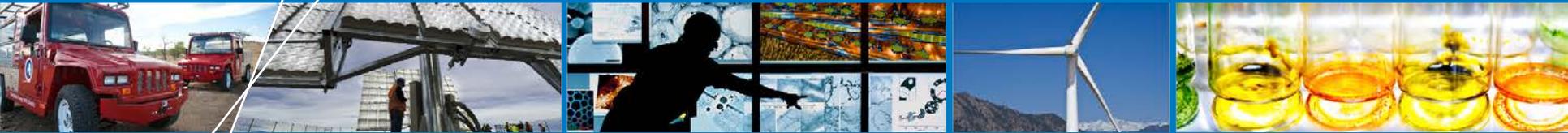


Gearbox Reliability Database: Yesterday, Today, and Tomorrow



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Outline

- **Before 2012**
 - Project background
 - Major accomplishments
- **October 2012 to September 2014**
 - Status update
 - Representative results
 - Observations
- **October 2014 to September 2016**
 - Project plan.



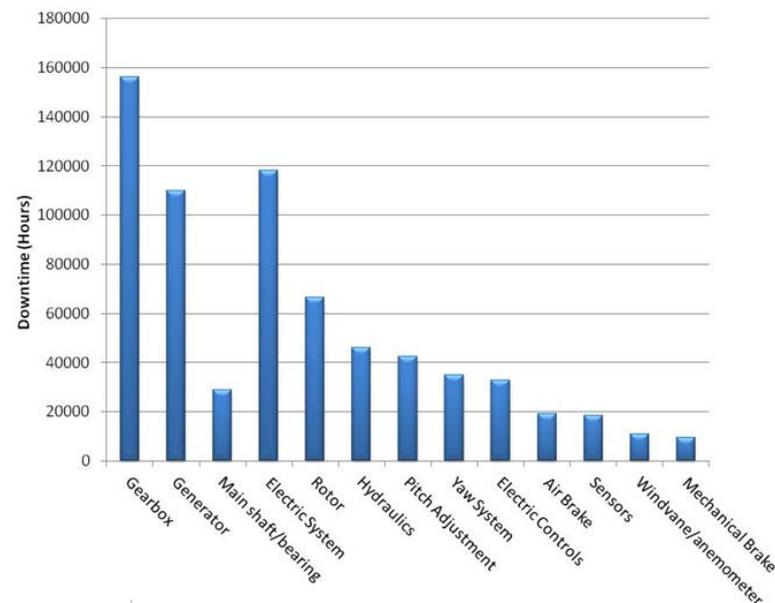
Project Background

▪ The Gearbox Reliability Collaborative:

- Aims to improve gearbox reliability and availability
- Takes a multifaceted approach: testing, modeling, condition monitoring, and database.

▪ The Gearbox Reliability Database project:

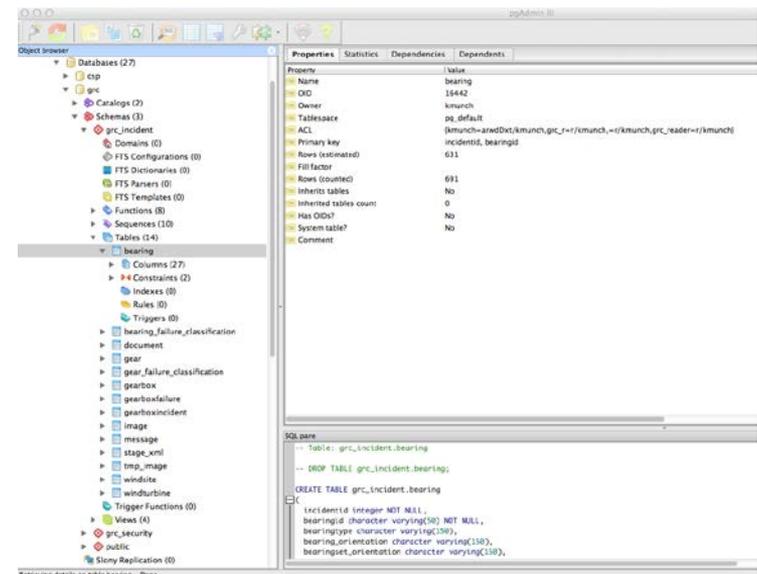
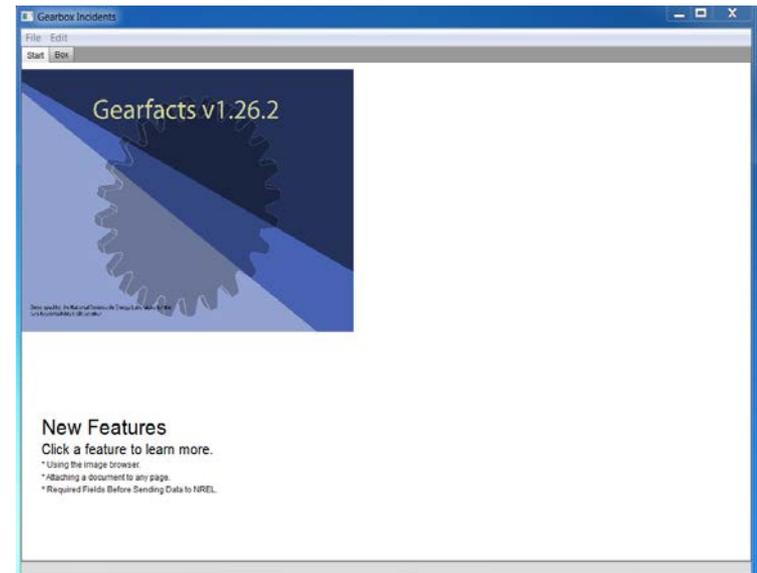
- Aims to quantify the magnitude of the problem and identify top failure modes and root causes
- Collects gearbox failure event data from project partners, all have executed nondisclosure agreements with NREL
- Directs wind turbine gearbox reliability research and development (R&D) and provides a benchmark for evaluating technology advancements.



Plot source: Sheng, S.; Link, H.; LaCava, W.; van Dam, J.; McNiff, B.; Veers, P.; Keller, J.; Butterfield, S.; Oyague, F. (2011). *Wind Turbine Drivetrain Condition Monitoring During GRC Phase 1 and Phase 2 Testing*. 58 pp.; NREL Report No. TP-5000-52748. Golden, CO: National Renewable Energy Laboratory.

