DOE / SNL Scaled Wind Farm Technology (*SWiFT*) Facility at TTU

swift.sandia.gov

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

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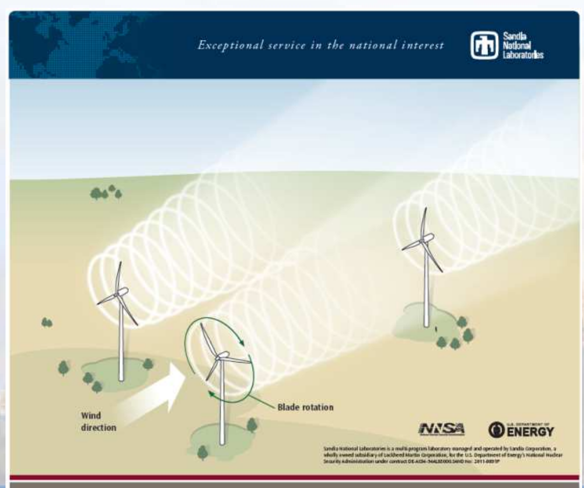
SWiFT Facility

SWiFT exists to:

- Reduce turbine-turbine interaction and wind plant underperformance
- Develop advanced wind turbine rotors
- Public open-source to advance simulation capabilities



Facilities:

- Three variable-speed variable-pitch modified wind turbines with full power conversion and extensive sensor suite
- Two heavily instrumented inflow anemometer towers
- Site-wide time-synchronized data collection

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Outline

- **What is the SWiFT Facility?**
- **What research projects use SWiFT?**
- **How can I use SWiFT?**

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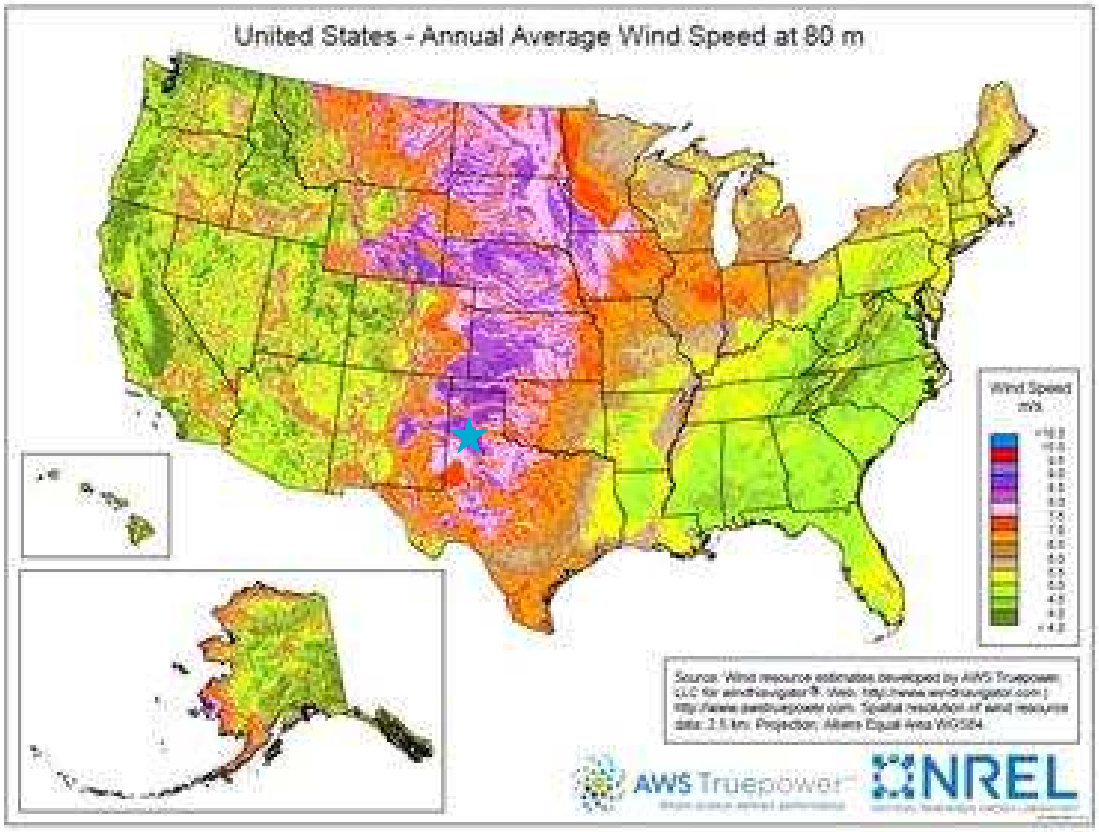
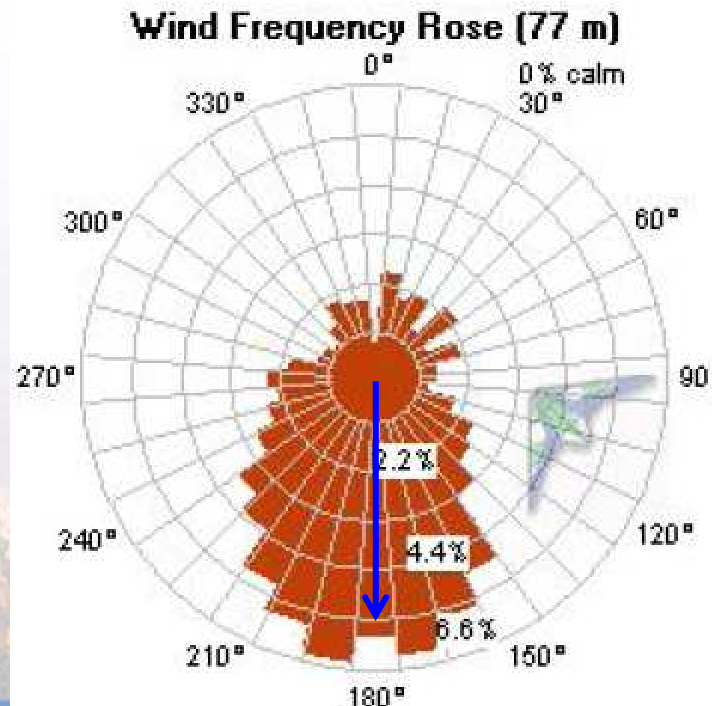
Location, Location, … Location

