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Modeling and Data Analysis Challenges in (Renewable) Energy

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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.

Outline

- Introduction & Overview
  - My Role
  - Key Concepts
  - Data Challenges
- Examples
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  - Photovoltaic Reliability
- Closing

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Introduction & Overview

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Introduction – My Role

- **My "home" departments:**
  - **System Readiness & Sustainment Technologies**
  - **Military Systems & Analysis**
- **My energy projects**
  - **Wind Plant Reliability**
    - Matrixed 50% to Wind Energy Technologies department
  - **Power Electronics Reliability**
    - Partnering with Energy Infrastructure department
  - **Geothermal Plant Reliability**
    - 2008 small business project to demonstrate proof of concept

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Introduction – ISOs

- **ISO: Independent System Operator**
  - **Formed under FERC's direction (FERC: Federal Energy Regulatory Commission)**
  - **Role: coordinate, control, and monitor operation of electric power system**

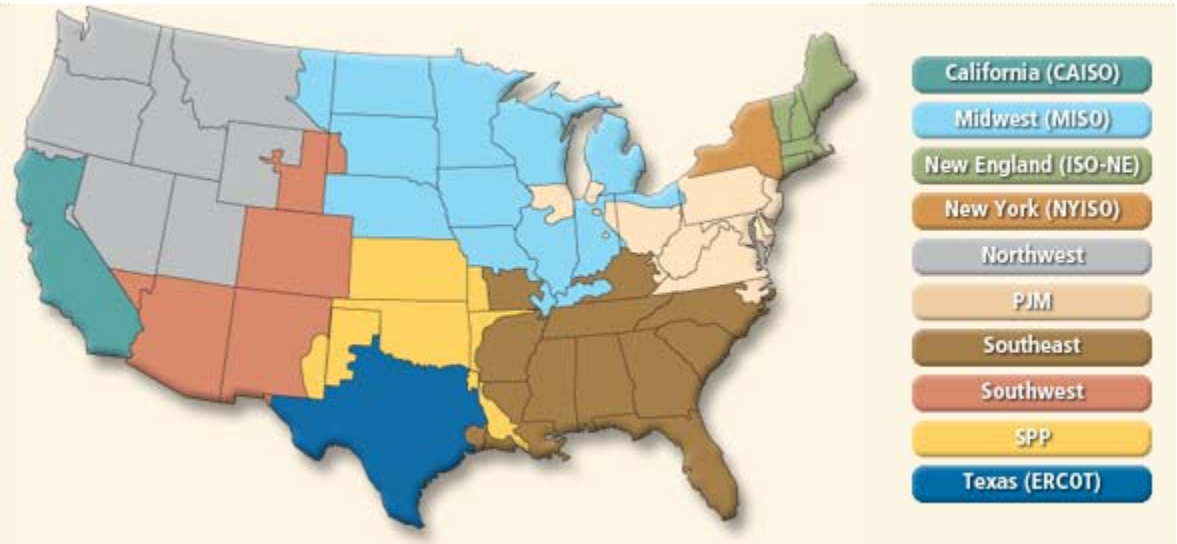

Image Source: FERC: http://www.ferc.gov/market-oversight/mkt-electric/overview.asp
Source: Wikipedia, http://en.wikipedia.org/wiki/Independent_System_Operator

