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DOE/SNL Wind Energy Reliability Program

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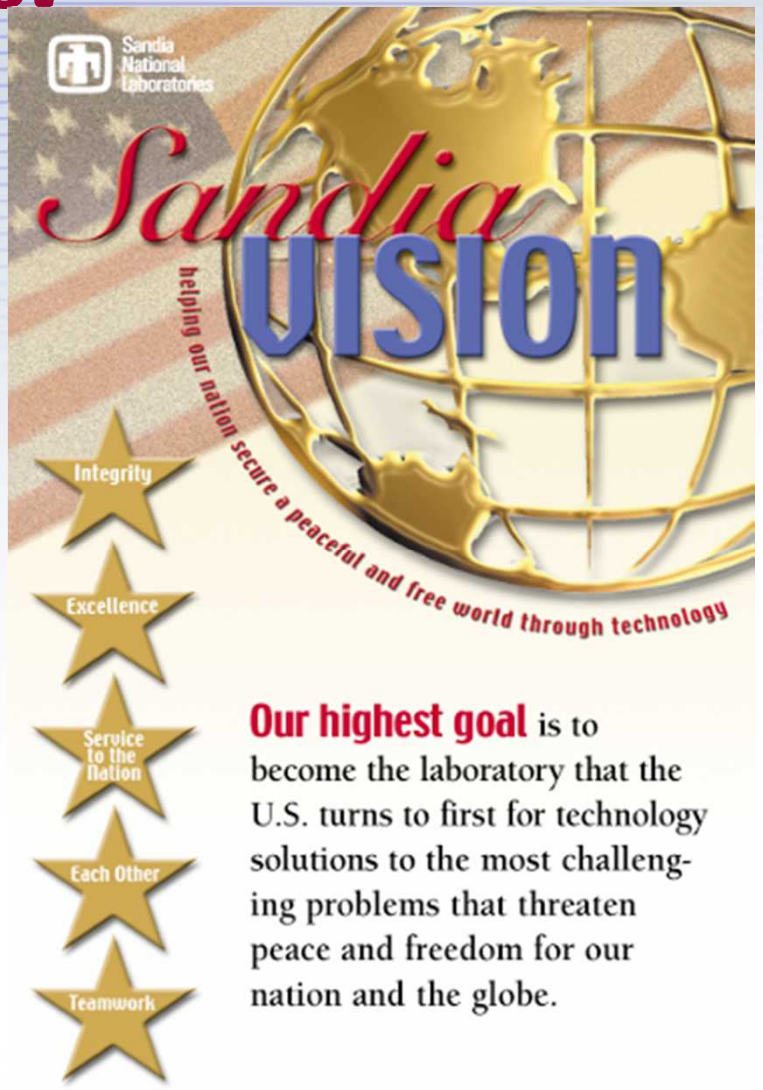
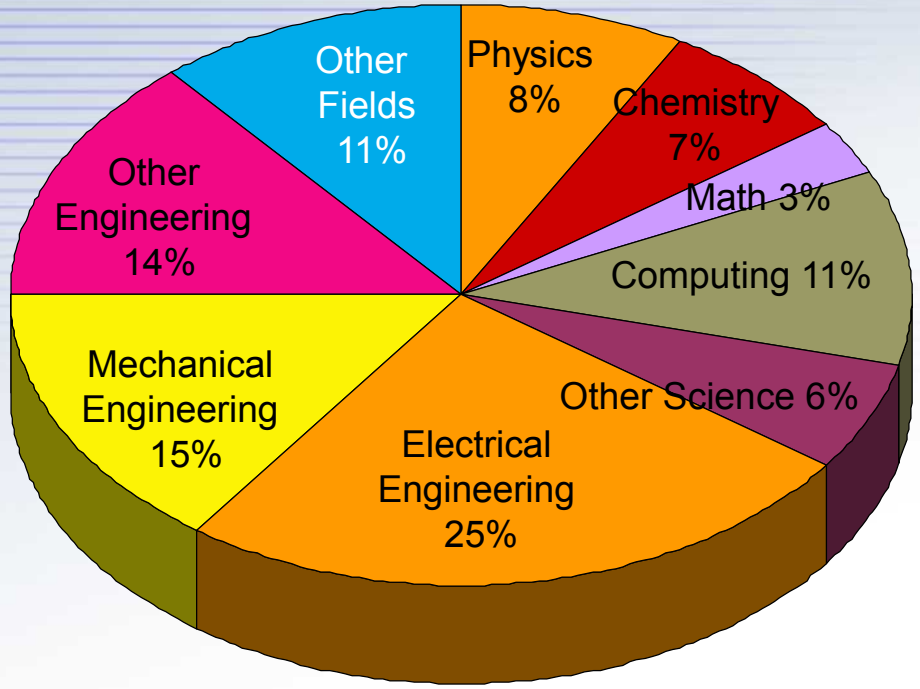
Sandia National Laboratories