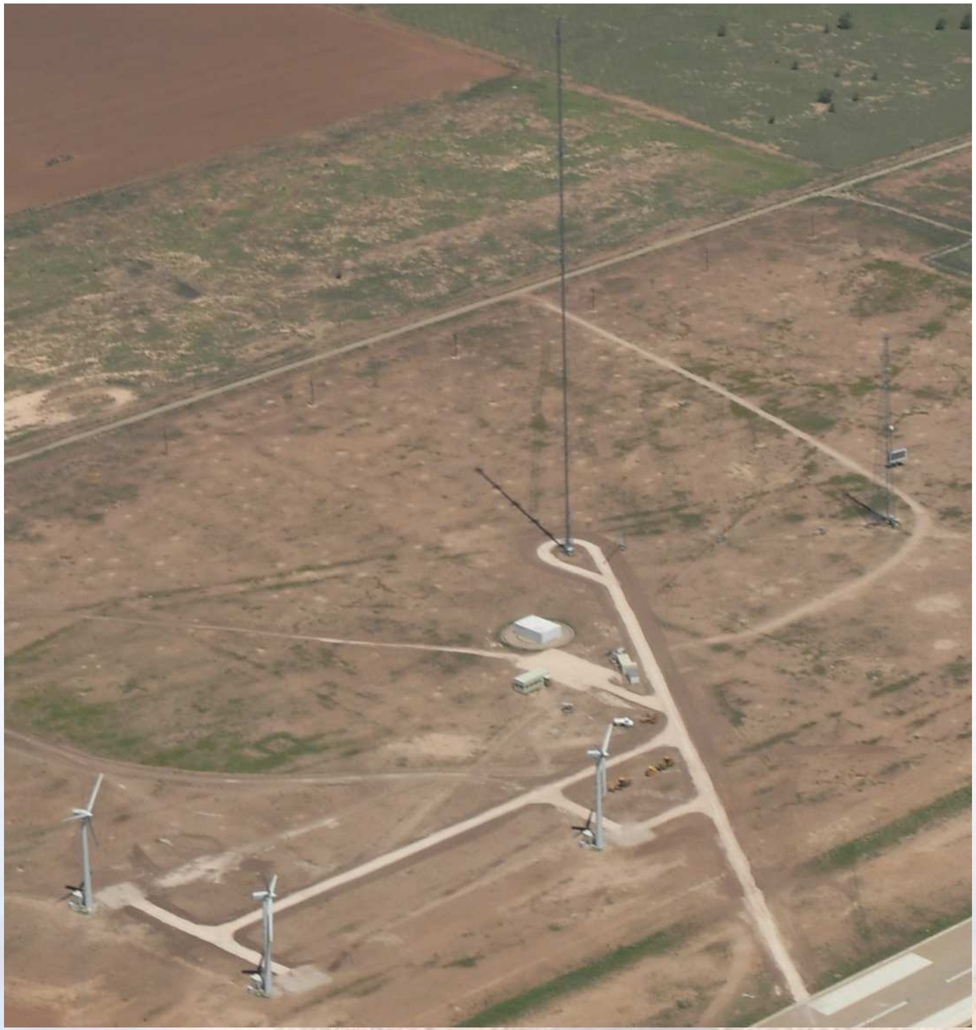


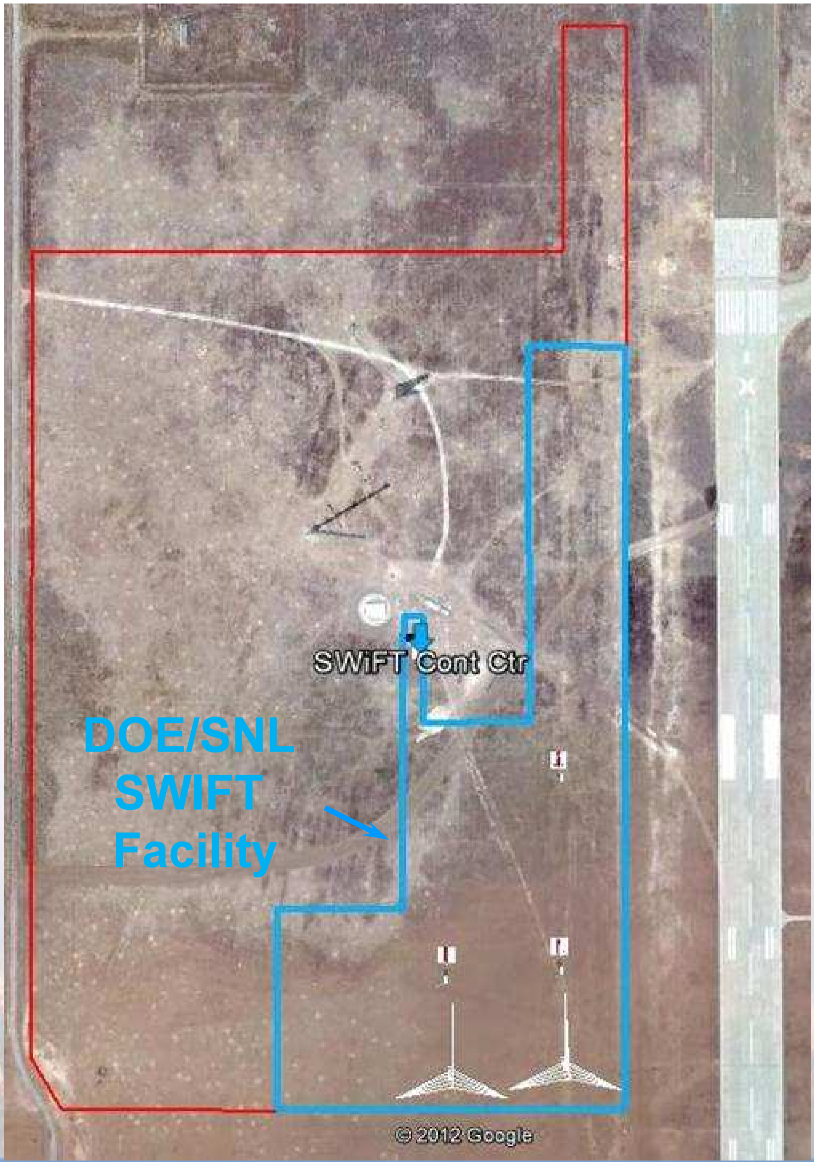
- **7.5 m/s at 50 m, Class 5 Wind Site!**
- **Consistent South Wind, 180.5° Average**



TEXAS TECH UNIVERSITY.

Layout





SWiFT Wind Turbines

Hardware

- Collective Pitch System
- 300 kW Variable Speed Generator
- AC-DC-AC Full Scale Convertor
- National Instruments controllers
- Complete turbine / rotor state instrumentation
- Fiber Optic blade sensing system

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Why this size?

Research-Scale

Minimum research
cost and time

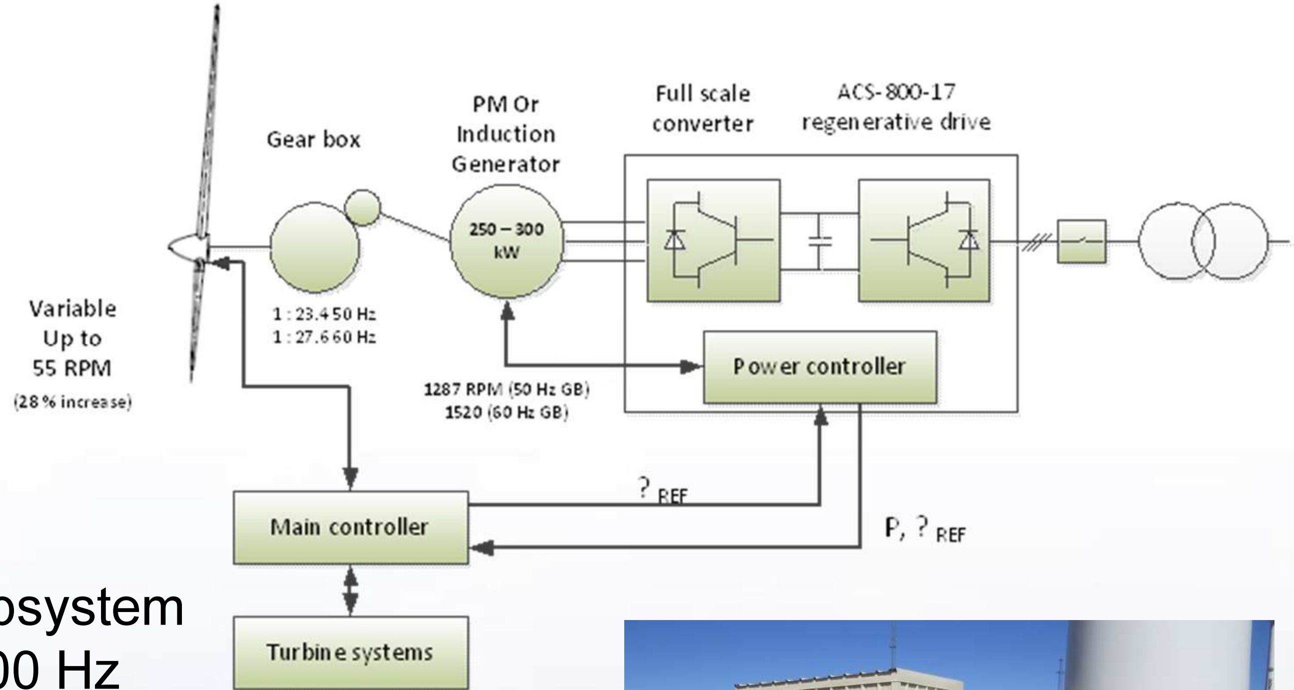
Exact
Scaling

Megawatt-Scale

- **A cost-efficient size for which research can be directly scaled to larger, more costly and time-consuming sizes.**
- **Requirements:**
  - Operation at Reynolds Number (scaling parameter) between 10^6 and 10^7
  - Tip speeds approaching 80 m/s for acoustics and large rotor projects
  - Variable-speed variable-pitch operation
  - Minimal cost and time associated with research operations
  - Highly reliable turbine
  - Minimal restrictions on publication and intellectual property