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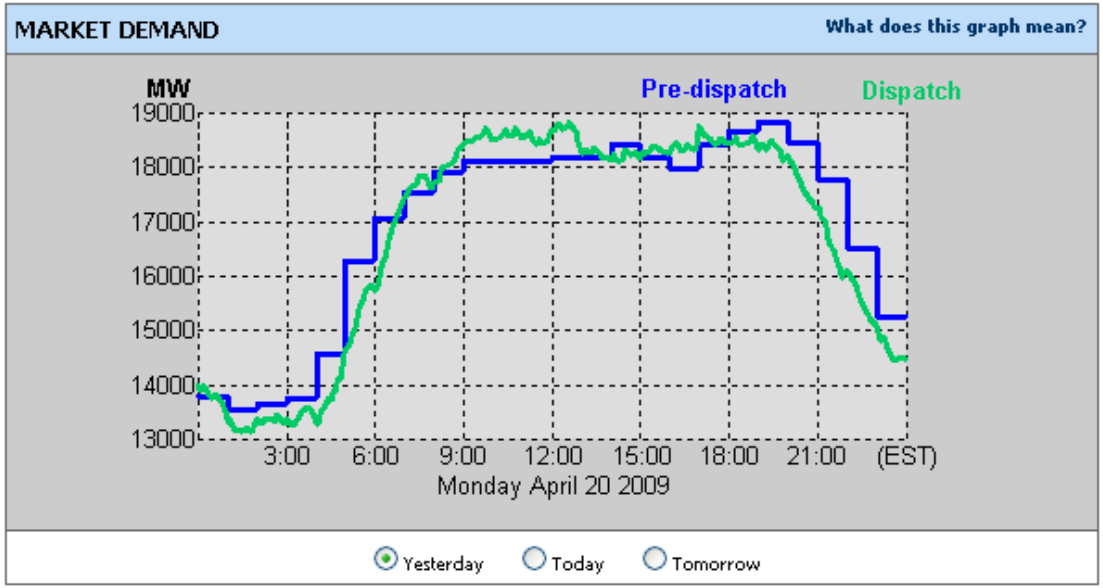
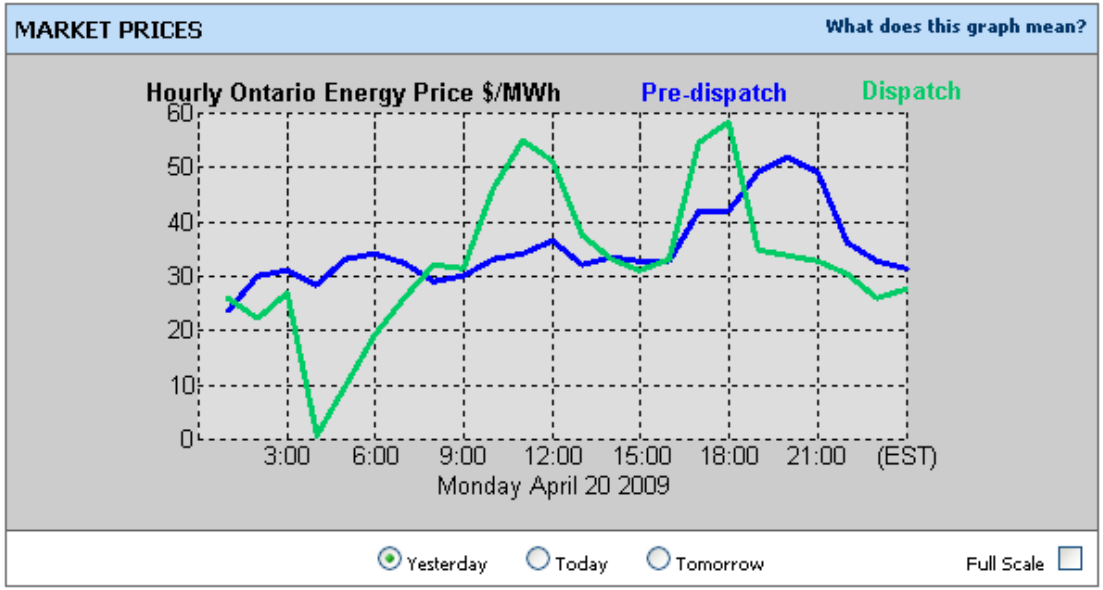
Introduction – Markets

Market Demand: total volume of transactions (local + export)
- **Pre-dispatch**: highest demand expected + economic exports
- **Dispatch**: actual volume of electricity sold



Market Prices: hourly energy price *(for each hour, average of five-minute market prices)*
- **Pre-dispatch**: projected prices
- **Dispatch**: actual price



