Wind Power Peer Review

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Energy

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DOE/SNL SWiFT Facility

Development of the DOE/SNL Scaled Wind Farm Technology Facility

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Purpose & Objectives

Problem Statement: A world-class, public, open-source testing facility is required to develop wind-plant technology from basic research up to commercialization.

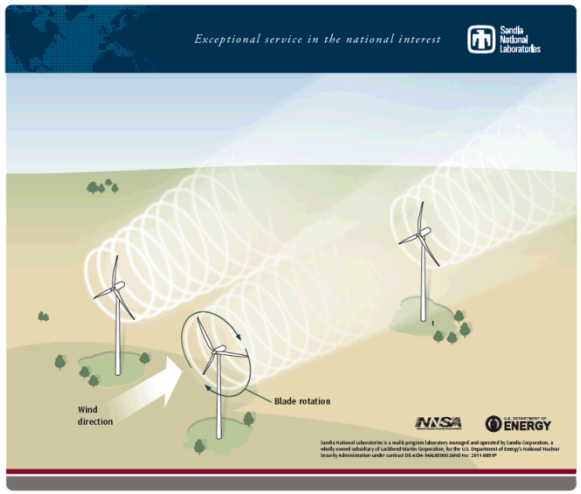
Impact of Project: Lower cost of energy with innovative advancements to wind energy, developed in the most rapid and cost-efficient process possible.

This project aligns with the following DOE Program objectives and priorities:

- ✓ **Optimize Wind Plant Performance:** Reduce wind-plant levelized cost of energy (LCOE)
- ✓ **Accelerate Technology Transfer:** Lead the way for new high-tech U.S. industries
- ✓ **Mitigate Market Barriers:** Reduce market barriers to preserve or expand access to quality wind resources
- ✓ **Advanced Grid Integration:** Provide access to high wind resource areas, and provide cost effective dispatch of wind energy onto the grid
- ✓ **Testing Infrastructure:** Enhance and sustain the world-class wind testing facilities at universities and national laboratories to support mission-critical activities
- ✓ **Modeling & Analysis:** Conduct wind techno-economic and life-cycle assessments to help the program focus its technology-development priorities and identify key drivers and hurdles for wind-energy technology commercialization

Relevance to Industry

Provide a public, open-source, experimental wind-plant facility with a validated model that can be used by international consortia of industry, academia, and national laboratories to:



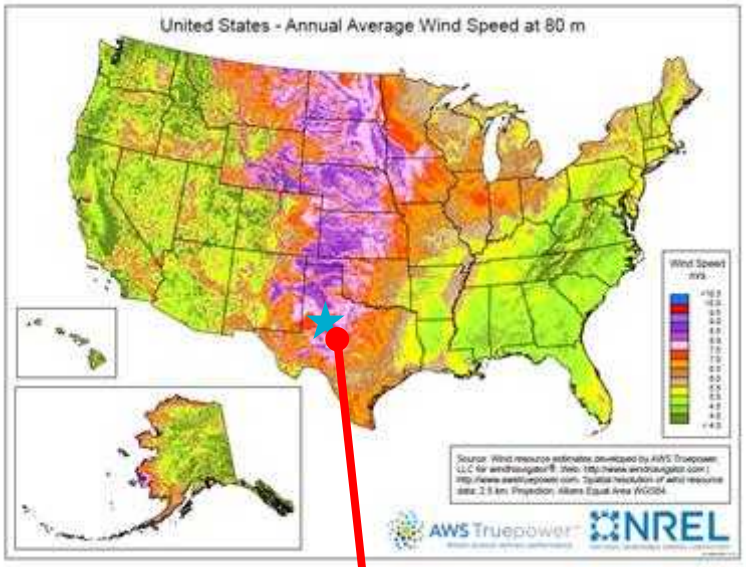
1. Reduce power losses and damage caused by turbine-turbine interaction through study of complex wake flows
2. Enhance wind-plant energy capture by developing the next generation of rotor technology
3. Perform rapid, cost-efficient research in aeroacoustics, aeroelasticity, aerodynamics, and reliability

