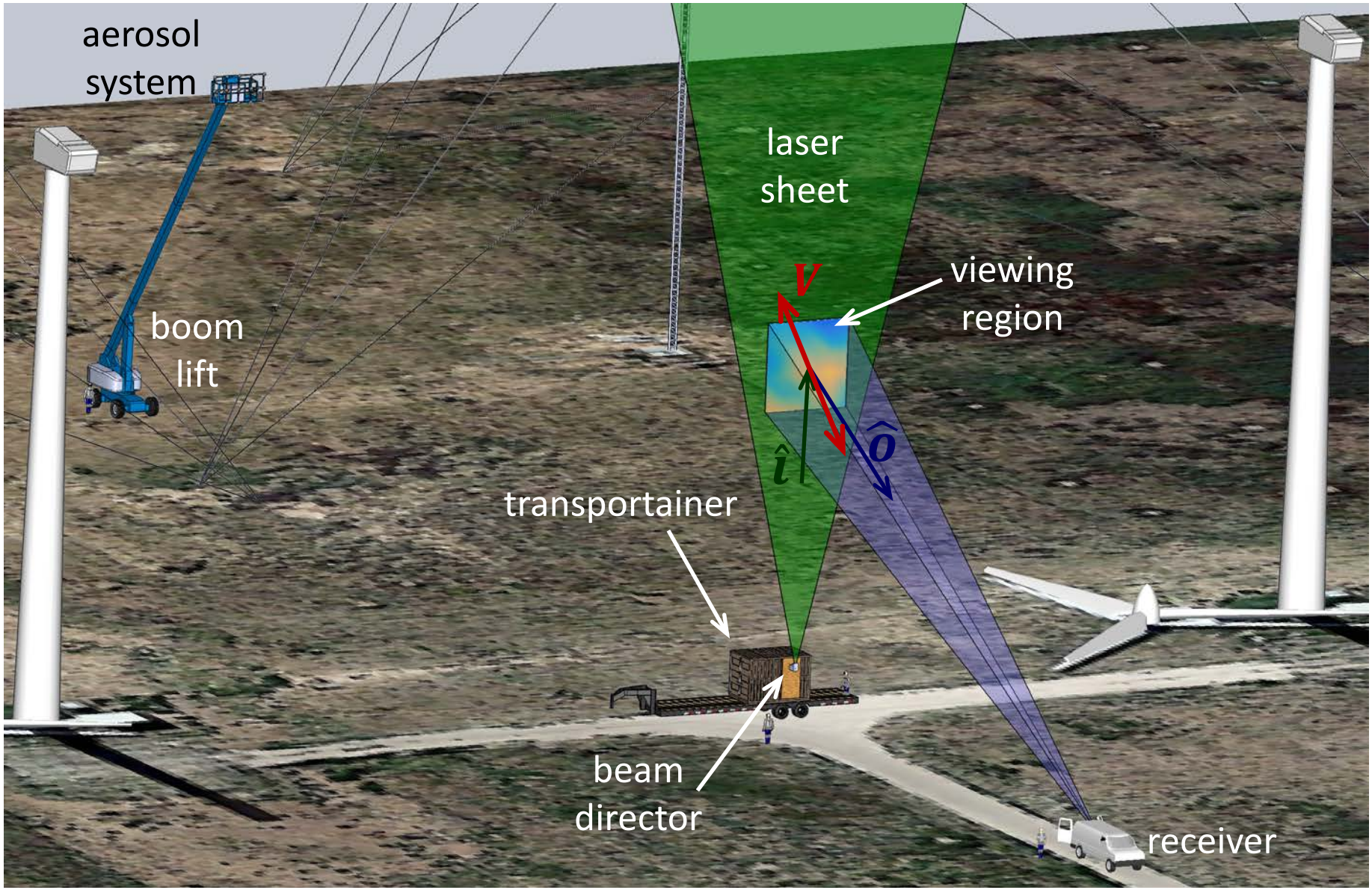
Success Criteria

A documented velocity image of a flowfield at the SWiFT facility and field test report detailing process.