Source: IESO: http://www.theimo.com/imoweb/marketdata/marketToday.asp

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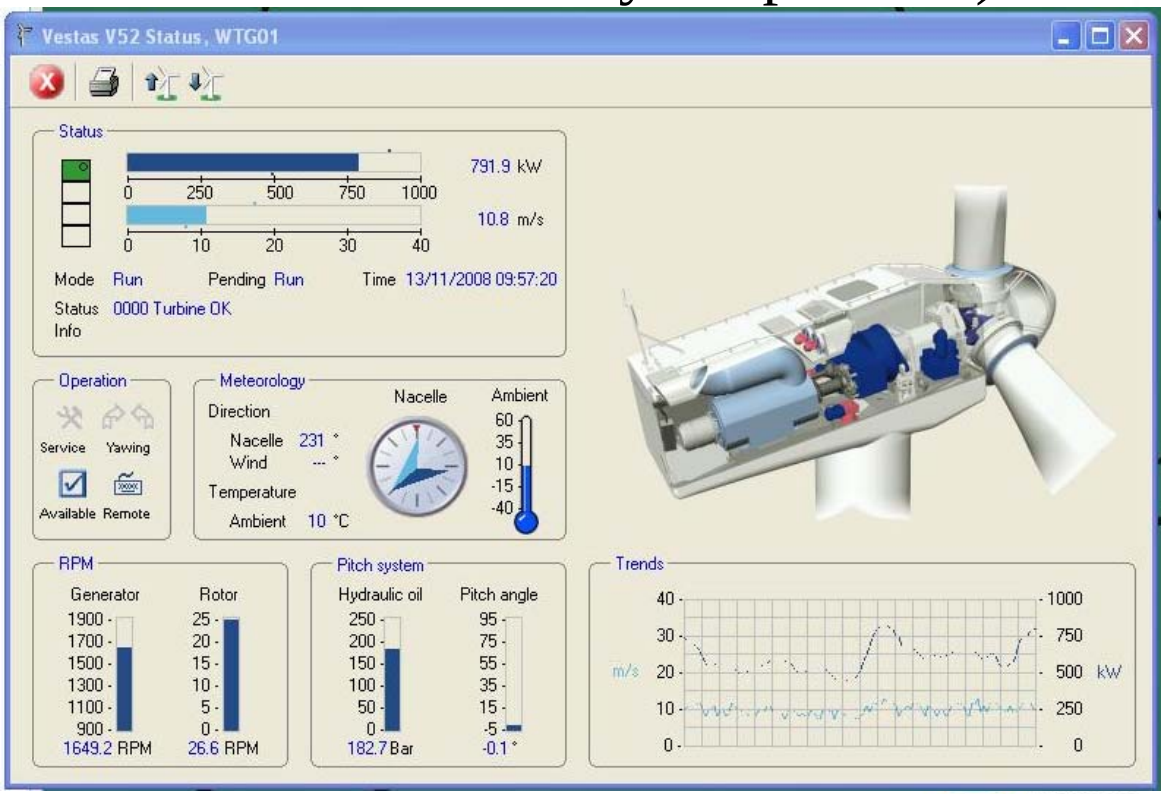
Introduction – SCADA