SWiFT Wind Turbines

Control Software



- Open Source Code
- Modularized by Subsystem
- EtherCAT up to 1000 Hz
- All DAQ signals available for control
- Running on NI Veristand
- Parameterized Variable Speed and Torque Controller
- Maintains all original safety systems and alarms

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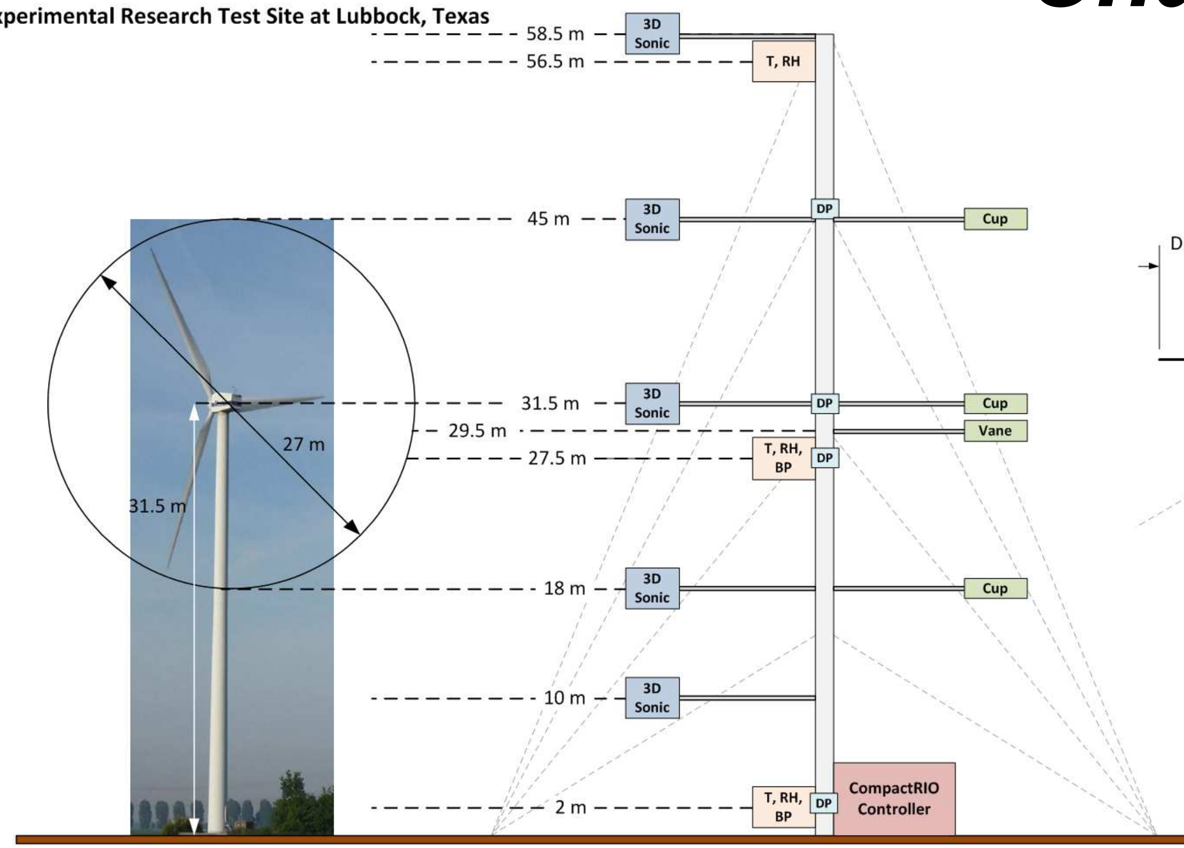
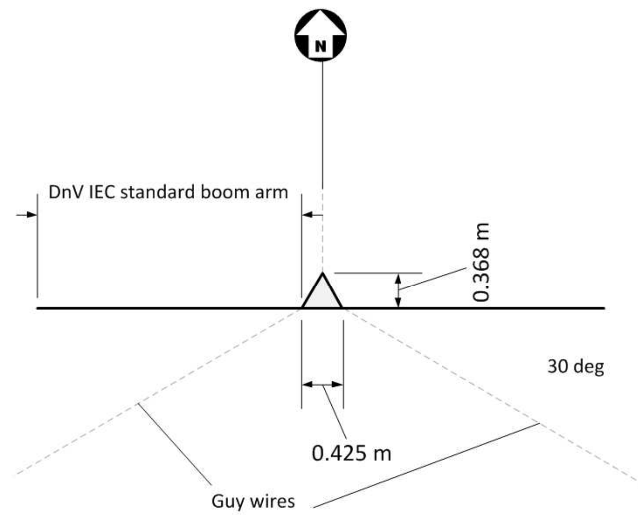
Inflow Characterization

Met Mast Configuration

Experimental Research Test Site at Lubbock, Texas





Met mast sensors

3D Sonic: ATI SATI/3A Sonic Anemometer
Cup: Thies Wind Sensor First Class Advanced (IEC accred)
Vane: Thies Wind Direction Sensor First Class
T: 592 Met One Temperature sensor
BP: 092 Met One Barometric Pressure sensor
RH: 593 Met One Relative Humidity sensor
DP: ATI PAD-401 DataPacker

Met mast heights*

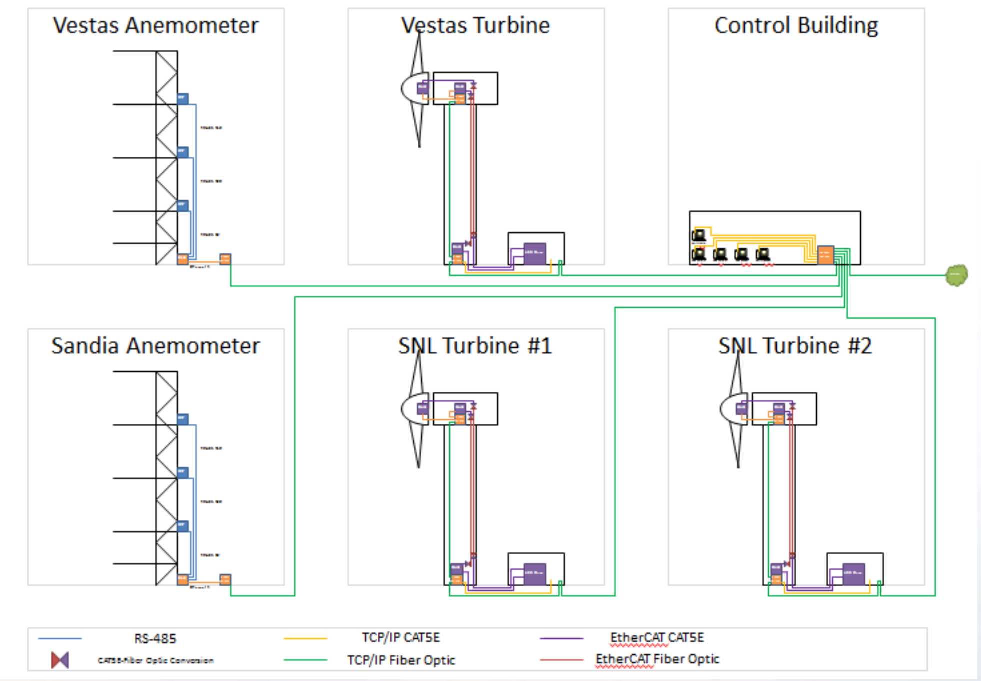
58.5 m: 3D Sonic
56.5 m: T, RH
45 m: 3D Sonic, Cup
31.5 m: 3D Sonic, Cup
29.5 m: 3D Sonic, Vane
27.5 m: T, RH, BP
18 m: 3D Sonic, Cup
10 m: 3D Sonic
2 m: T, RH, BP