Secondary test objectives

Collect additional data sets to verify system technical capabilities

Test Configuration



SWIS Field Demonstration

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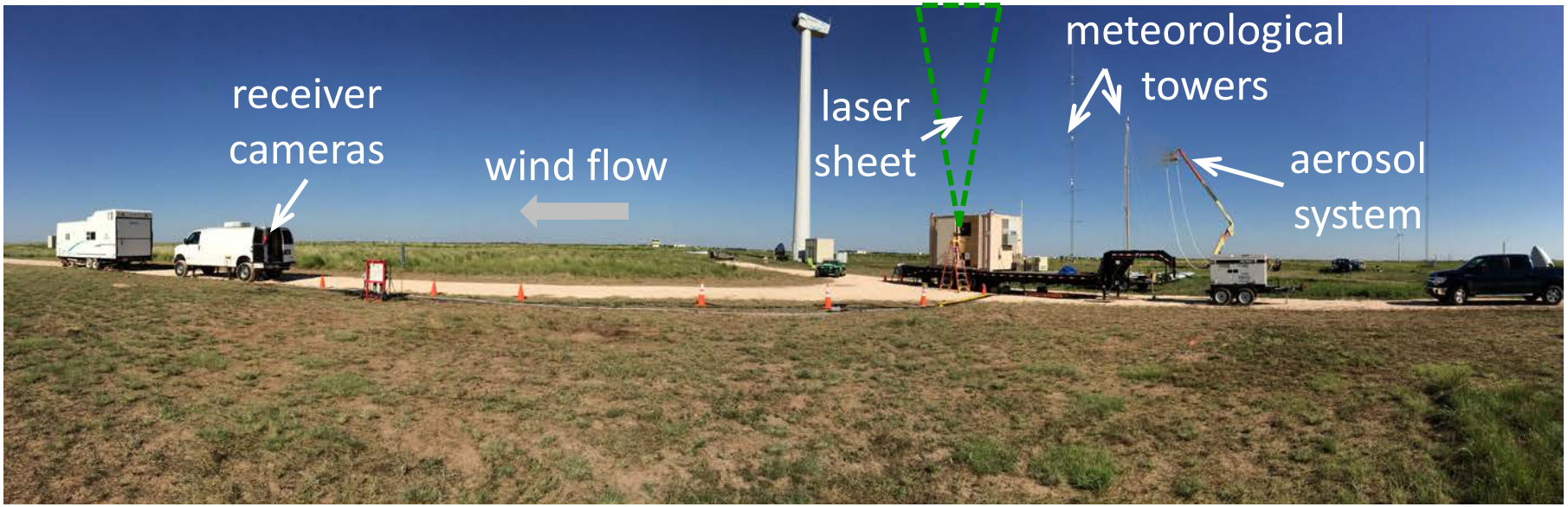
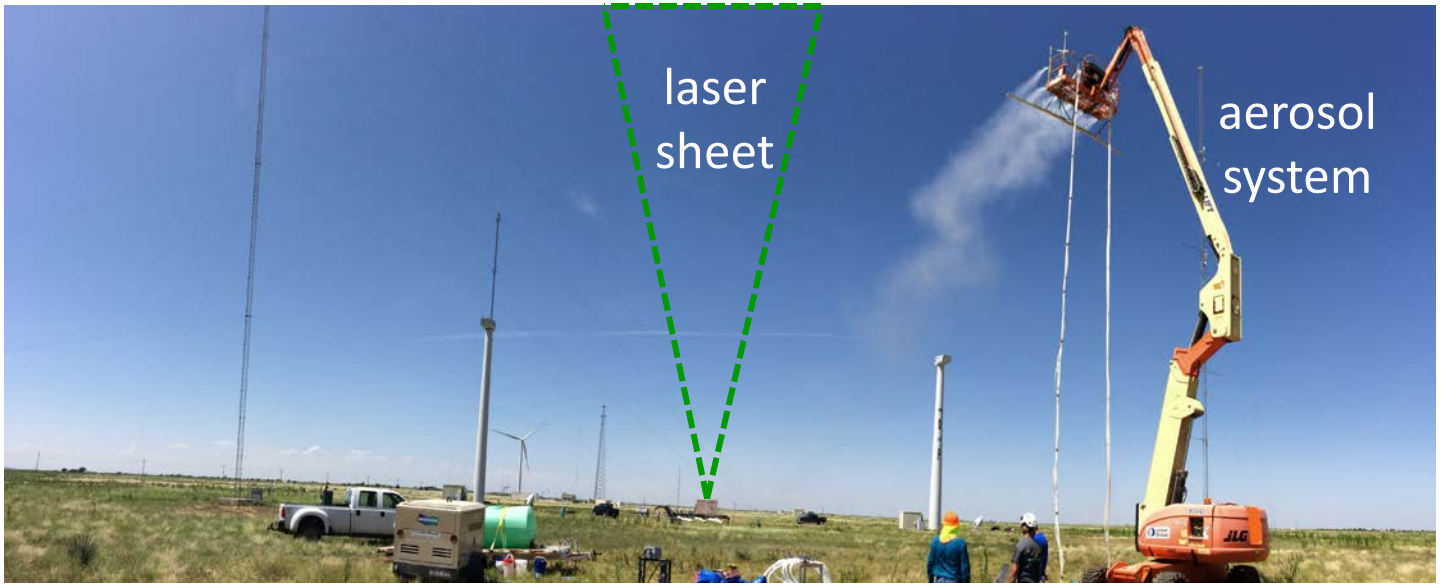
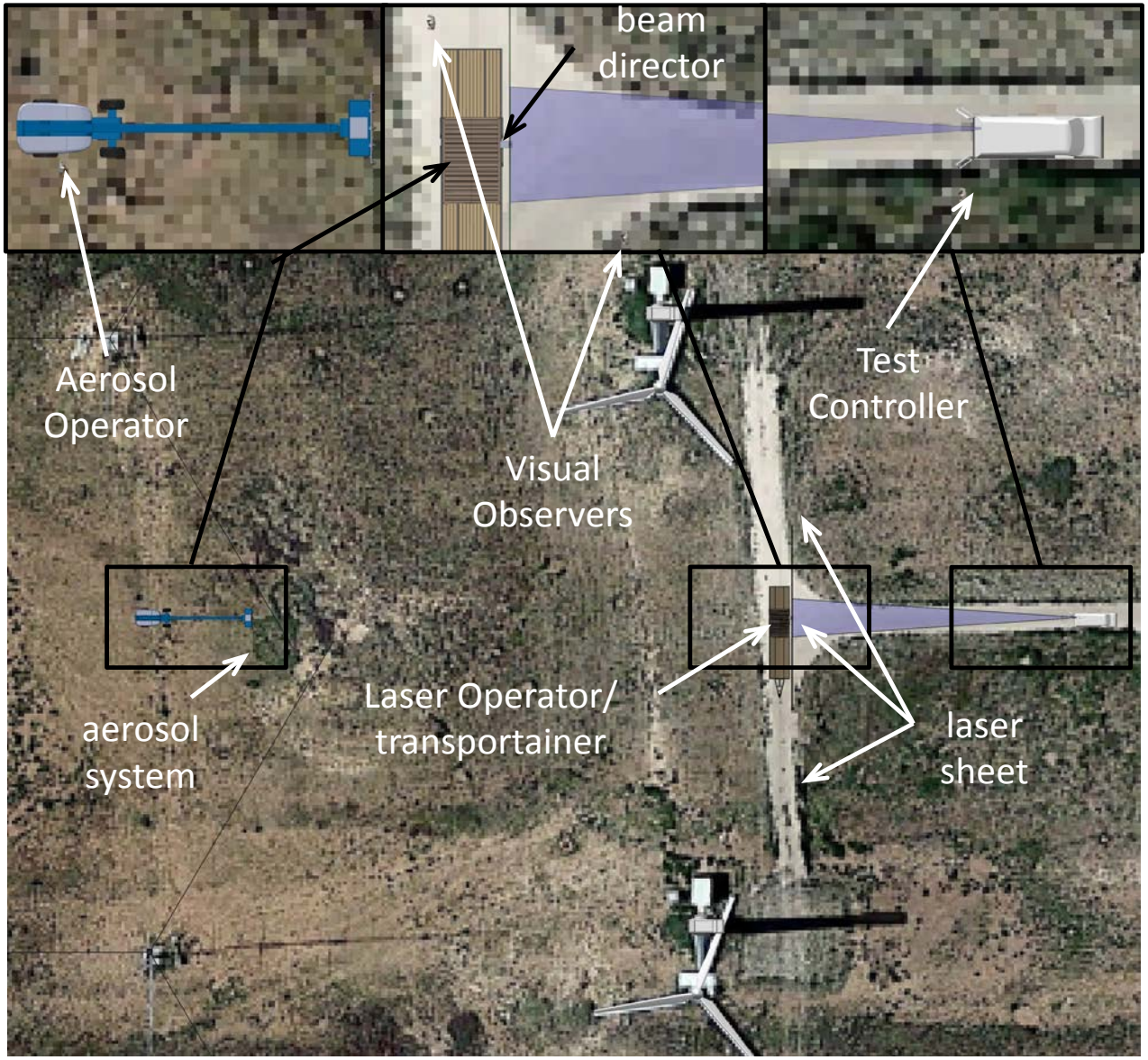