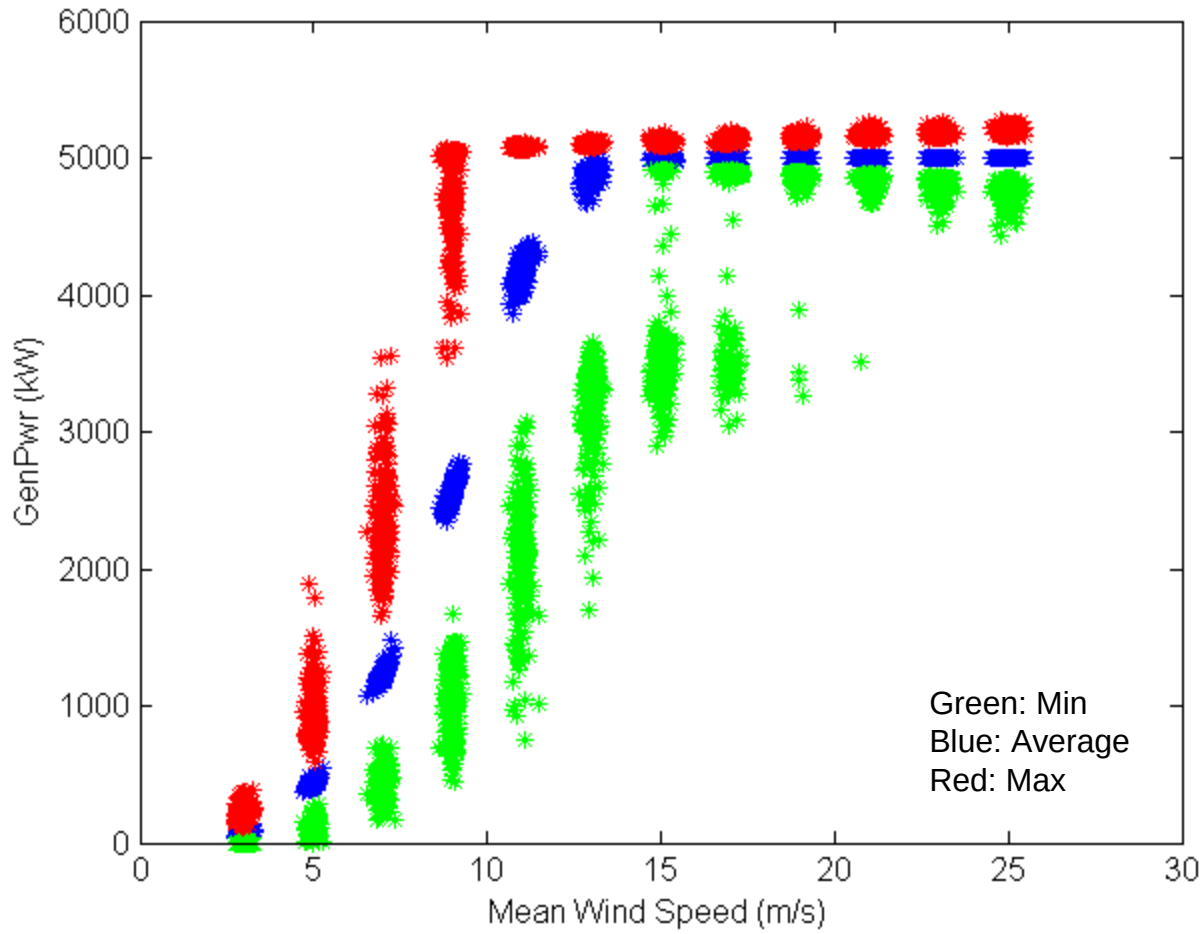
- **SCADA: Supervisory Control And Data Acquisition**
  - **Computerized industrial control system**
- **All modern electrical generation has some type of SCADA**
  - NERC (North American Electric Reliability Corporation) specifies electrical system data should captured by the millisecond



Source: Wikipedia: http://en.wikipedia.org/wiki/SCADA

Image Source: University of Exeter: http://www.exeter.ac.uk/cornwall/academic_departments/csm/research/renewable-energy/images/scada.jpg

Introduction: SCADA Example Wind Power Curve



Source: National Renewable Energy Laboratory, Pat Moriarty

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Data Challenges for Energy

- SCADA provides lots of input & output
- Complex business & regulatory environment
  - National grid, regional regulation, local utilities
  - Day ahead, hour ahead, 15 minute markets
  - Simultaneously a business industry (private control) and a utility (public control)
- Great variety in the types of generation and load needs

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Data Challenges for Renewables

- **Predicting "fuel" (wind, sunlight) more difficult**
  - **All the challenges of the existing generation technologies, plus meteorological prediction**
- **Even more data is available**
  - **Equipment is new & has many sensors**
  - **Orders of magnitude more generators**
    - **Gas Turbine Plant: 1-4 generators**
    - **Wind Turbine Plant: 20-500 generators**
      - IID not a valid assumption for co-located generators relying on same fuel
- **Outdoors → meteorological data is required for operations**