"Exceptional Service in the National Interest"

- National Security Laboratory
- Broad mission in developing science and technology applications to meet our rapidly changing, complex national security challenges
- Safety, security and reliability of our nation's nuclear weapon stockpile

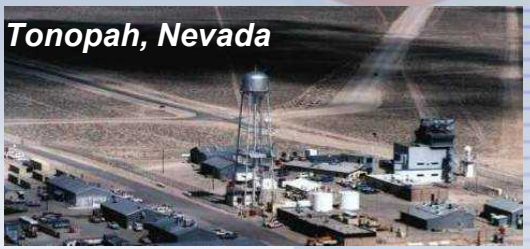


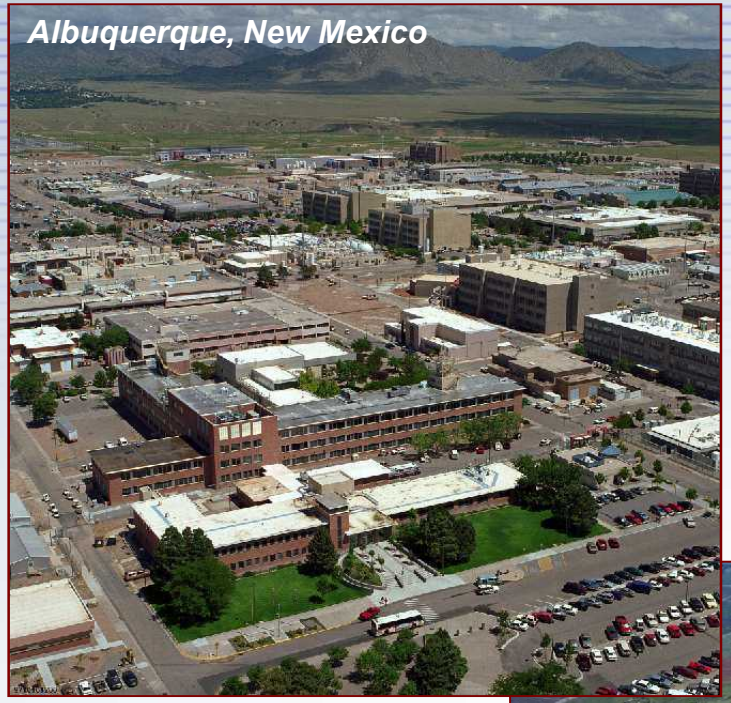
Sandia is Engineering Focused and Grounded in Science