Guy wires
Radius 47.5m

57.91 m
45.11 m
29.87 m
14.63 m

Networking Infrastructure

- GPS synced measurements
- Up to 1000 Hz
- Currently 500+ channels
- Centrally logged data
- Fiber optic data transfer
- Localized deterministic control loops



Control Building

- Central control and operations
- 700 sq. ft. with 2 temporary offices for proprietary work
- Electrical troubleshooting lab

Experimental Preparation Lab

- 4,500 sq. ft. environmentally controlled high-bay experimental rotor preparation
- 1,000 sq. ft. machine shop

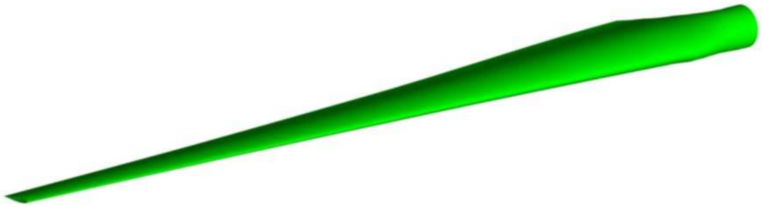
Outline

- What is the SWiFT Facility?
- **What research projects use SWiFT?**
- How can I use SWiFT?

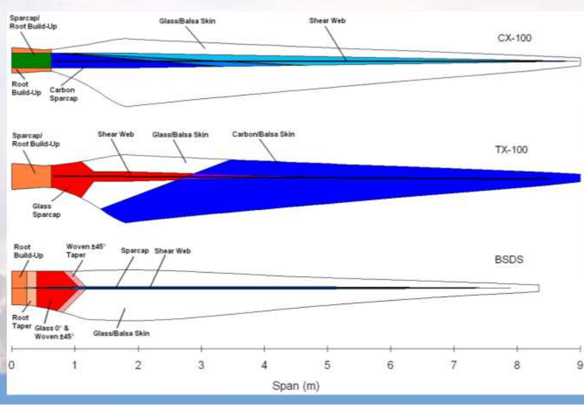
SWiFT Baselining

- Detailed analysis of fundamental turbine-turbine interaction
- Calibration and verification of public open-source wind turbine / plant model
- Data quality analysis and troubleshooting

National Rotor Testbed



- The National Rotor Testbed is a rotor innovation to enable technology acceleration
- Baseline blades represent functionally scaled-down aerodynamics and structural dynamics of a modern megawatt-scale rotor
- Baseline blade design is public and open
- Enables research in: wake interactions, aero-acoustics, inboard aerodynamics, controls, aeroelastic dynamics



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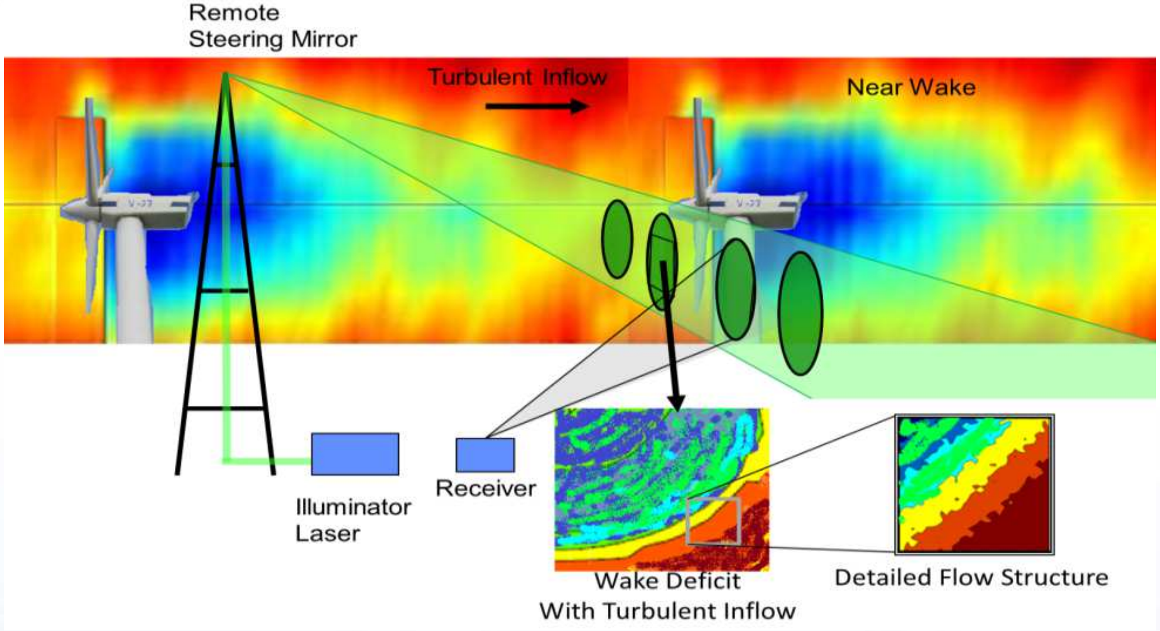
Wake Imaging Measurement System



- Capture detailed 3-D flow structures that convect downwind
- High spatial resolution: 16,000 data points per sample
- Imaging allows for fast scanning sufficient to capture sub-rotor scale turbulent flow structures
- Enables direct comparison with high-fidelity and engineering level models

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Future SWIFT Research Ideas

- Partnership opportunities:
  - Rotor design for wind plant (wake reduction)
  - Quiet rotor design
  - Active / passive load control
  - CM and SHM validation testbed
  - Blade repair validation rotors
  - Stealth rotor
  - Advanced materials rotor testing
  - Component field testing (sensors, blades, controllers, etc.)
  - Land-based offshore simulator

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How to partner

- SWiFT is open to all partnership opportunities:
  - Partners include industry, academia, laboratories, etc.
  - Facility has been designed to minimize research cost
  - Public, public / proprietary and solely proprietary all possible
  - Partnership agreements include:
    - Work For Others (WFO)
    - Collaborative Research and Development (CRADA)
    - Memorandum of Understanding (MOU)
    - Joint Funding Opportunities (FOA)

Partnership Examples

- **Vestas** installed a turbine owned by Vestas and managed by Sandia as a technology accelerator for their product development (rotors, acoustics, wind plant control)