- **Renewables are necessary, but currently most are more expensive than traditional technologies**
  - **How can good analysis help drive down cost?**

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Example – Wind Plant Reliability

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Wind Plant Reliability – Mission

- **DOE/Sandia Project**
- **Mission**
  - **Characterize reliability performance issues and identify opportunities for improving reliability and availability performance of the national wind energy infrastructure**
- **Logistics**
  - **In 2008, there were 25,300 MW of wind installed (~17,000 turbines)**
  - **DOE/Sandia Goal: Track 10-30% of the US Fleet**
    - For 30%, for 5 years of data

      ~10 Million downtime Events

      ~800 Billion 1-second SCADA readings (per data stream!)

Source: AWEA, Annual Wind Energy Industry Report. April 13, 2009.

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Wind Plant Reliability – 20% Report

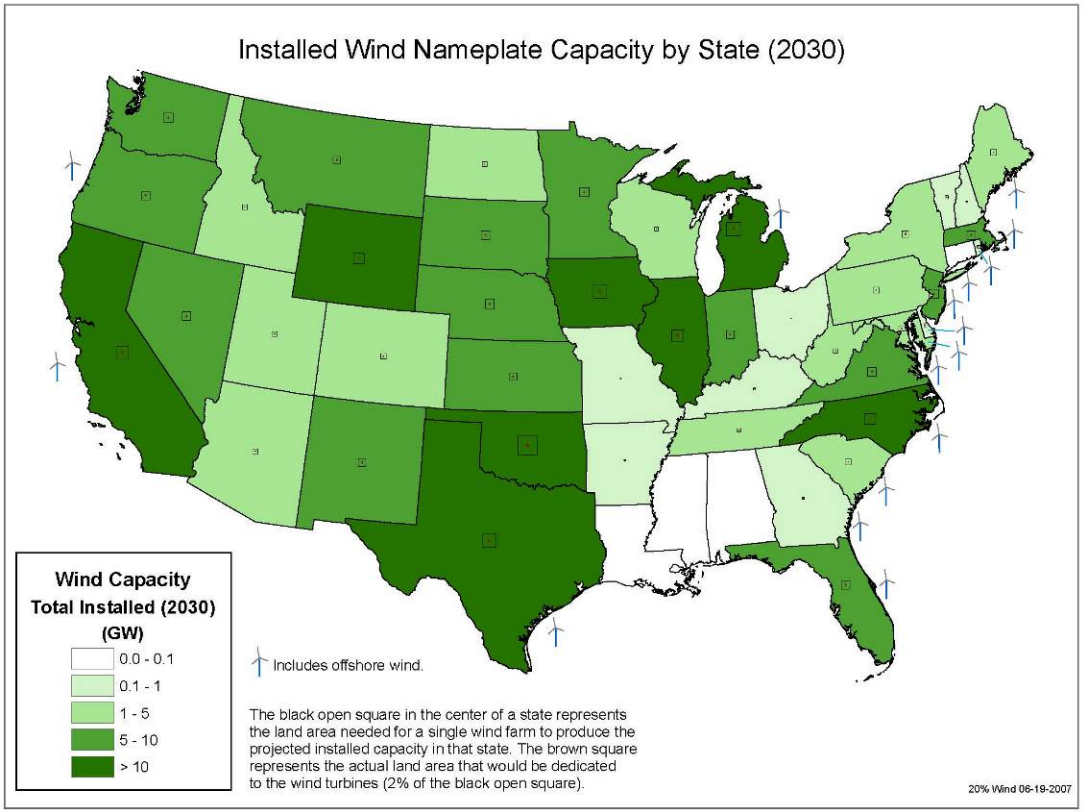
20% (Wind) Report: Challenges for Reliability

- **Requires**
  - **Massive growth in installations**
    - ~12GW in 2006 → 300+GW in 2030
  - **Increases in technology performance**

