CREW Reliability Benchmark

Initial Findings and Lessons Learned

Wind Energy Technologies
Sandia National Laboratories

SAND2011-6520C
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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CREW: Continuous Reliability Enhancement database for Wind

Create a *national reliability database* of wind plant operating data to enable reliability analysis

- ❑ Track operating performance at a system-to-component level
- ❑ Characterize issues and identify technology improvement opportunities
- ❑ Enable O&M cost reduction
- ❑ Benchmark reliability performance
- ❑ Protect proprietary information
- ❑ Increase confidence: financial sector and policy makers

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SPS

A Comprehensive Data Model for Reliability

Challenge:
Size of database –
Dozens of operators,
Thousands of turbines,
Millions of data records per day

Data

Data Warehouse

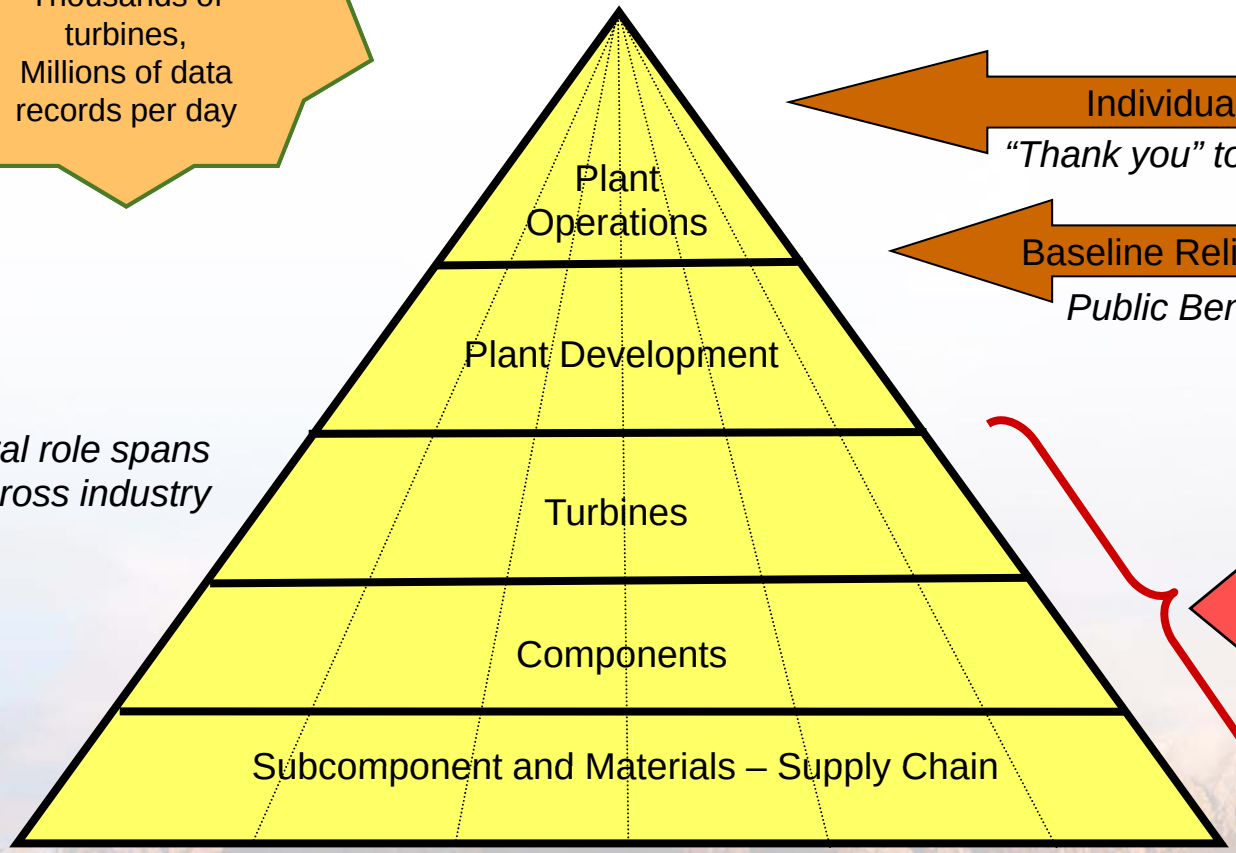
Reliability Analysis

Individual Reports

"Thank you" to our Pilot Partners!