Technical Approach

Innovating wind-energy plants requires:

1. High winds in a consistent direction to minimize measurement time
2. Flat terrain to minimize uncertainty for validation campaigns and to allow the discrete addition of well-understood, man-made terrain features.
3. Open-source wind turbines that do not have restrictions to enable cross-cutting collaborative research between laboratories, industry, and academia
4. An on-site, research-quality assembly building to prepare experiments and create rapid-response testing components
5. An open-source, variable-speed controller that is integrated with data acquisition system to facilitate collaborative research
6. A site-wide time-synchronized control and data-acquisition network to allow direct, time-based data analysis, instead of statistical representations
7. Cost efficient testing required to enable high-risk early-stage technology
8. A functional scaling methodology (including limitations) to transfer technology development to current and future utility-scale

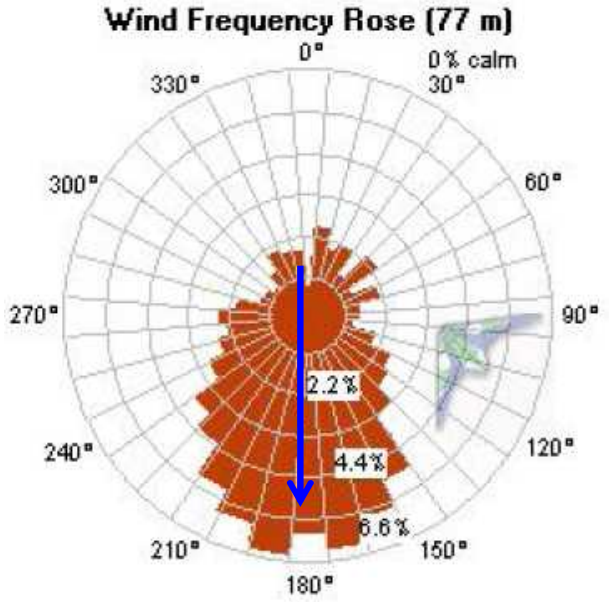
High, Consistent Wind Is Key to Rapid Research Execution



Location is in the best part of the US wind corridor—with favorable weather year-round and the most US wind installations: 12 GW and continued growth.

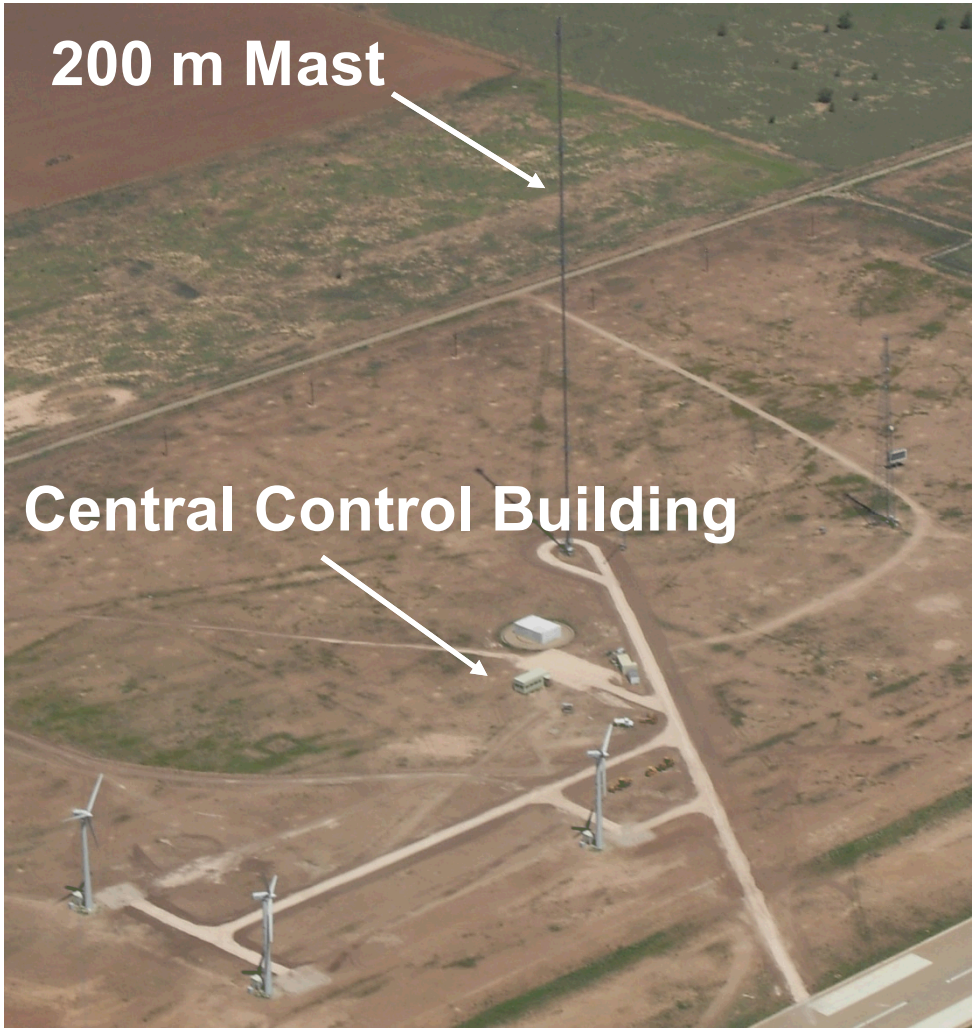
Consistent high data rate and efficient research execution due to:

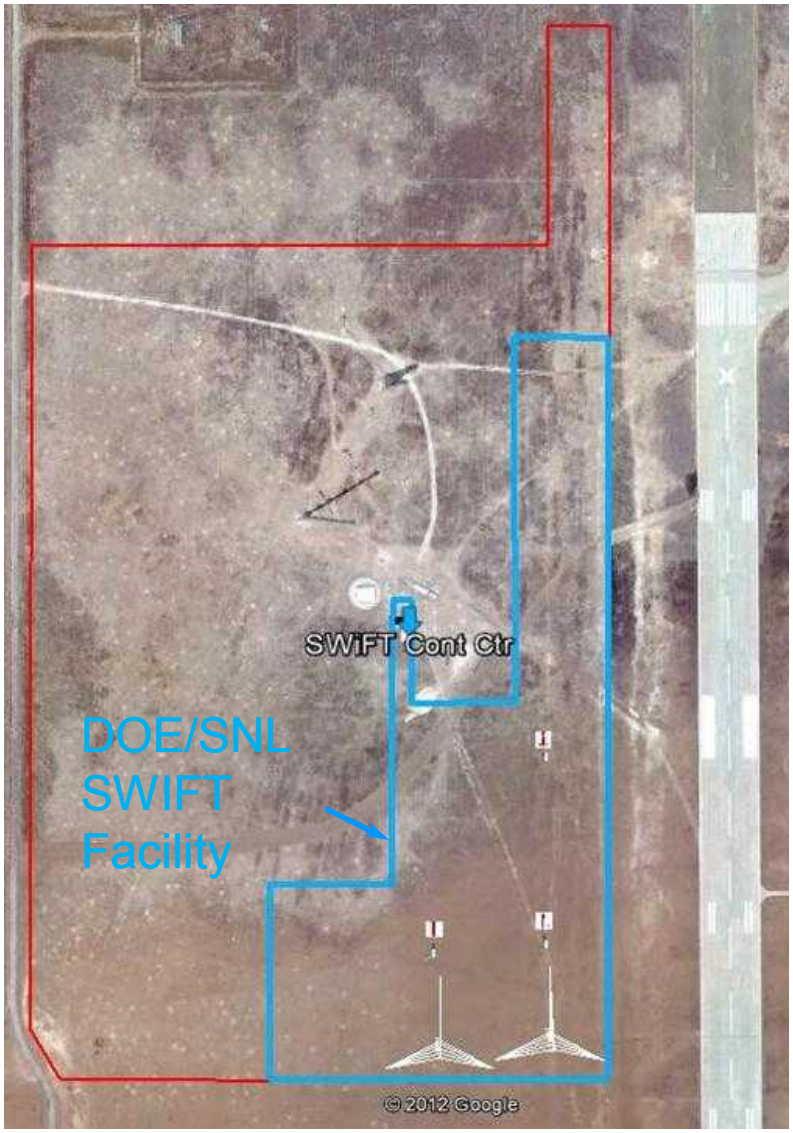
- High winds (7.5 m/s at 50 m) with low variability
- Narrow wind rose, which provides consistent data for chosen array configuration
- Current and historical data from unique, site-adjacent 200 m meteorological mast
- Flat terrain, which allows reduced validation uncertainty and the opportunity to add man-made terrain effects in the future