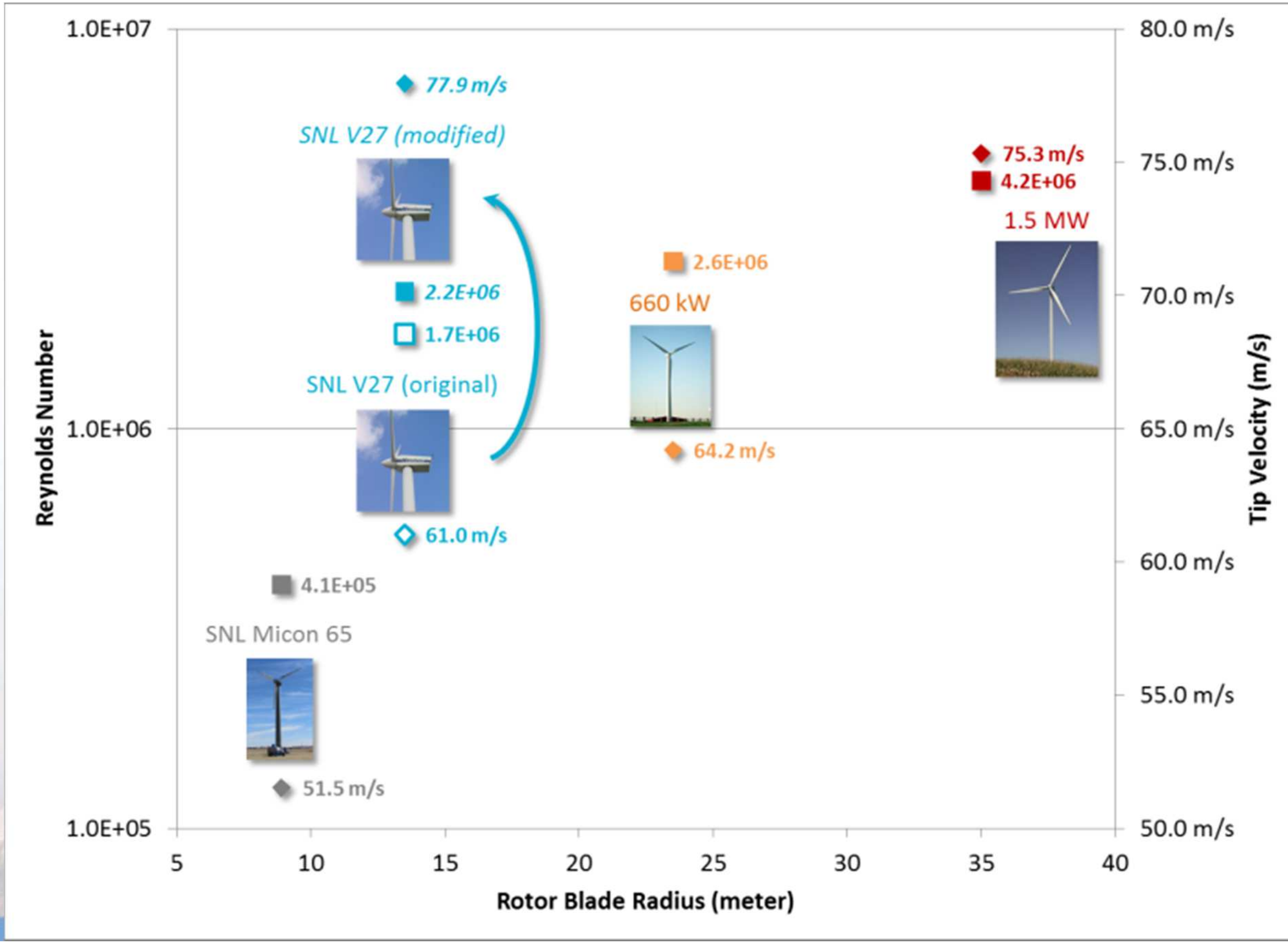
- **National Instruments** is co-developing cRIO hardware and Veristand software for distributed control

- **ABB** is using power electronics equipment to improve wind market products

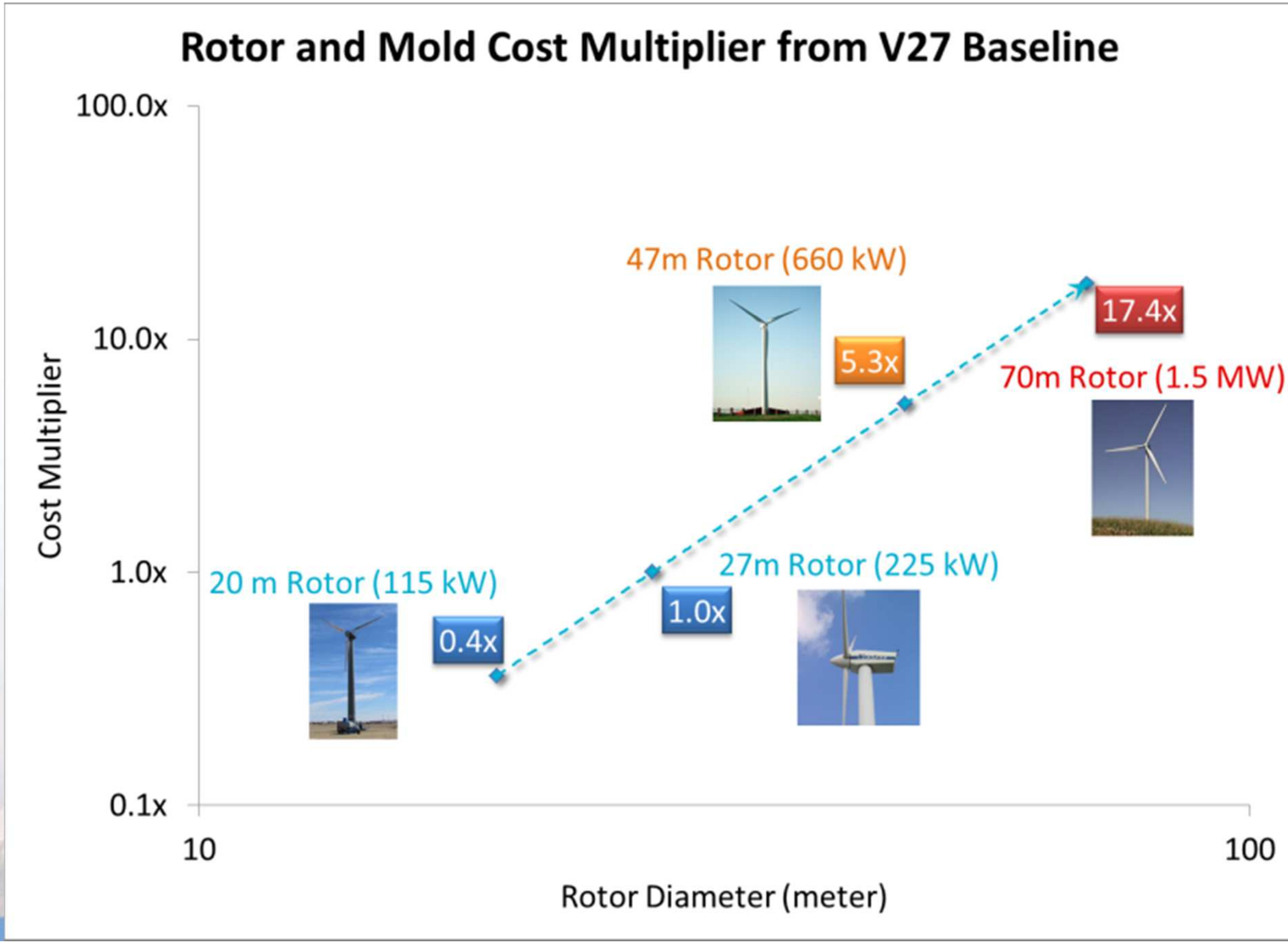
Thank you!