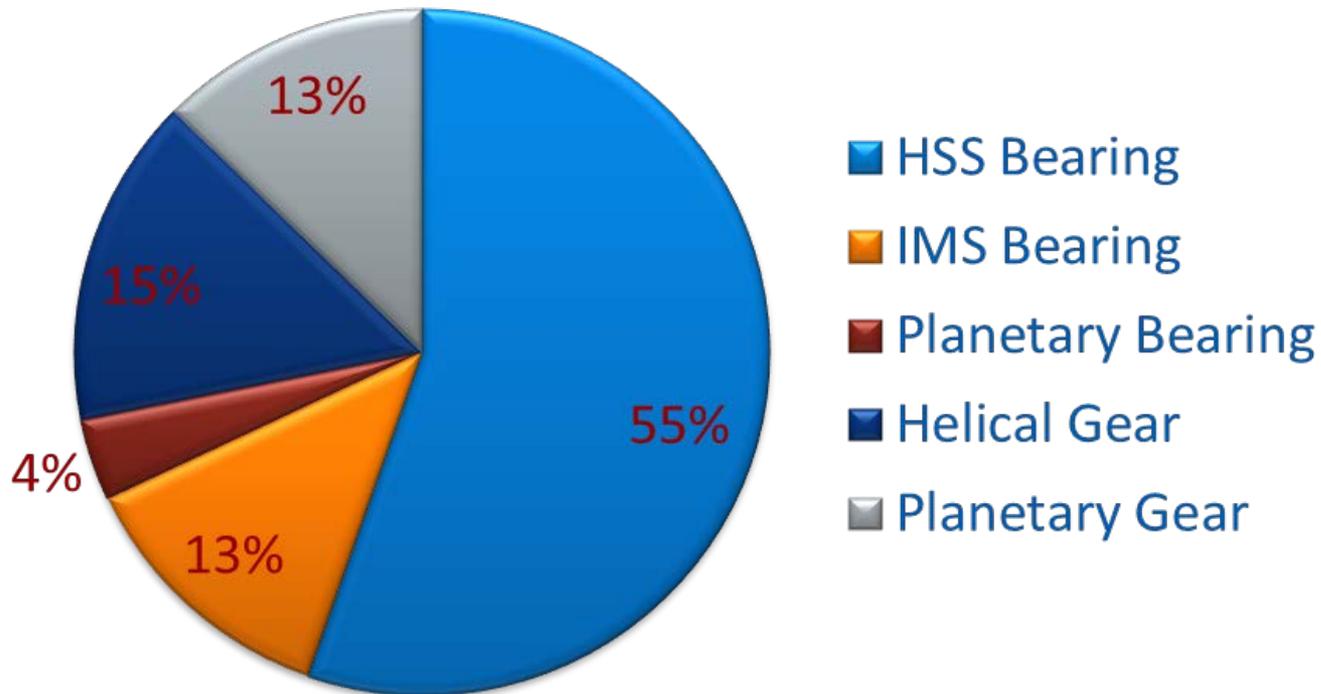
Major Accomplishments

- Developed GearFacts, a gearbox rebuild event data recording tool and a PostgreSQL database
- Collected some data at very detailed levels
- Built a Sharepoint site hosted by NREL for data sharing and information exchange
- Provided training to project partners on gearbox failure analysis.



Major Accomplishments (Cont.)

- Released first round of damage distribution based on confirmable damage records



- Samples: 34 incidents, 4 original equipment manufacturers (OEMs)
- Bearing failures dominant
- Bearing faults are concentrated in the parallel section; gear faults are concentrated in the planetary section.

Status Update

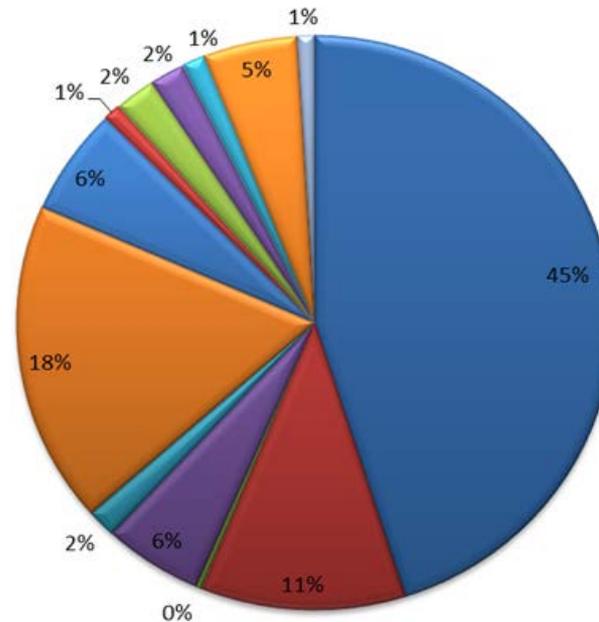
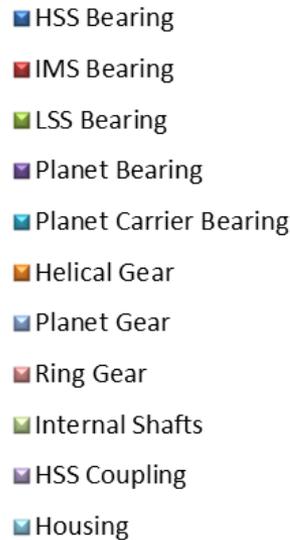
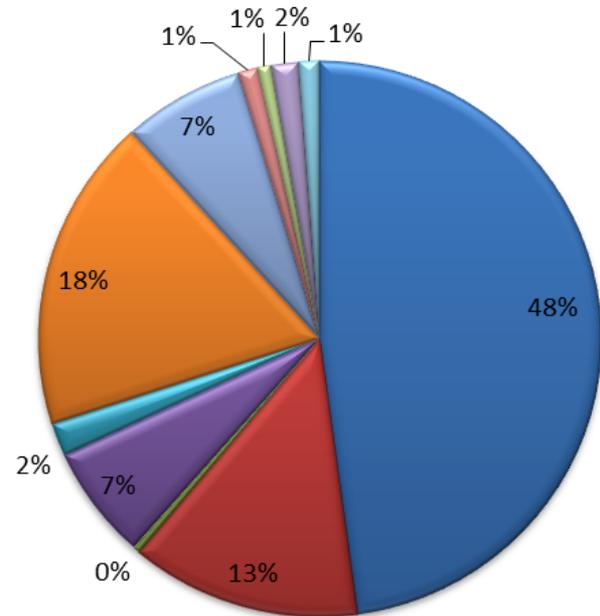
- Continued most activities from before October 2012
- Initiated the normalization of taxonomy for wind turbine and plant based on ReliaWind and Sandia CREW databases
- Reduced data collection complexity by examining data fields collected by GearFacts and prioritizing them into three categories: high, medium, and low
- Introduced Microsoft Excel spreadsheet template for data collection with only high priority fields.