TEXAS TECH UNIVERSITY

Taking Advantage of Consistent Wind Direction

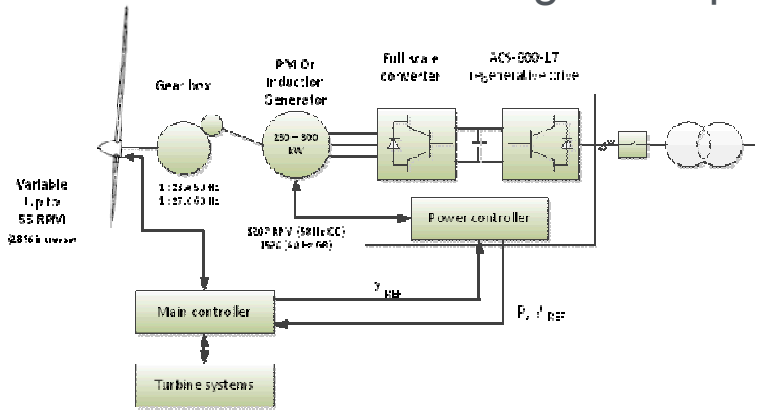




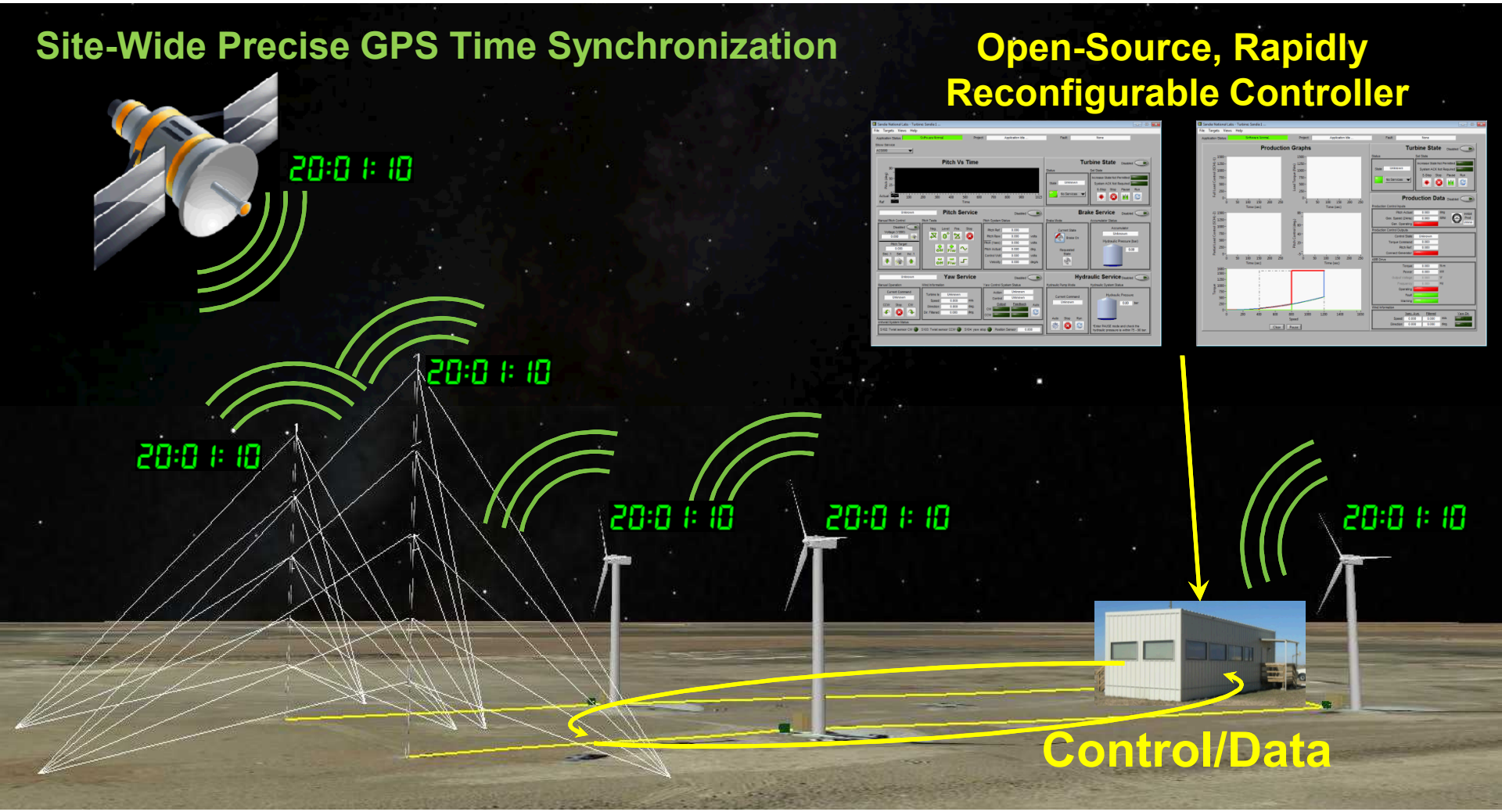
Open-Source Wind Turbines

Fully documented open source hardware, developed in collaboration with Vestas

- Solid, proven machines with collective-pitch system that allows almost any type of research to be performed
- 300 kW variable-speed generator
- AC-DC-AC full-scale convertor designed with ABB, Inc.
- Open-source controllers based on National Instruments
- Complete turbine/rotor state instrumentation including fiber-optics



Comprehensive and Easy Controls Integrated with Site-Wide Measurement System



On-site Workshop Allows Fast Turn-around and Rigorous Preparation

- 4,500 sq. ft. high-bay for experimental rotor preparation and calibration
- 1,000 sq. ft. machine shop to produce unique, critical, and rapid-turnaround parts
- Environmentally controlled, with high-intensity lighting

Accomplishments and Progress

- Developed public, open-source variable-speed controller for SWiFT
- Installed three wind turbines & two meteorological masts without (safety) incident
- Performed rigorous characterization tests on component and full-system scales, to ensure the accuracy of a public wind-turbine model
- Commissioned three wind turbines—are being readied for open-source R&D
- Trained and employed technician and operational staff, in partnership with Texas Tech
- Refurbished a comprehensive on-site workshop for research preparation

Project Plan & Schedule

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Summary	
WBS Number or Agreement Number	
Project Number	
Agreement Number	

Legend	
	Work completed
	Active Task
	Milestones & Deliverables (Original Plan)
	Milestones & Deliverables (Actual)