Test Personnel

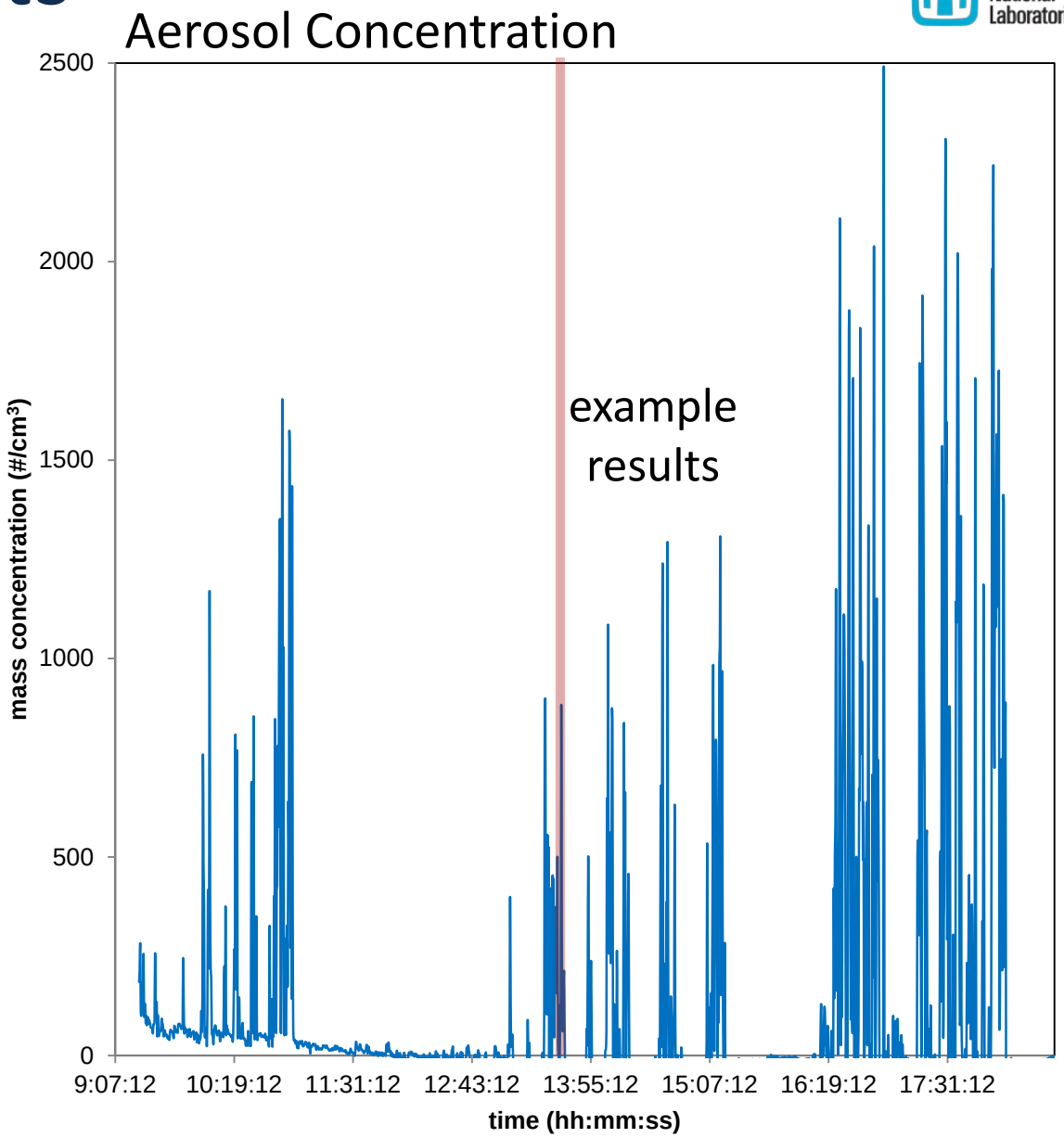


Roles

1. Test Controller
2. Laser Operator
3. Aerosol Operator
4. Data Acquisition Operator
5. Visual Observer #1
6. Visual Observer #2
7. Site Supervisor

Aerosol Results

- Aerosol particulates introduced to increase receiver signal levels
- Produce KCl/water mist
- Water dries out leaving salt particles
- Drying issue forced aerosol generation further from measurement area
- Hit rate of only 24%