Backup Slides

Aerodynamic Scaling



Cost Efficiency



Crane Cost Comparison

Research Scale (225 kW)

Megawatt Scale

Costs

$5,000 v. $250,000

Scheduling

Days Ahead v. Months Ahead

Testing Risk

Low v. High

National Open-Source Research Asset

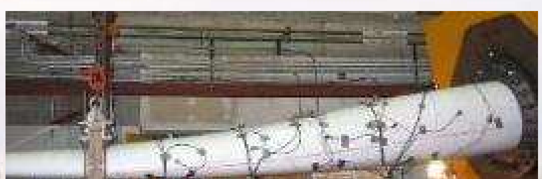
DOE / SNL Rotor Blade Designs

DOE / SNL FAST / ADAMS Model of V27

Feasibility Proof **Technology Demonstration** **Commercialization**

TRL-1 **TRL-2** **TRL-3** **TRL-4** **TRL-5** **TRL-6** **TRL-7** **TRL-8** **TRL-9**

Basic Research **Technology Development** **Sub-Scale Testing**



DOE / SNL Advanced Blade Testing at NREL-NWTC

DOE / SNL SWIFT Facility at TTU

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Research-Scale
Examples of Success

Risø DTU
National Laboratory for Sustainable Energy

DTU

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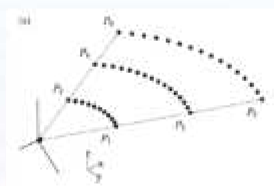
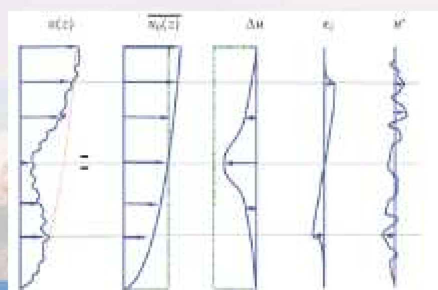
- *"Light detection and ranging measurements of wake dynamic Part I & II" 2011*

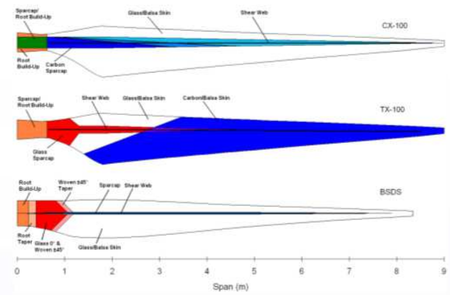
LIDAR Scanning of 95 kW Turbine Wake



Decomposition of Wake Deficit



- CX / TX / BSDS Blade Family Study



Fabrication and Testing at the 115 kW Scale

tpi

USDA United States Department of Agriculture
ars Agricultural Research Service
Conservation & Production Research Laboratory

Result: **24% reduction in damage equivalent load and initiated industrial use of carbon, flatback airfoils and twist-bend coupling.**

DOE/SNL/TTU Partnership

- ***Wind Science and Engineering Research Center (WISE) has a 40 year history in wind-related research and development***
- ***Unique Capabilities and Facilities***

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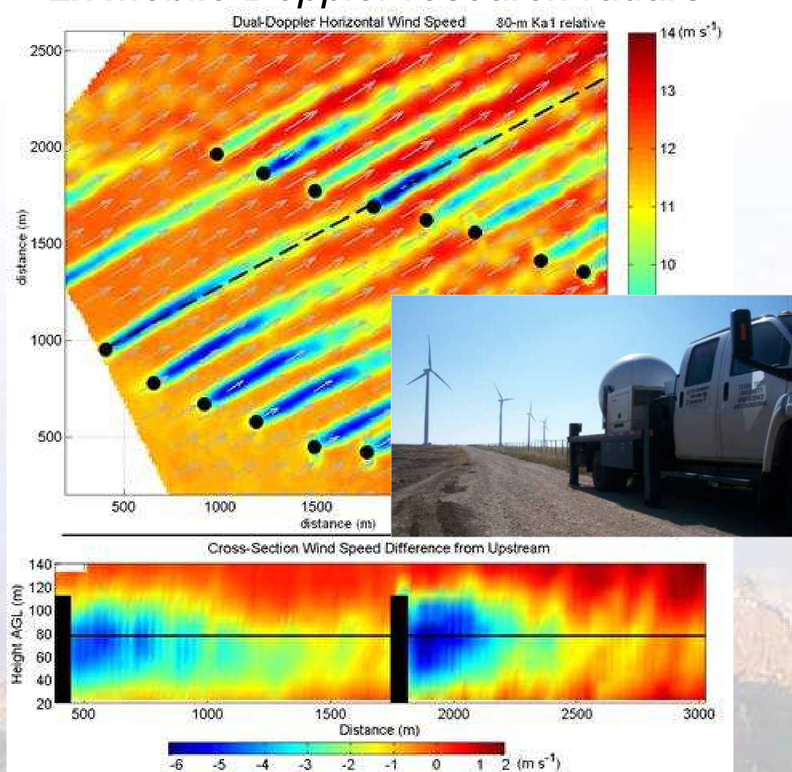
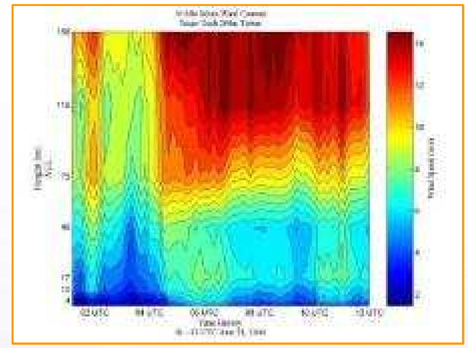
Distributed Wind Resource Assessment

2x mobile Doppler research radars



Large-scale Test Infrastructure

200 meter anemometer tower



MW Wind Turbines

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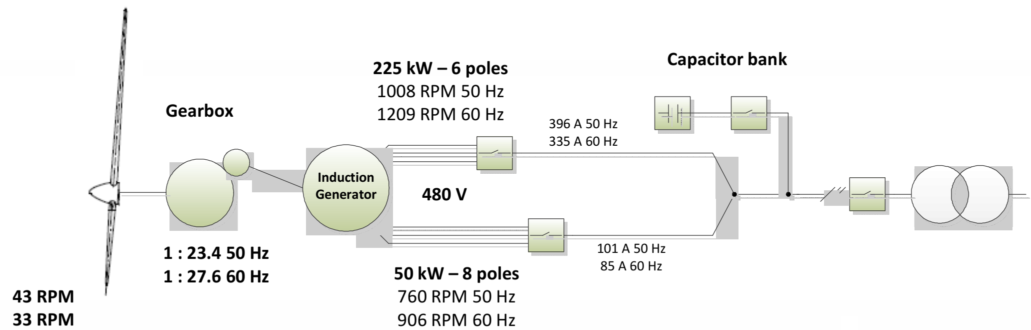
Variable-Speed Upgrade

Fixed Speed



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Vestas

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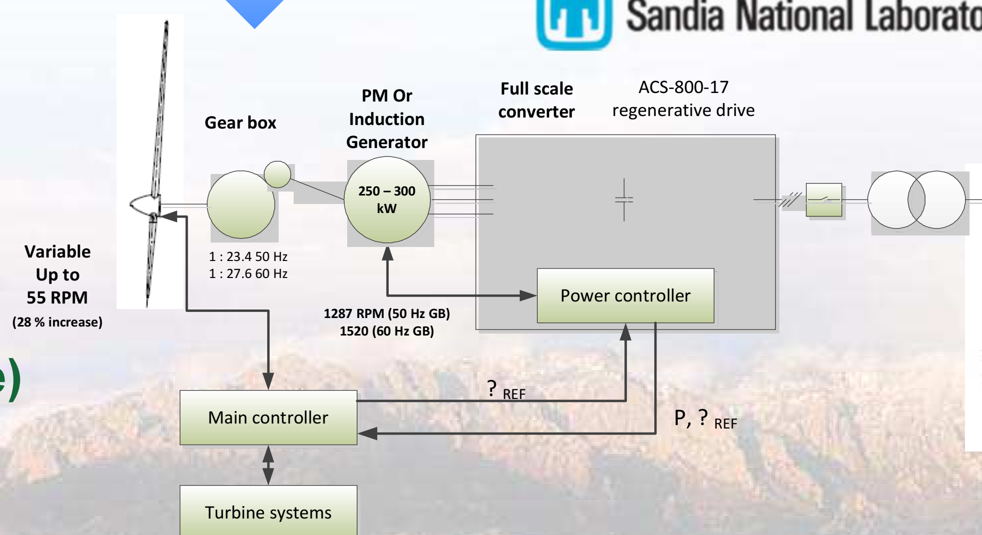
DOE/SNL Variable Speed (Open-source)