Task / Event	FY2012 Q1 (Oct-Dec)	FY2012 Q2 (Jan-Mar)	FY2012 Q3 (Apr-Jun)	FY2012 Q4 (Jul-Sep)	FY2013 Q1 (Oct-Dec)	FY2013 Q2 (Jan-Mar)	FY2013 Q3 (Apr-Jun)	FY2013 Q4 (Jul-Sep)	FY2014 Q1 (Oct-Dec)	FY2014 Q2 (Jan-Mar)	FY2014 Q3 (Apr-Jun)	FY2014 Q4 (Jul-Sep)
Project Name: Scaled Wind Farm Testing Facility Development												
SNL/USDA Bushland Facility												
Q2 Milestone: SMART Rotor Test and Data Collection												
Q3 Milestone: SNL/LANL SHM Rotor Test												
Q4 Milestone: Decomission USDA-Bushland Facility												
SWiFT Facility												
Q1 Milestone: Detailed Facility Planning												
Q1 Milestone: Procure and Refurbish Wind Turbines												
Q2 Milestone: SWiFT Construction												
Q1 Milestone: SWiFT Commissioning												
Current work and future research												
SWiFT Baselining, Verification and Validation												
Wake Imaging System Preliminary Field Testing												

Comments

- Facility technical capabilities and agreements designed through 2022
- Two unsuccessful turbine procurements and a protracted refurbishment accounted for most significant four-quarter delay
- Outstanding refurbishment issues added one quarter to construction

Project Budget

Budget History					
FY2012		FY2013		FY2014	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
Budget / Spent $4020k / $2006k	$1050k	Budget / Spent $2928k / $2457k	$2200k	$1422k	

- In FY12:
  - $2M was invested in purchases and planning labor/$2M was carried over toward installation
  - Vestas provided $300k toward variable-speed conversion, $300k toward site grid installation
  - TTU provided $250k toward (a) an environmental avian and bat study and (b) assembly building preparation
  - NIRE provided $100k in cost-share—preparing the interconnection and power-purchase agreements
  - Component suppliers provided $100k in miscellaneous cost share
- In FY13:
  - DOE/SNL completed installation of two SWiFT wind turbines and two meteorological masts, at a cost of $2.5M
  - Vestas completed installation of third SWiFT wind turbine, at a cost of $2M
  - ATA Engineering provided $200k in cost share for turbine characterization
  - Spending is on schedule
- Total SWiFT Investment was $8M (~ 50% DOE)

Research Integration & Collaboration

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Partners, Subcontractors, and Collaborators:

2 OEMs: Vestas*, GE**

15 Companies: Group NIRE*, ATA Engineering*, Micron Optics*, National Instruments*, GL-DNV*, Broadwind*, ABB*, CC Jensen*, Cascade, Baker, Met One, Thies, ATI Inc., Rohn, GearWorks, Halus

3 Laboratories: NREL, SRNL, LANL

5 Universities: TTU, U-Minnesota, UC-Davis, Texas A&M, Purdue

*Providing cost-share **Providing advisory guidance

Communications and Technology Transfer:

Technical Presentations: 2014 AIAA ASME Wind Energy Symposium, 2013 SNL Reliability Workshop, 2012 SNL Blade Workshop

Technology Transfer: Rotor Fiber Optic Instrumentation methods to Vestas, Variable Speed Controller to ABB, SWiFT Facility Commissioning, Public SWiFT Wind Turbine Model, Public Open-Source Variable Speed Controller

Next Steps and Future Research

FY14/Current Research:

- SWiFT Baselining Project: Verify and validate instrumentation/data, site operations, and turbine performance in preparation for future DOE and collaborative R&D projects. Create a website to transfer SWiFT models, documentation and data to collaborators.
- Wake Measurement System: Preliminary field deployment of high-resolution wake-imaging measurement system.