Preliminary Measurement Results

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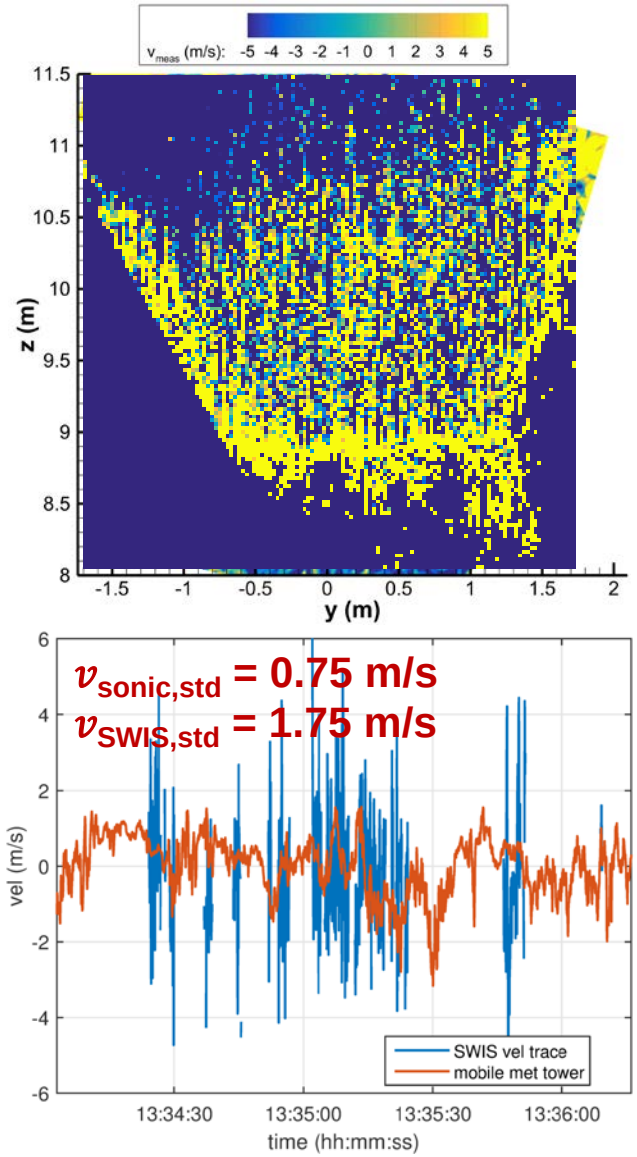
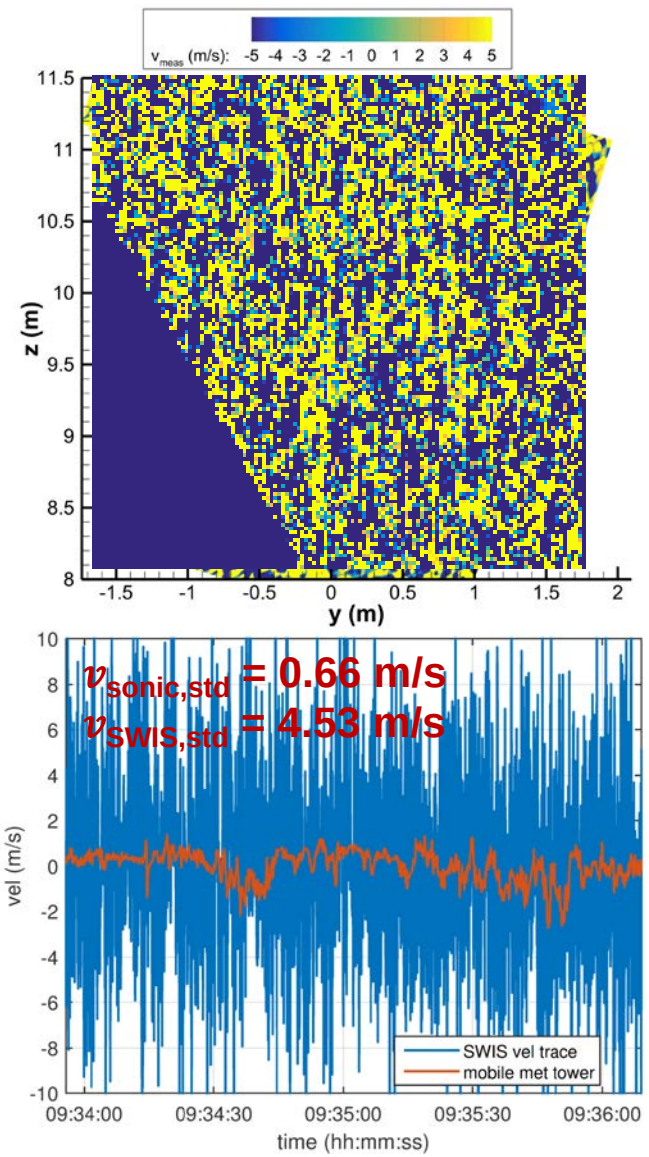
KCl Aerosol