| |
|----------------------------------------------------------------------------------------------------------------------------------|
| Wind Site Name |
| Wind Site State Province Region |
| Wind Site Country |
| WTG Make/Model |
| WTG Pad No. |
| WTG Total Run Hours Estimation |
| WTG Total Production kWh Estimation |
| WTG Type of Power Conversion |
| WTG Type of Generator |
| Gearbox Maker/Model (if you are not comfortable sharing this with NREL, please skip) |
| Gearbox Serial No. (if you are not comfortable with the full description of the serial No., please share the last three digits.) |
| Gearbox Originally New or Rebuilt |
| Install Date |
| Failure Date |
| Gearbox Run Hours Estimation |
| Gearbox Production Estimation (kWh) |
| Original Lubricant Type |
| Current Lubricant Type |
| Inline Filter Rating (50 microns, 20 microns, 10 microns, or 5 microns) |
| Offline Filter Rating (3 microns) |
| How was Damage Detected |
| Dominant Failure (Worst) Location |
| Secondary Failure (2nd Worst) Location |
| Dominant Failure (Worst) Mode |
| Secondary Failure (2nd Worst) Mode |
| Corrective Actions (Uptower repair, internal component replacement, or gearbox replacement) |
| Other Drivetrain Component Failures Before this damage |
| Other Drivetrain Component Failures After this damage |
| Additional Notes |

Status Update (Cont.)

- Developed new data collection tool with less complexity than GearFacts and deployable on portable devices
- Partners increased to more than 20 including turbine and gearbox OEMs, gearbox rebuild shops, wind plant owner/operators, and consulting companies
- Total assets represented by owner/operator partners reached more than 34% of the U.S. end of 2013 installed capacity
- Data entries on gearboxes increased to about 900, among which about 1/3 with confirmable damage locations/components => **need to standardize data collection**
- Six major gearbox OEMs are represented by the data.

Representative Results

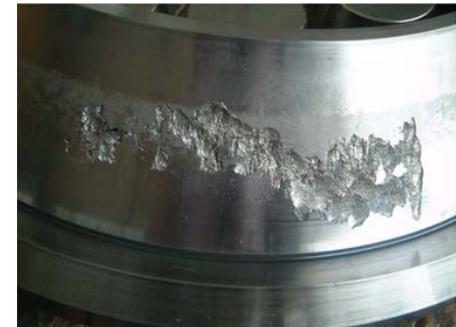
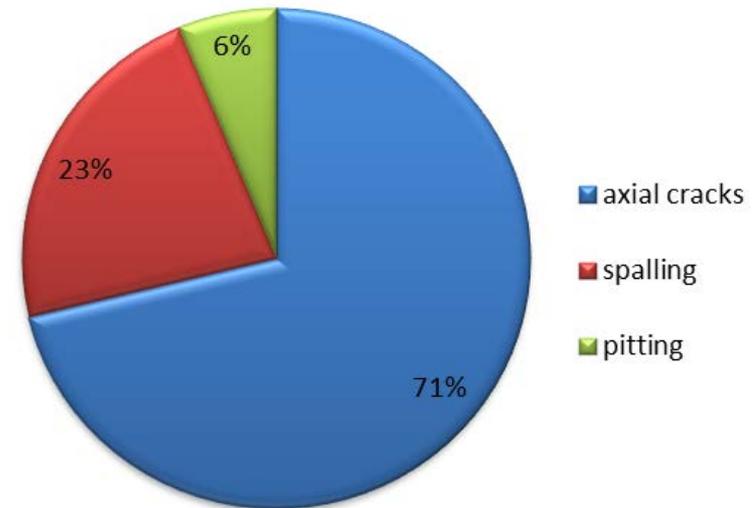


The left chart was released in 2013, based on 257 damage records, and the right graph was released in 2014, based on 320 damage records.