    Capital cost: down 10%

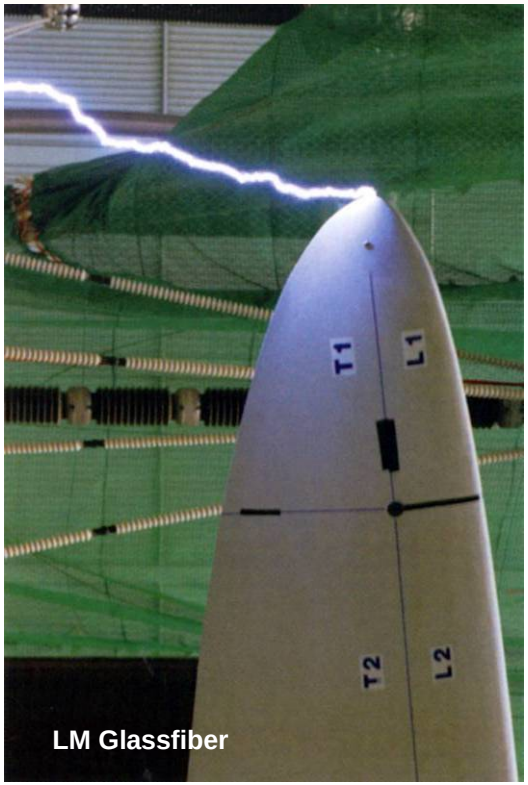
    Capacity Factor: up 15%

    O&M cost: down by 35%



Source: Sandia, Dr. Paul Veers

Wind Plant Reliability – Initiative Phases

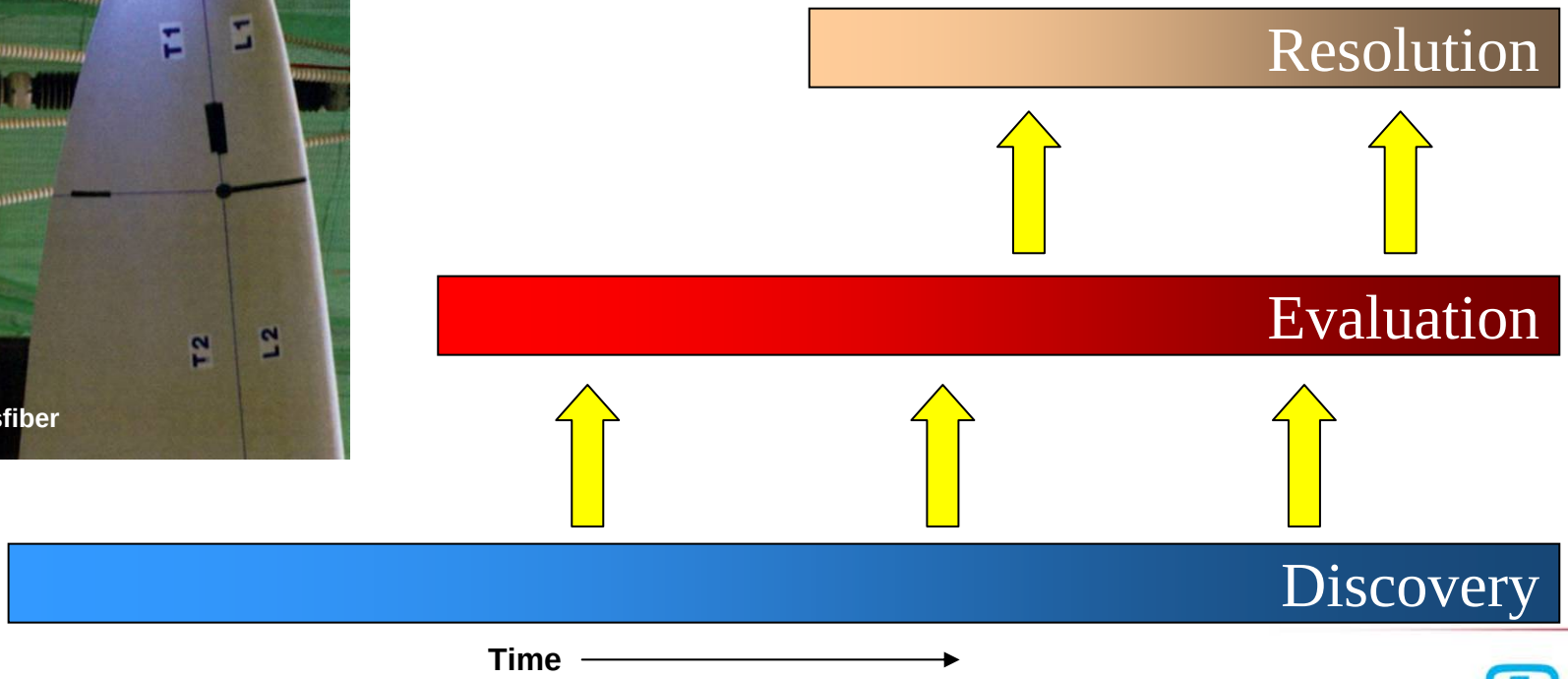


3 Phases of Reliability Improvement Initiative

Discovery **– Define the nature and extent of the issues:**
Focused on field work and full-scale testing