Baseline Reliability Information

Public Benchmark Fall 2011



Federal role spans across industry

Technology Improvement Opportunities (TIO's)

Inform DOE funding decisions

Reliability Improves from the bottom up

Public Benchmark

- To be published Fall, 2011
- Today's view: top contributors to unavailability
- Analysis based on aggregated data collected from a variety of industry partners – represents 23k turbine-days of data
- SCADA (Supervisory Control and Data Acquisition) data and events
- Sub-system level
- CMMS (Computerized Maintenance Management System) data is critical to "filling in the blanks"

Terabytes & Anonymity

Why We Need CREW

- Track operating performance at a component level
- Characterize issues and identify TIOs (Technology Improvement Opportunities)
- Enable O&M cost reduction
- Benchmark reliability performance
- Increase confidence of financial sector & policy makers

Why It Is So Difficult

- Protect proprietary data, NDAs
- Gather and manage terabytes of data
- Sanitize and analyze terabytes of data
- Share results publically

Fault Analysis
Initial Findings

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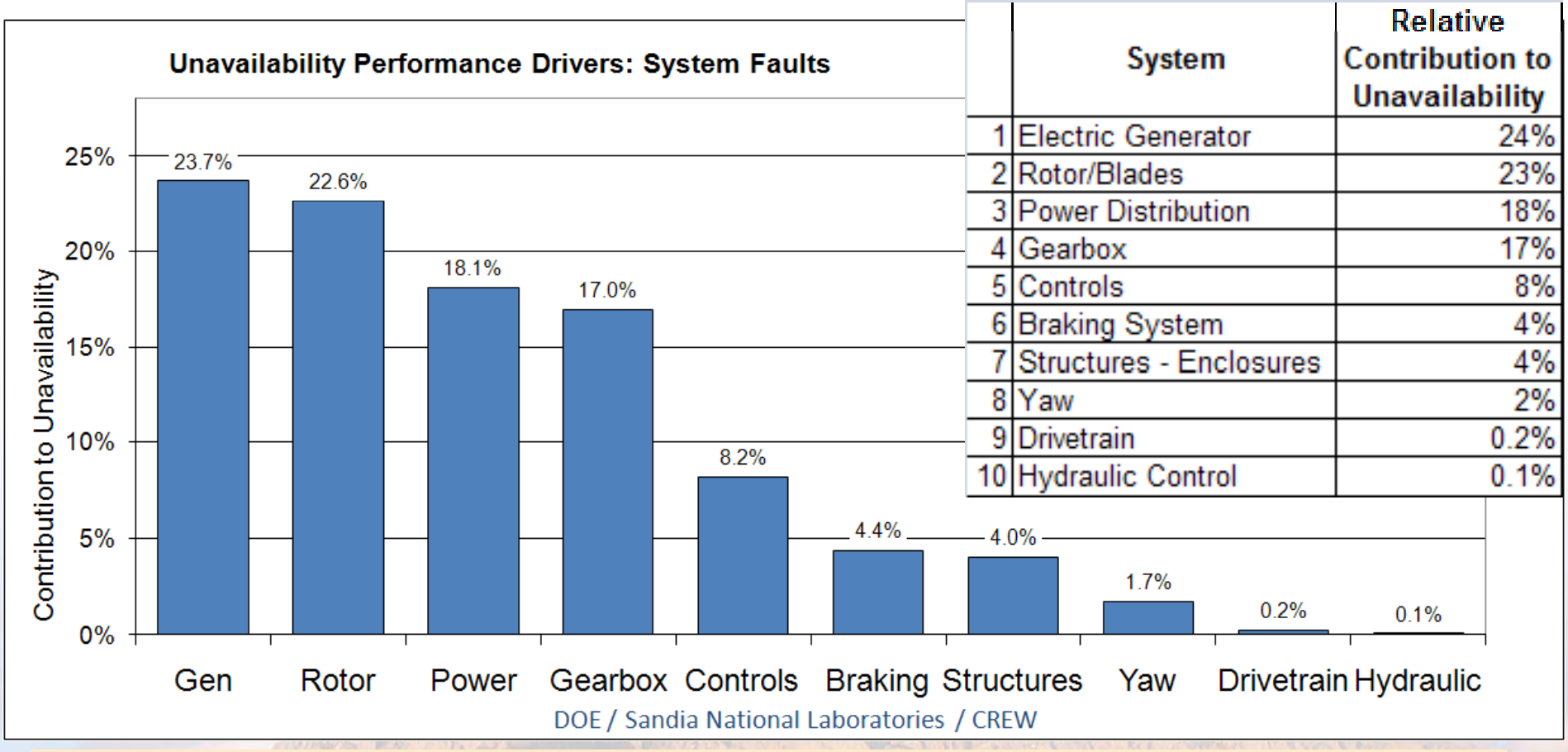
Key Definitions