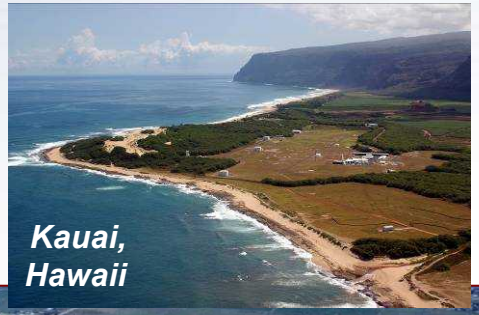


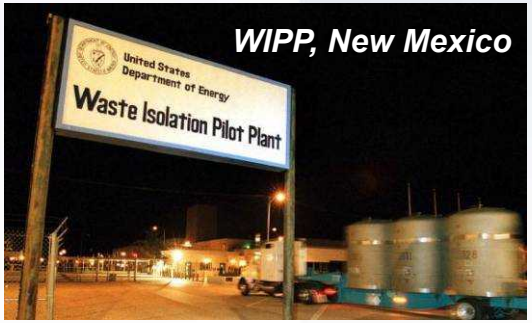
- **Over 8,500 employees**
- **Over 1,500 PhDs; over 2,500 MS/MA**
- **Over 1000 on-site contractors**
- **$2.3 billion operating budget**

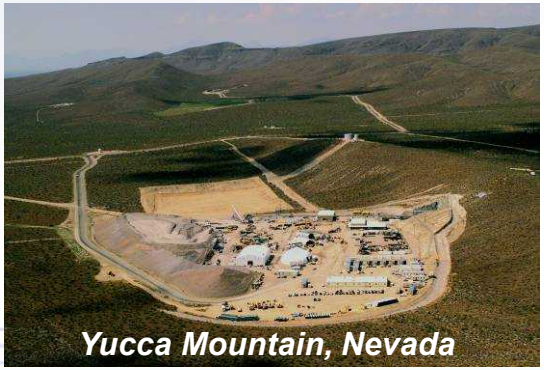
Sandia National Laboratories is Geographically Distributed











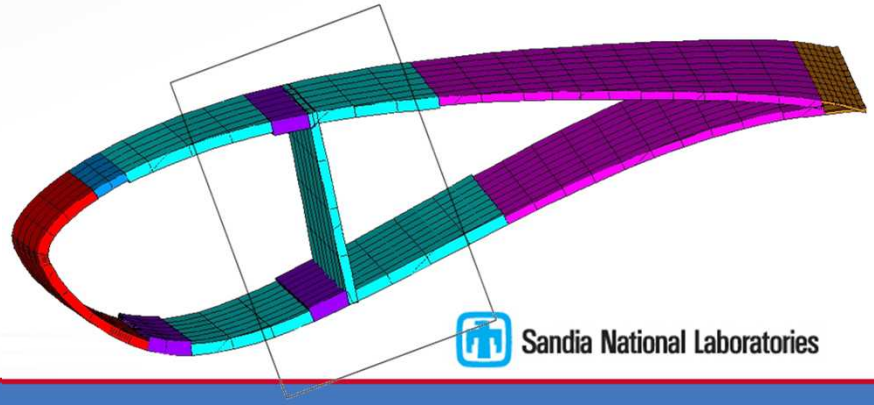
Wind Energy Technology Department

- **Established in mid 70's**
  - **Focused on vertical axis wind turbines**
  - **Industry partnerships**
- **Blade focus began in early 1990's**
- **15 full-time employees, several contractors and students**

1975	SNL Wind Program Established
1977	17m VAWT Fabricated
1981	1st Wind-Turbine Specific Airfoils
1982	FloWind Technology Transfer
1984	34m VAWT Test Bed
1988	SNL/MSU Material Dbase Established
1994	SNL Blade Program Started
1998	Blade Manufacturing Initiative
2003	Incorporation of Carbon on Blades
2005	K&C Swept Blade Contract
2006	Reliability Program Started

Mission:

Provide knowledge-based expertise in the design and advancement of composite wind turbine blades and turbine and wind farm system reliability to accelerate the penetration of Wind Energy.