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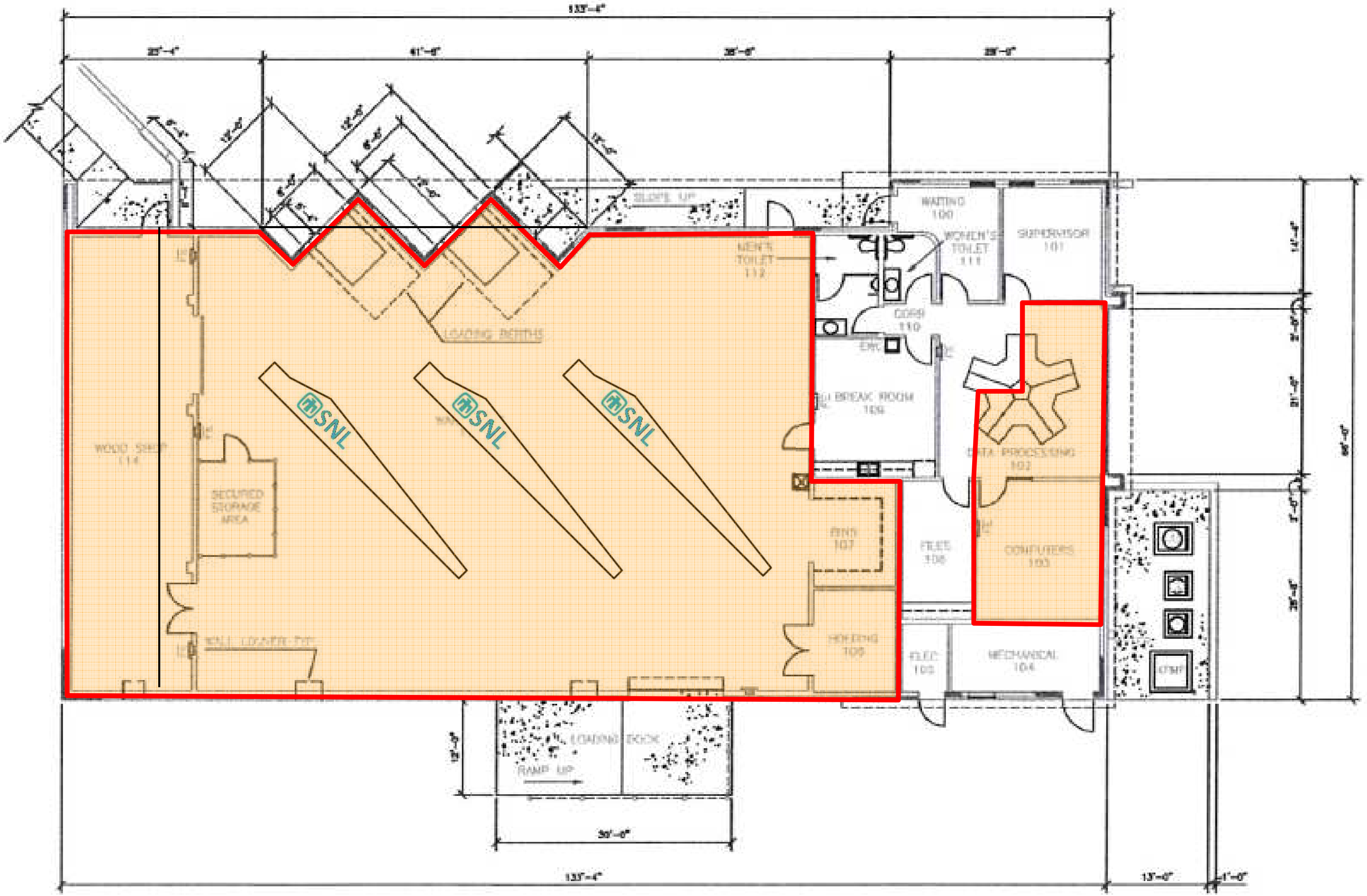
Re-purposed Assembly Building



Site Construction

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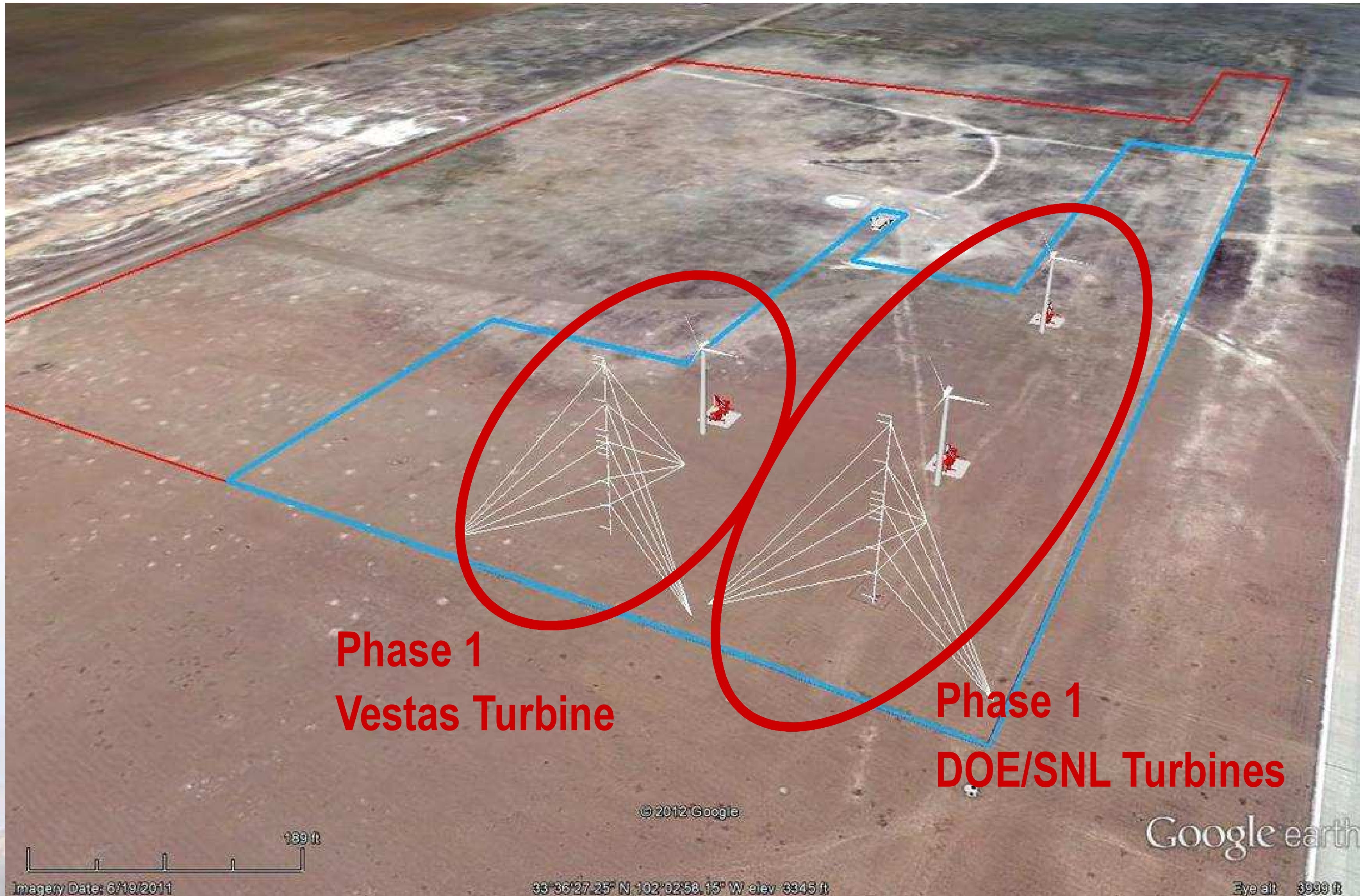
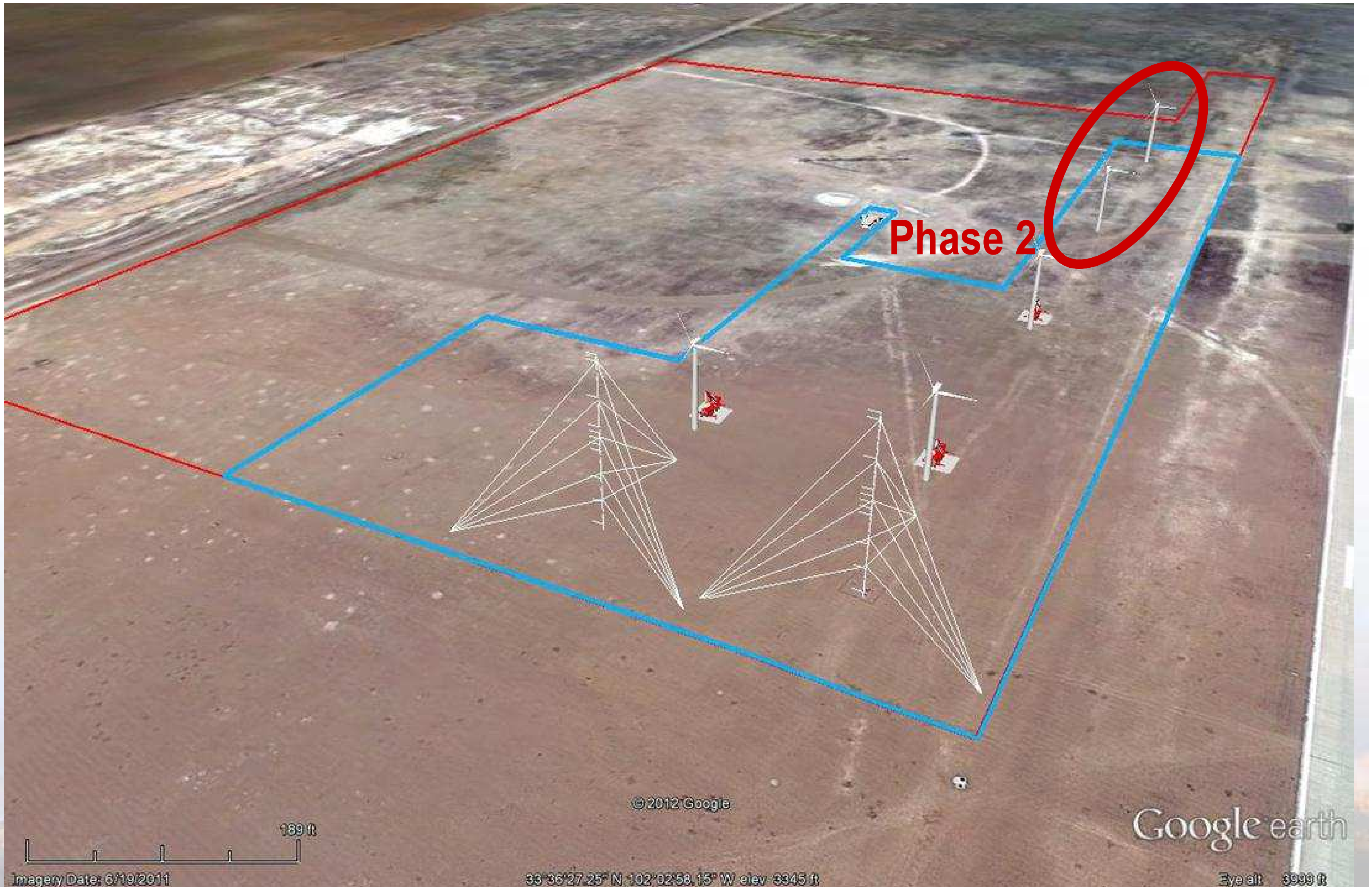
Anemometer Tower