Proposed Future Research:

- Development of functional scaling methods in partnership with National Rotor Testbed, TTU Ka-band Radars and OEMs
- Detailed characterization and control of scaled wake structures to increase wind-plant performance
- Wake merging, meandering, and complex deep array studies
- Advanced rotor designs with passive and active load control
- Rotor aero-acoustic generation and propagation measurements

Basic Turbine to Turbine Interaction

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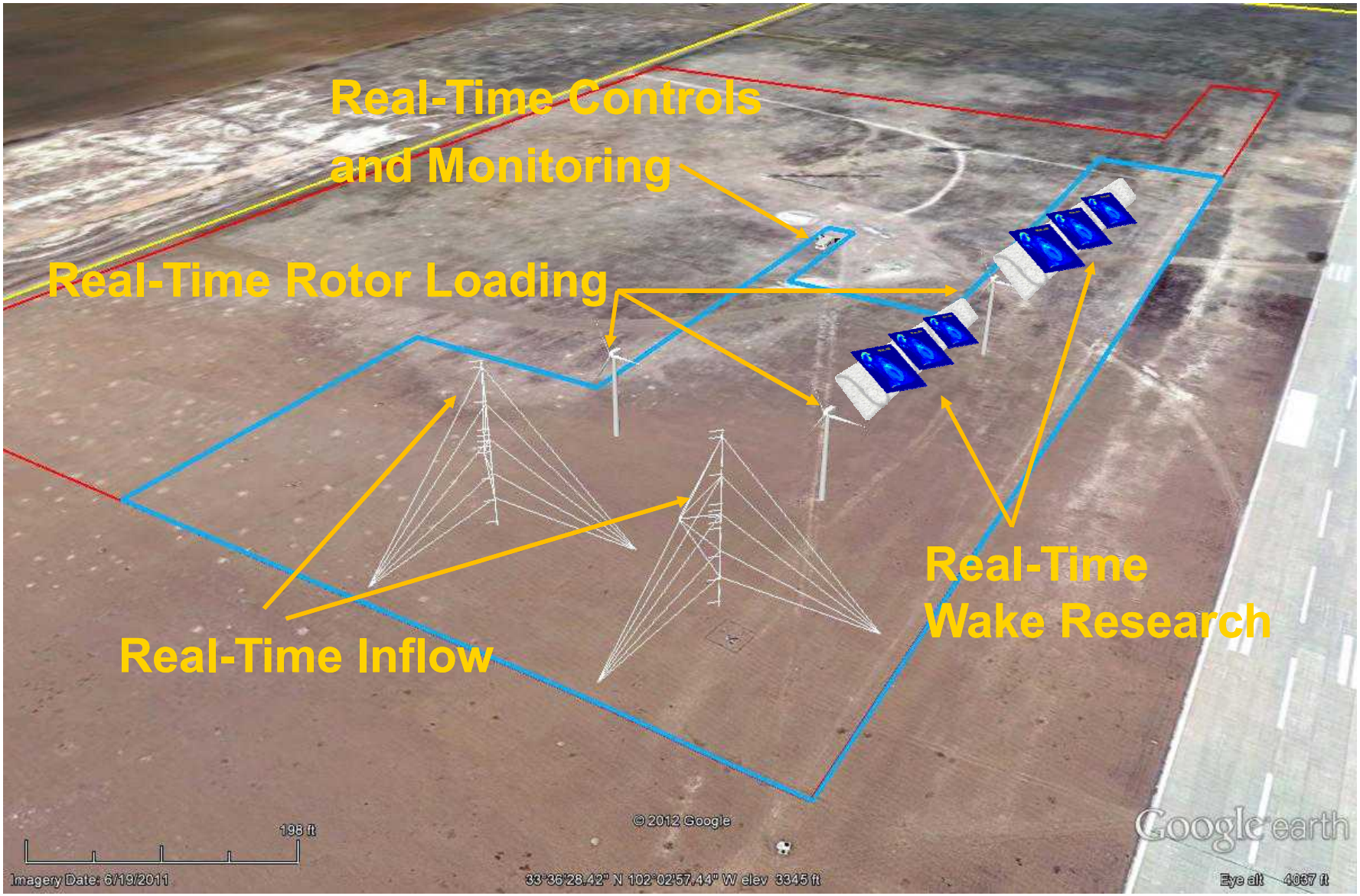