Sandia Labs Reliability Background

- Broad historical roots in reliability
- Nuclear Weapons Program
  - Independent reliability predictions and assessments on nuclear weapon components, subsystems, and systems throughout the conceptual design-to-retirement life cycle
- The Center for System Reliability (CSR) started in 1998
  - CSR develops methodologies and software tools (Pro-Opta) to address a wide range of reliability issues
  - Application areas ranging from nuclear power and missile systems to aviation, automotive, energy, and manufacturing

Sandia's Capabilities

- Sandia has a reputation and the infrastructure to solve problems
- Sandia's extensive reliability expertise, focus on leveraged research and technology development, and *culture of information protection* make it the ideal place to house the national reliability program
- As a National Laboratory, Sandia is in a unique position to engage with a broad spectrum of industry players

Using analysis based on statistically significant data, Sandia works with stakeholders to reduce risks to investors, developers, operators, utilities, manufacturers and their customers.

Why we need a data driven, national program

Owners and operators are faced with reliability issues that are often worse than anticipated; there is a role for DOE and the National Labs to catalyze a national, industry-wide reliability effort

Anonymous industry quotes – sometimes contradictory

"Our energy company has chosen NOT to go into the ownership of any more wind farms due to high failure rates of the equipment. We are faced with replacing gearboxes, blades, and generators several times throughout the life cycle of the turbine."

"We have had to replace all of our blades within the first three years of operation due to manufacturing defects"

"Blades are not a big problem, except for lightning and manufacturer defects"

"It can take months to get a gearbox or a crane – and that's months when the turbine is not producing"

We can't have a viable program based on anecdotal information – it has to be data driven

SNL/DOE Reliability Program is Unique

Typical corporate reliability program

- GOAL – Profit
- Analyses done before deployment to field
- Focus on a single product
- Own their own data
- Single source for data
- Results kept in house
- No desire to improve industry as a whole
- Detail oriented – down to the nuts and bolts level
- Work directly with design and engineering
- Profit oriented

SNL/DOE wind reliability program

- GOAL – improve industry as a whole (i.e. blade collaborative)
- Analyses done with field data (owned by others)
- Various products (many manufacturers, sizes, and types of turbines) – systems engineering
- Data acquisition is complex
  - **Security – anonymity**
  - **Many data sources – electronic, SCADA, paper work orders, - data must be normalized**
  - **Large amounts of data**
- Results shared with industry (and individually)
- Create guidelines, standards, and Technical Improvement Opportunities (TIO's) for manufacturing, operations, and engineering
  - These design improvements under a reliability umbrella
- Strategically oriented – improve markets

The result of any reliability program should be continuous product, system or process improvement.

Reliability Program Goals and Objectives

Working through industry partnerships to:

- Develop reliability baselines for the US wind industry
  - What is failing, when is it failing, how is it failing, how often is it failing?
- Targeted efforts to address important component reliability problems
- Improve asset management for effective planning
- Provide data to optimize operational and maintenance practices
  - Condition based monitoring
  - Preventive maintenance
  - Spares strategies
  - Etc…… This is industry driven
- Optimize best design and manufacturing practices
- Identify industry reliability improvements over time

OSIsoft Collaboration with the DOE/SNL program

- PI system means easy to get, manage, store, and analyze data
- Easier to normalize data
- More extensive data analysis
  - Quick input into Pro-Opta and other programs
  - All of the data, not just a subset
- Better, faster, easier reporting
- Communicate with other (relational) databases
  - Weather (wind speed, lightning)
  - Attributes (wind class, location, size, etc.)

Data Warehouse

Other relational databases

European, NREL, etc.

Data formatting – SNL staff

Data Warehouse

Relational Database

Time Series data system

SCADA reports

SCADA raw data

Work orders – Maximo, electronic, manual

NRD Relational Database

Publicly available normalized statistical results

SNL Informational Firewall

Normalized statistical reports/analyses to industry

Proprietary reports/analyses to data partners

Info to National Renewable Energy Laboratory (NREL), Guidance to DOE program: TIOs, etc.