- **"Event": any activity that results in the turbine stopping or being taken out of service**
  - SCADA fault
  - Manual stop, work order, planned or unplanned maintenance
- **"Fault" (for this analysis): unplanned event indicating system-level alarm or component failure**
  - Forced Outages; caused by automatic trips
  - Associated with specific turbine systems
    - Omitted generic faults for the whole turbine (E.g., generic shut down)
    - Omitted 'Balance of Plant' faults (E.g., grid instability)
- **"Failure": unplanned event indicating a major repair is needed**
  - Almost exclusively based on work orders
  - NOT included in today's presentation

Fault Pareto

- **Contribution to unavailability due to faults**
  - Combined impact of fault rate (how often) & fault downtime (how long)



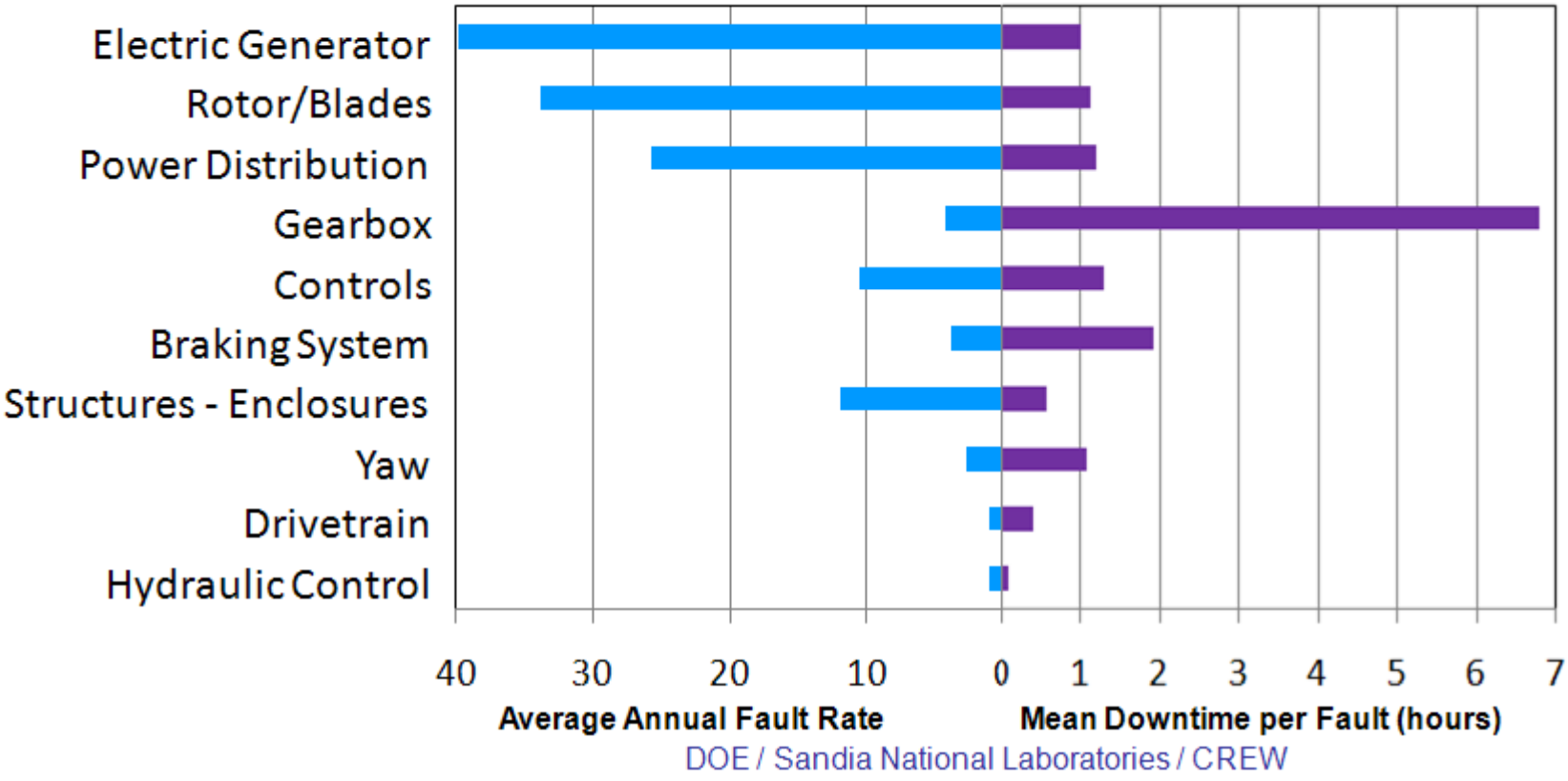
	System	Relative Contribution to Unavailability
1	Electric Generator	24%
2	Rotor/Blades	23%
3	Power Distribution	18%
4	Gearbox	17%
5	Controls	8%
6	Braking System	4%
7	Structures - Enclosures	4%
8	Yaw	2%
9	Drivetrain	0.2%
10	Hydraulic Control	0.1%