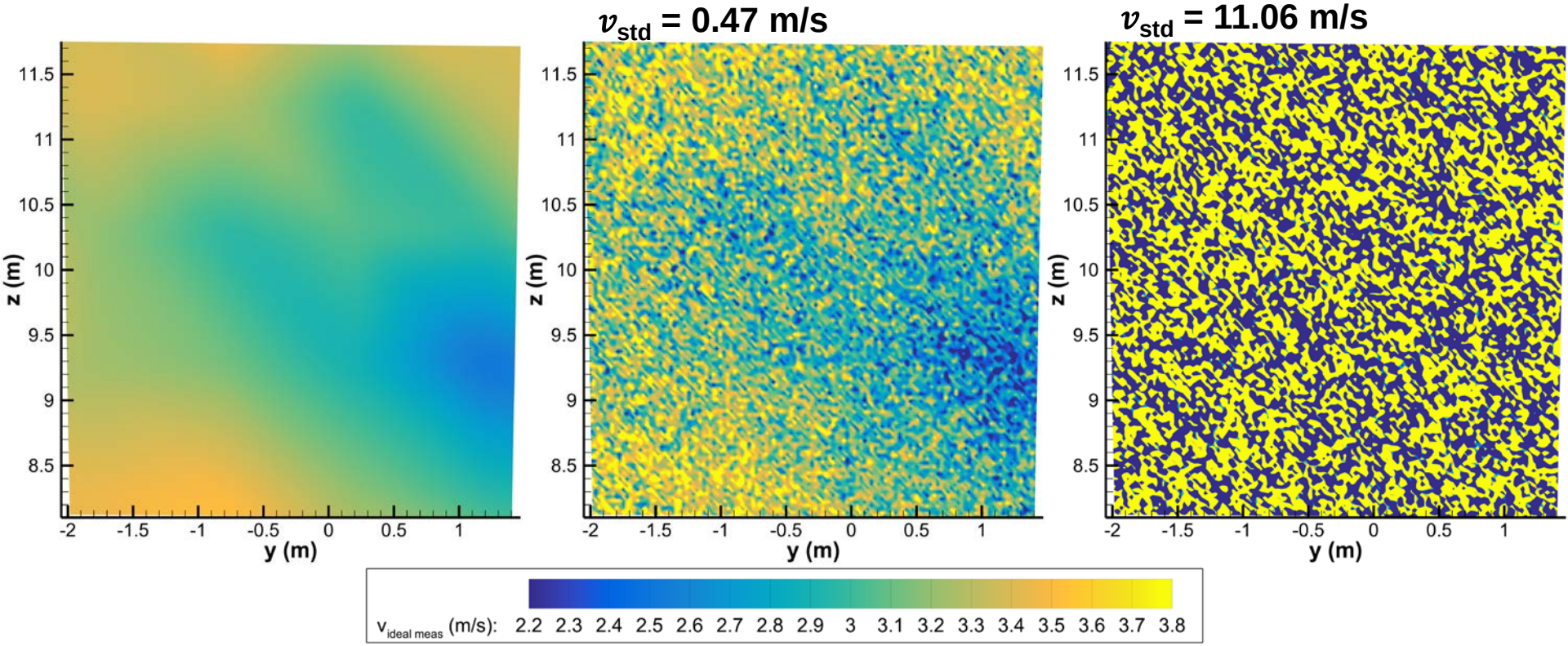


Native Aerosol



- KCl ≈ 1000 #/cm^3
- Native ≈ 13 #/cm^3
- Reduced light from native aerosols increases velocity noise
- Average velocity image subtracted to remove spatial frequency variation in laser sheet
- Thus, velocity images show Δv relative to time sample average
- Specifically designed laser can improve absolute velocity measurement

Simulated Results



- Created MATLAB based SWIS modeling tool for experimental planning and optimization
- Radiometric model calibrated from zero-velocity scaling test in Sprung
- Model incorporates 3D setup, pin-hole camera model, lens aperture size, super Gaussian laser intensity profile, Mie scattering angle, and aerosol concentration
- Imports representative flowfield and predicts measurement uncertainty/noise