Publicly available information

Proprietary information - available to Sandia and data partners only

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Security and Data Transfer

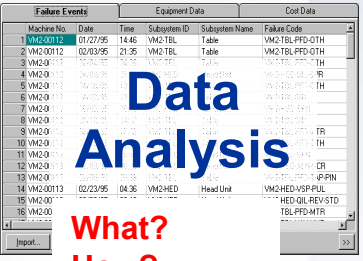
- Partner data is not disclosed, made public, or compromised in any way
- Non-disclosure agreements
- Location, owner, manufacturer data scrubbed in any public reporting
- Data transfer
  - PI to PI interface – in batches
  - Batch file interface using CD of data or online transfer
  - SCADA interface

Value to our partners

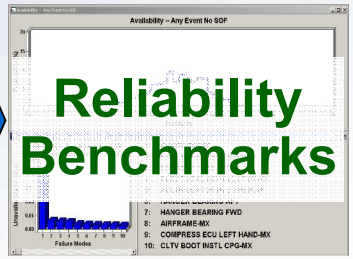
- Individualized analysis and reports
  - Raptor – commercially available reliability block diagram
  - Pro-Opta analyses and optimization - SNL developed software
  - Propose best practice for operations and maintenance strategies
- Benchmark performance against national statistics
- Have access to industry-wide operations and maintenance "best practices"
- Provide feedback to DOE's research and development efforts for reliability improvements
  - What fails the most, what costs the most, where R&D dollars need to be spent
- Input into design standards

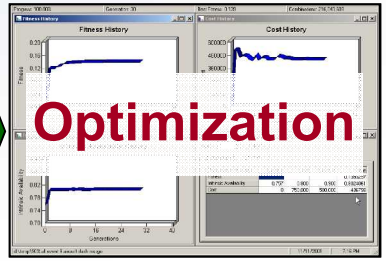
Analysis - Sandia's "Pro-Opta" Reliability Software

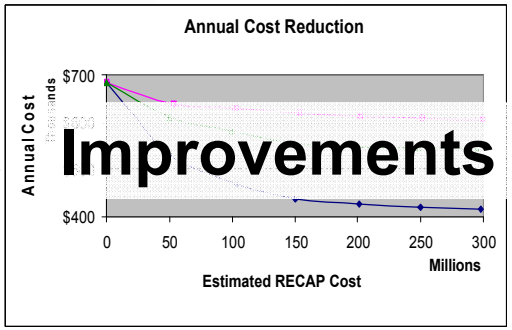
- **Reliability optimization for wind turbines**
  - **What changes give the "biggest bang for the buck?"**
    - Minimizing annual cost while maximizing availability
  - **Changes can include**
    - Component upgrades
    - Spares strategies
    - Repair strategies
    - Maintenance procedures
  - **Incorporates user-defined constraints, including development cost, weight, strength, …**



What?
How?
How Often?
How Long?
How Much?







Translate Investment into Availability

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Pro-Opta Outputs

- **Reliability optimization for selected upgrades/modifications**
  - Baseline reliability model results
  - Failure rate improvements of upgrades/modifications
  - Downtime improvements of upgrades/modifications
  - Costs associated with each upgrade/modification ($$s, weight, volume, etc.)