Evaluation **– Characterize the issues and evaluate mitigation:**
Focused on laboratory testing and inspection

Resolution **– Validate the methods of resolving specific issues:**
Targeted R&D to solve specific problems



Source: Sandia, Dr. Paul Veers

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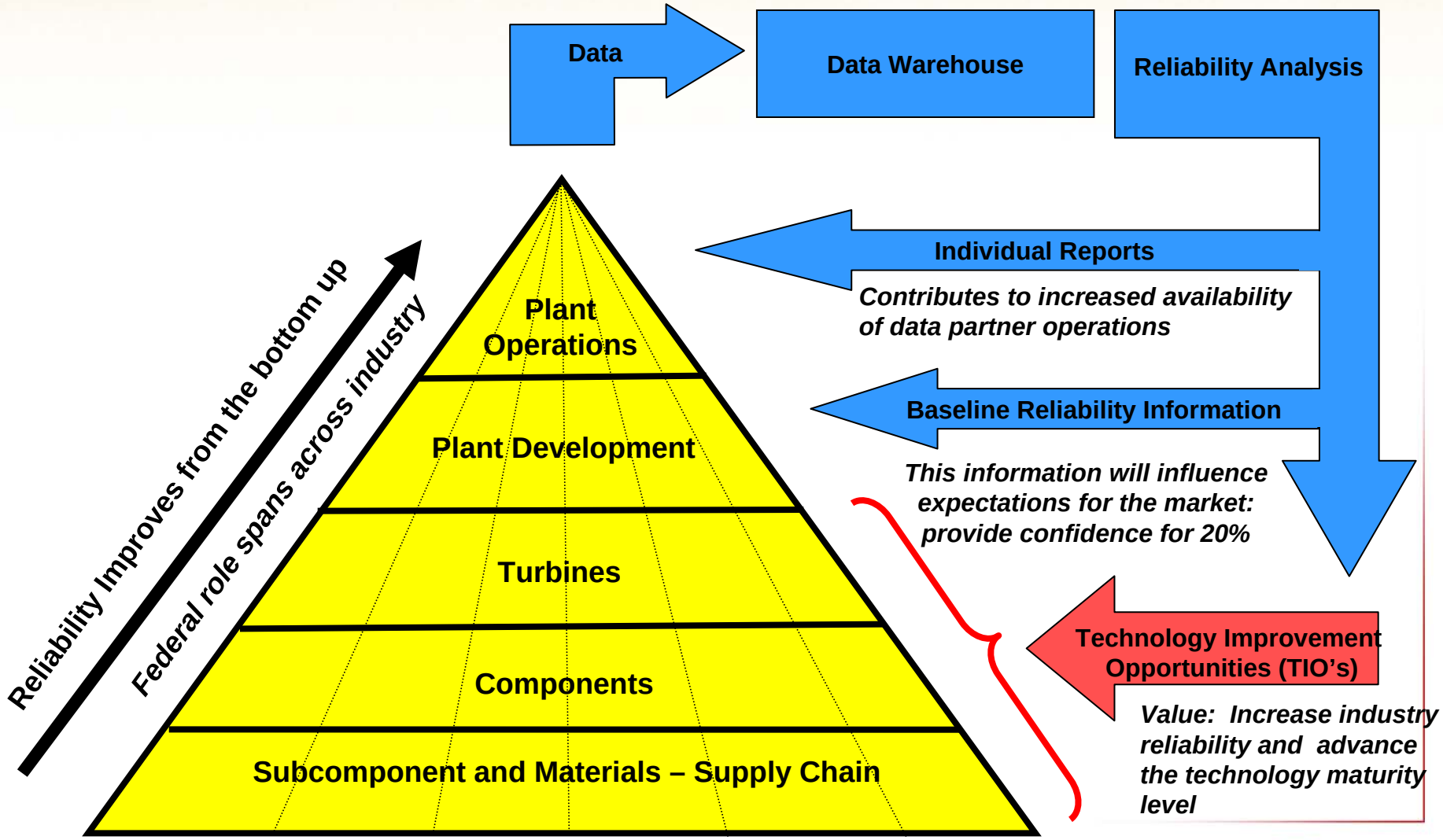
Wind Plant Reliability – Collaboration Framework