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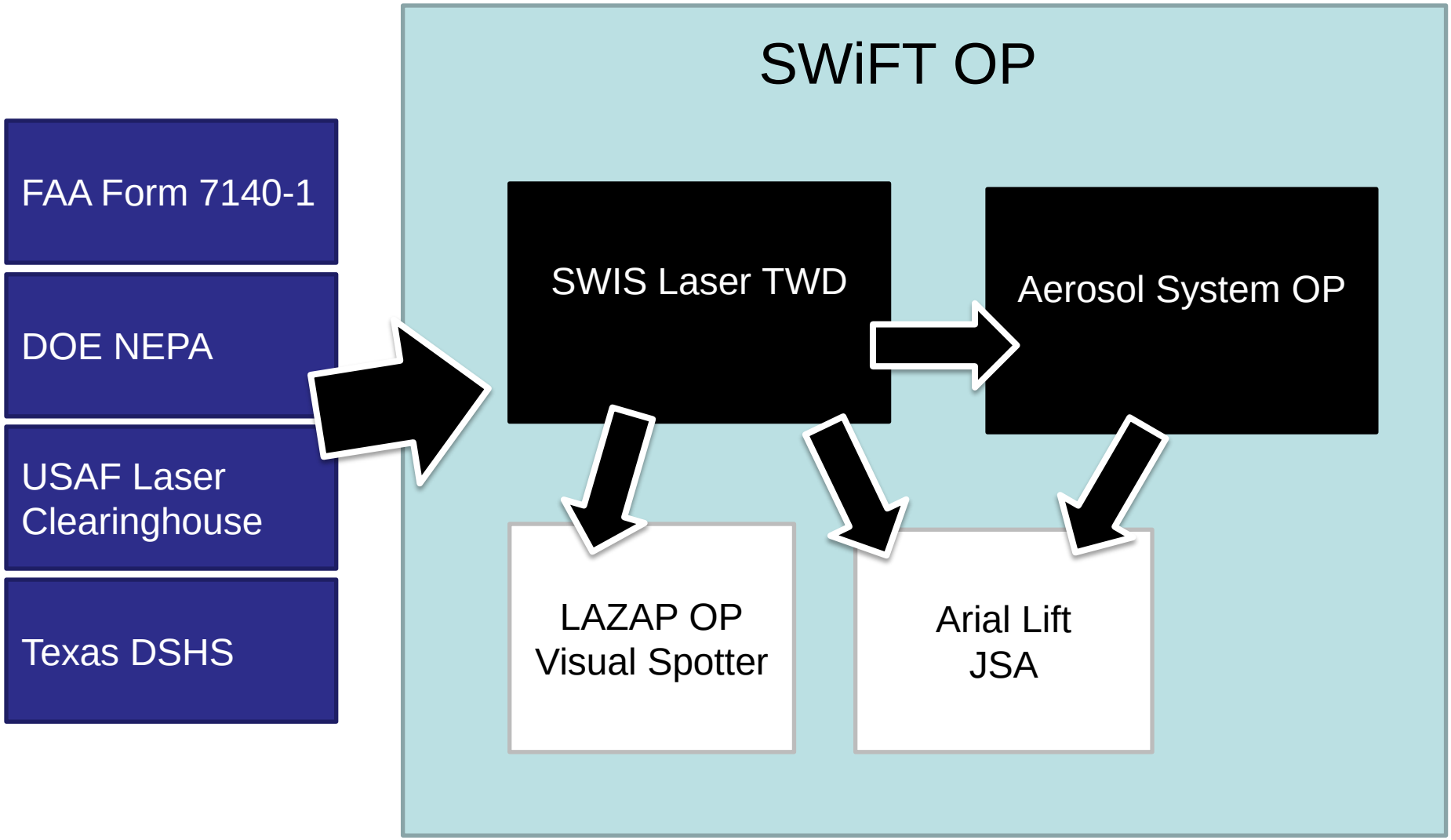
Safety Case