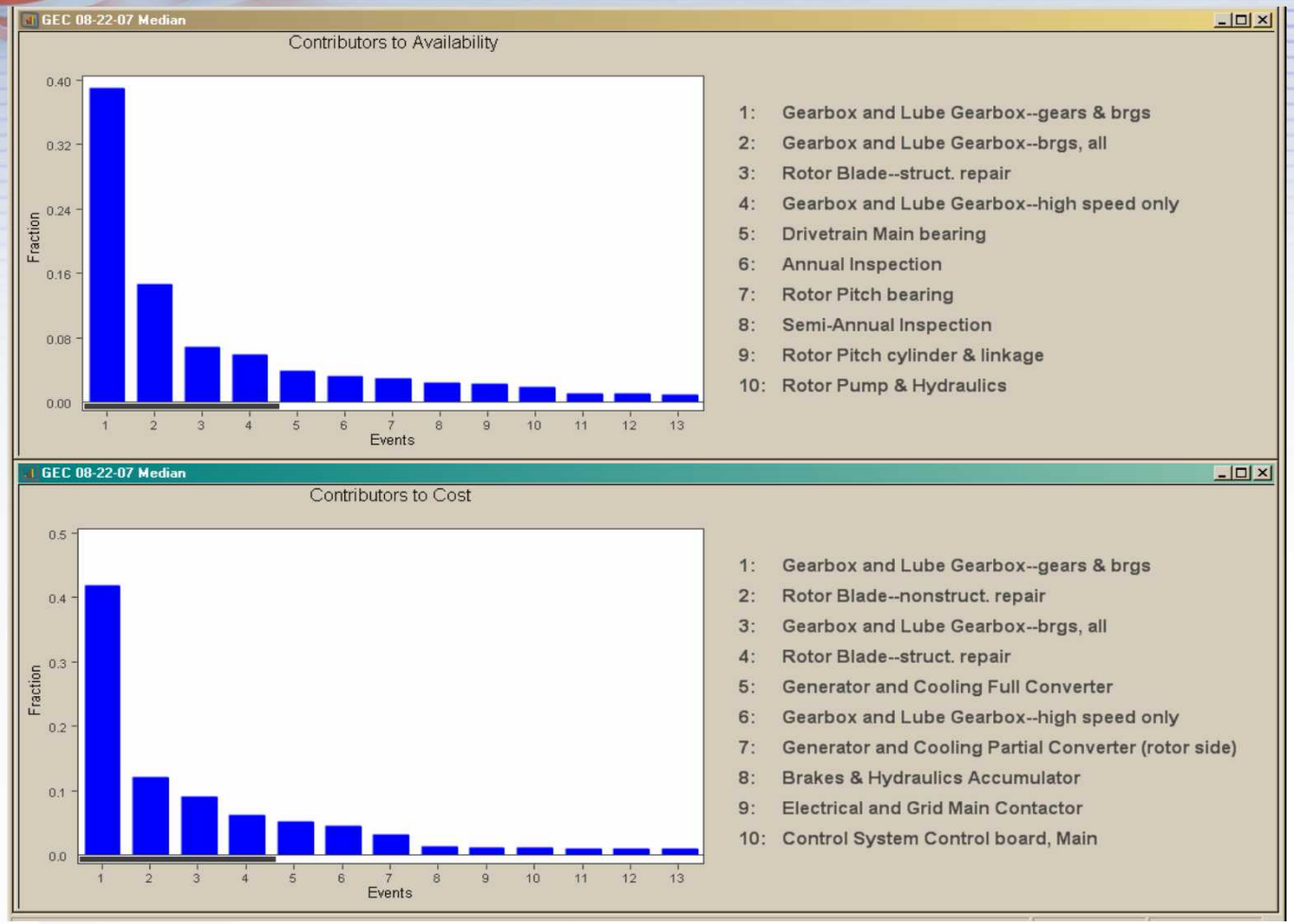
  Note: Multiple levels of each upgrade/modification can be optimized if the failure rates and associated costs are known for each level

- **Unit-Level spares optimization**
  - Baseline reliability model results
  - Downtime with/without an on-site spare
  - Spares purchase and annual storage costs
  - Spares restock time

- **Can be used for pareto inputs to TIOs**

- **Reliability results provide feedback in many ways**

Baseline Model Results



Conclusion

- Data collection should be as easy and efficient as possible
- Our goal is to improve the industry
  - Gearbox collaborative
  - Blade collaborative
  - Other
- Security requirements are taken seriously
- We're always looking for additional partners
  - Reliability engineer/analyst meeting upcoming

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