Data Driven Analysis Improves Reliability

Source: Sandia National Laboratories, Roger Hill

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Example – Photovoltaic Reliability

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Photovoltaic Reliability – Mission

Apply Sandia's extensive technical resources to create a suite of PV-specific reliability tools to enable reliability growth

Project structured into 5 Tasks:

- **Predictive Model Development**
- **Real-time Reliability Studies**
- **Accelerated and Diagnostic Testing**
- **Industry Outreach and Standards Support**
- **Mitigation and Failure Analysis efforts**

Source: Sandia National Laboratories, Jennifer Granata

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Photovoltaic Reliability – Mission, *cont*

Overall impact of a successful Reliability Program:

- **Achieve Grid Parity with other electrical generation sources:**
  - **Costs**
    - Reliable products reduce LCOE
      - LCOE ("Levelized Cost Of Energy"): break even price energy must be sold for; includes installation, operations & maintenance, fuel, etc.
  - **Availability**
    - Reliable products enhance amount of energy produced and delivered to the grid with reduced operations & maintenance costs

Source: Sandia National Laboratories, Jennifer Granata
Source: Wikipedia, http://en.wikipedia.org/wiki/LCOE

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Photovoltaic Reliability – Data Needs

- **Data Needs for reliability predictions**
  - **Field Operations & Maintenance and failure data**
  - **Component degradation rates**
  - **Component accelerated life test data**
  - **Transfer functions**
    - Correlations between real time and accelerated test data
  - **Failure statistics**
  - **Performance data**
  - **Weather/Metrological data**

Source: Sandia National Laboratories, Jennifer Granata

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Photovoltaic Reliability – Data Challenges

- **Data Challenges**
  - **Not all data exist**
  - **Owners unwilling to share data**
    - May be seen as proprietary or as a “competitive edge”
  - **Operations & Field data**
    - Collection is sporadic
    - Methods differ by location
  - **Degradation data**
    - Takes years to collect; requires well-instrumented systems in various climates/environments
    - Technologies change quickly –10 year degradation rates may not be relevant to new installations
  - **Accelerated Life Testing**
    - How to ensure its actually accelerating the field failure mode

Source: Sandia National Laboratories, Jennifer Granata

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Closing

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Other Areas for Modelers

- Wind/Weather prediction
- Physical modeling of components
- Economic modeling
  - Energy supply & demand
  - Equipment/component supply & demand
  - Effects of policy
- Industry support
  - Manufacturing
  - Transportation
  - Supply/Repair chains
- Etc.

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Closing Thoughts

- **Challenges for Modelers**
  - **Lots of data (both a blessing & a curse)**
  - **Goal is to consolidate data into actionable information**
- **Renewables industry anxious for help, but**
  - **Nervous about sharing**
  - **Facetime with experts is hard to get (fast growing industry with lots of national spotlight)**
  - **Smaller plants & smaller operators don't have staff with time to understand modeling**