Deep-Row Wake Deficit and Meandering Studies

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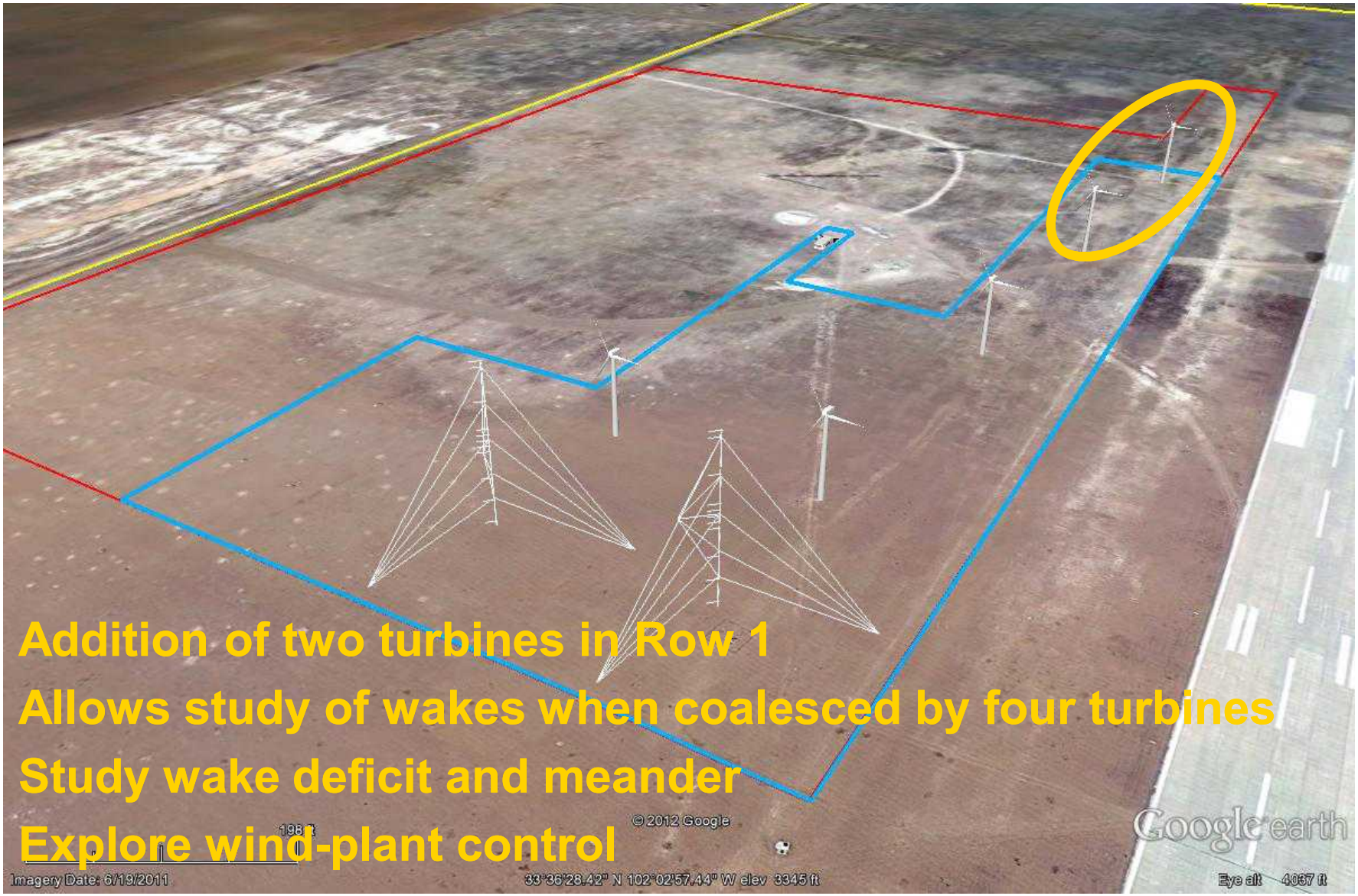

Complex Lateral Wake Merging and Meander