Only includes faults attributable to a specific turbine system (no generic faults; no Balance of Plant faults)

Event Data Source: ORAP for Wind ®

Fault Summary

- **Fault Rate & Fault Downtime, ordered by unavailability impact**
  - Average Annual Fault Rate = expected # faults per year per turbine
  - Mean Downtime per Fault = average duration of a single fault



Event Data Source: ORAP for Wind ®

Initial Findings

- **Fault-Based Unavailability is driven by frequent faults for**
  - Generator 40/yr
  - Rotor/Blades 34/yr
  - Power Distribution 26/yr
- **Next largest contributor is lengthy Gearbox faults** 6.8 hours
- **Minimal impact from faults for**
  - Yaw, Drivetrain, Hydraulic Control

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65%

- **Reporting period, turbine coverage, and maintenance detail not yet sufficient to characterize large/catastrophic issues**
  - Highlighting typical, day-to-day operations (not 'tails of the distribution')
  - Not collecting long enough to estimate impact of major repairs

Event Data Source: ORAP for Wind ®

CMMS & Major Repairs

- **By design, SCADA captures when turbine is in generic maintenance mode (used for work done by technicians)**
  - No detail about the cause
  - Repairs & scheduled work *sometimes* differentiated
- **CMMS: Computerized Maintenance Management System**
  - Provides missing information about maintenance performed
  - Next big focus: develop robust method for matching CMMS data to SCADA

Benchmark Methodology

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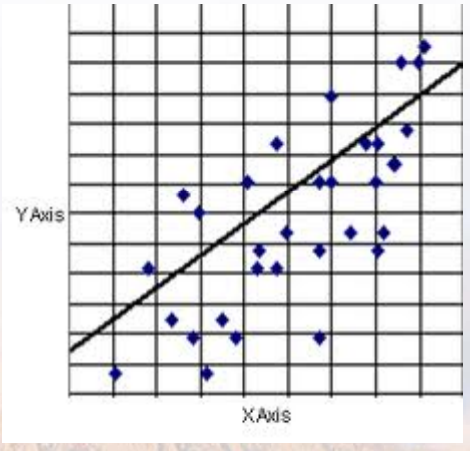
Data Foundation

- **CREW uses transformed data from Strategic Power Systems' ORAP for Wind software (Operational Reliability Analysis Program)**
  - Algorithms transform raw plant SCADA data into ORAP data, summarized into time, capacity and events
    - Time data = weekly time-based accounting of turbine status
    - Capacity data = energy-based accounting
    - Event data = details on downtime, including affected component
  - Adding CMMS is key part of development plan
- **CREW also uses SCADA time series data**
  - Captured by ORAP 5-30x/minute
  - Key goal: understand leading indicators to failure
  - Ex: acceleration, vibration, ambient temperature, wind speed

Aggregation Methodology

- **Goal**
  - Share data about the industry, while protecting proprietary data
- **Foundational Rules**
  - Anonymity; remove any indicators of data source
  - Aggregation; report on combined data vs. individual
- **Method**
  - Gather statistically appropriate sample
    - Sufficient data (duration, breadth) to aggregate without violating anonymity
  - Combine information, weighting by turbine-days



Availability Calculations

- **Wide variety of definitions for "Availability"**
- **Report on: basic availability metrics for CREW**
  - Operational Availability: 1 - (Unavailable Hours/Known Hours)
    - Unavailable Hours = (Reserve Hours + Unscheduled Maintenance + Scheduled Maintenance + Forced Outages/Unavailabilities)
    - Known Hours = total Calendar Time if the dataset is complete
  - Wind Utilization: Generating Hours / Wind Hours
  - Generating Factor (aka Utilization): Generating Hours / Known Hours
- **Also provide: Availability Time Accounting**
  - Generating Hours
  - Scheduled Maintenance
  - Unscheduled Maintenance
  - Forced Outages/Unavailabilities
  - (Non-Wind) Reserve Hours
  - Wind Reserve Hours
  - Unknown Hours

Industry is Maturing

Progress to Make

- **Using data for maintenance predictions**
- **Widespread CMMS use**
- **Integrating data from separate systems**
- **Collecting complete SCADA data**
  - Sufficient detail
  - Adequate storage & transfer
  - Addressing communication issues

Areas of Excellence

- **Collecting, storing, and analyzing SCADA data**
- **Installing CMMS systems**
- **Forming Performance and Reliability departments**
- **Using RAM metrics in financial reporting**