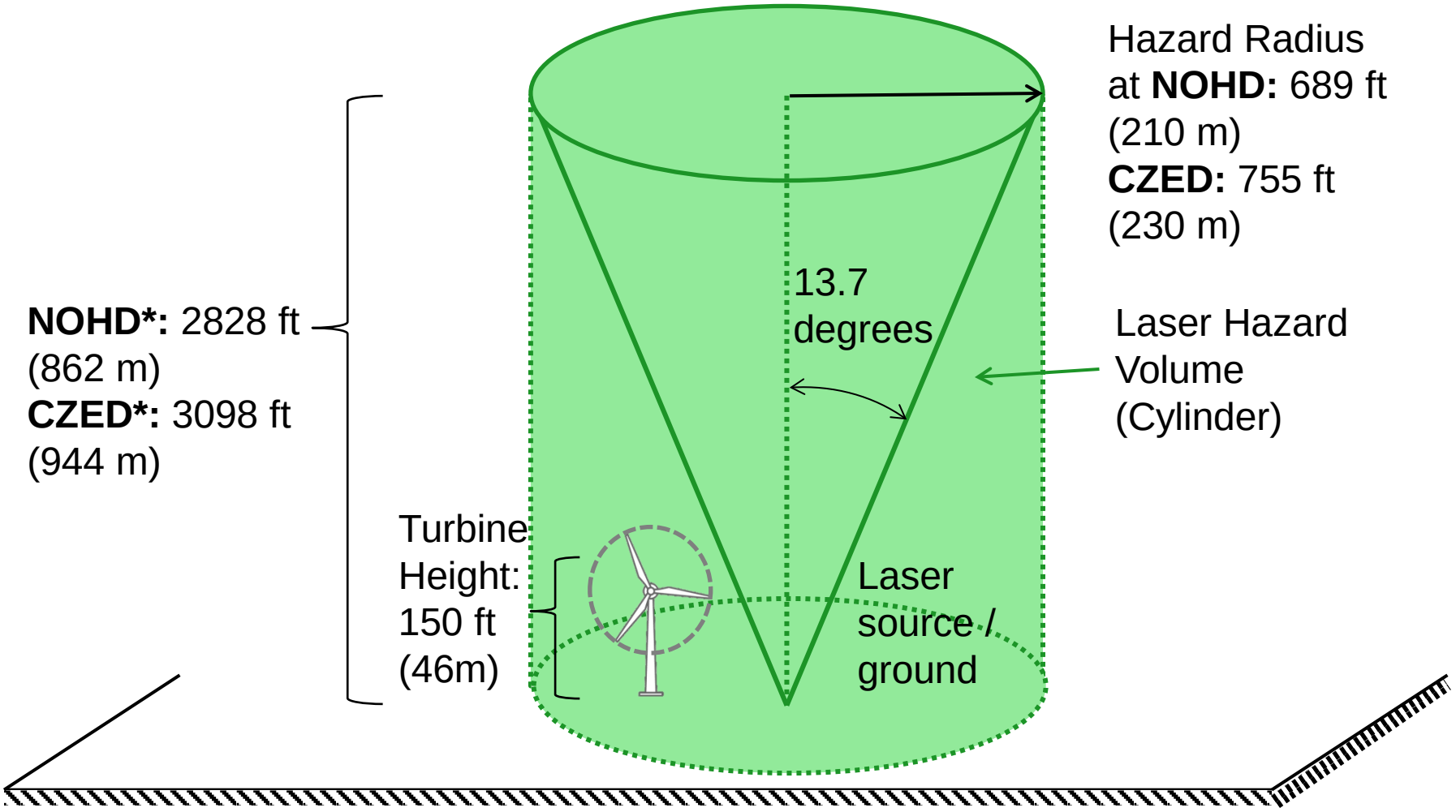
Safety Activities

Stakeholder	Work Product	Current Status
Department of Energy	SWiFT NEPA amendment	NEPA NM14-0084 has been approved by DOE Sandia Site Office.
Sandia ES&H	Work Planning and Control for Safe Design and Operations (Sandia ES&H documentation for new tasks)	• SWIS Laser Technical Work Document • Aerosol Operating Plan • SWiFT Site Operating Plan
Federal Aviation Administration (FAA)	Notice of Proposed Outdoor Laser Operations	FAA letter of non-objection received 05/06/2015
Laser Clearinghouse (Vandenberg Air Force Base)	Notice of Proposed Outdoor Laser Operations	Full waiver received 07/15/2015.
Reese Technology Center	Testing activity coordination	Draft testing parameters and notification protocol were established 2014. Final stakeholder meeting held 06/10/2015.
Texas Tech University (TTU)	Laser operations license, ES&H plan	State of Texas laser operations license has been obtained (November 2014). Presentation to TTU Laser Safety Committee was conducted in October 2014.

SNL Safety Case Structure



FAA Hazard Analysis



Nominal Ocular Hazard Distance (NOHD) area of laser sheet at 2828 ft (ZOOM)

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Next Steps

Potential SWIS Upgrades

- Specifically designed laser ≈ $500k
- Improved aerosol generation system:
  - ≈ $100k increased capacity of similar system
  - ≈ $400k fully redesigned system
- Improved iodine cells ≈ $8k per cell
- More receivers, more velocity components ≈ $150k per component

Takeaway

- Multi-organization project leveraging millions $ in personnel skills and equipment
- Unique measurement capability, never before performed outdoors at this scale
- Other Applications around Sandia or parts of DOE?