SWIFT Array Long-Term Plan



SWIFT Array Long-Term Plan



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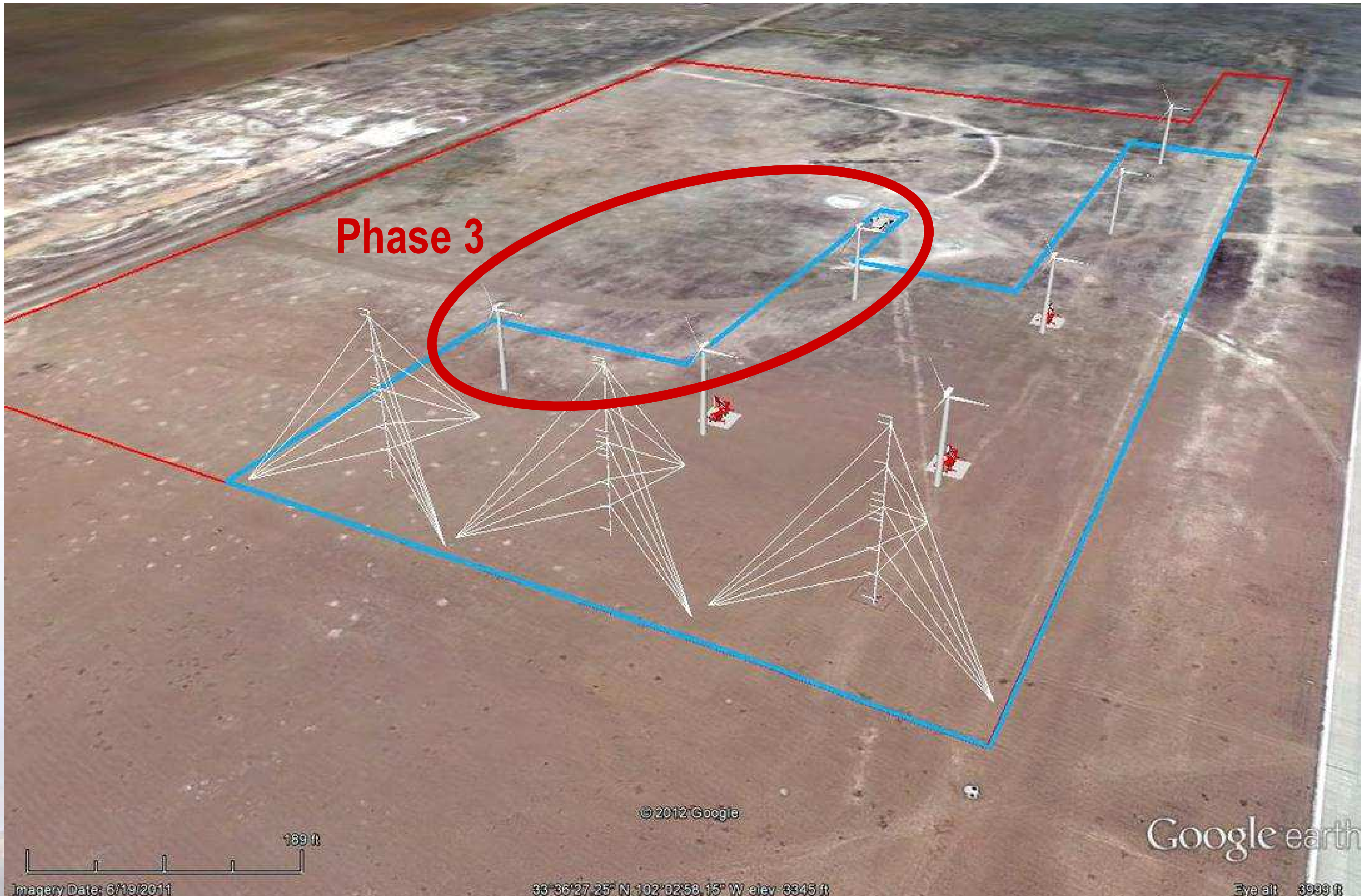

SWIFT Array Long-Term Plan