- Both represent six gearbox OEMs
- Both indicate gearboxes could fail in drastically different ways
- Bearings: 70% (2013) to 64% (2014), dominated by high-speed shaft (HSS) and intermediate-speed (IMS) bearings
- Gears: 26% (2013) to 25% (2014), dominated by Helical gears
- Others: 4% (2013) to 11% (2014), dominated by **lubrication and filtration system**
- Both bearing and gear faults are concentrated in the parallel section.

Representative Results (Cont.)

- Samples: about 80 records
- Axial cracks: 71%
- Spalling: 23%
- Pitting: 6%



Axial cracks (dominated by high-speed and intermediate-speed stage bearings inner raceway)

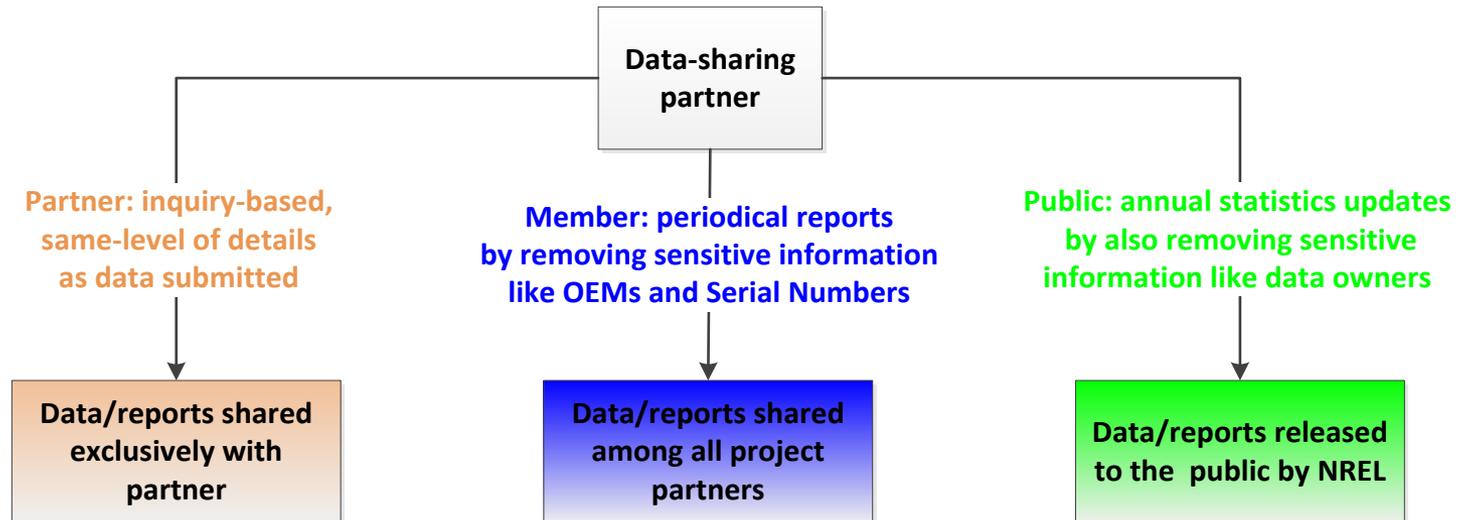
Photo sources: Gary Doll, University of Akron (left two), and Ryan Evans, Timken (far right)

Current Observations

- Value of and need for a reliability database demonstrated by:
 - Participation of more than 20 partners
 - Inquiries on gearbox reliability information from the global wind community
 - Direction of reliability R&D and mitigation strategies.
- Challenges:
 - Standardized reliability data collection practices for not only gearboxes but also other major components/subsystems
 - Lack of representative data at a bigger population to better reflect the reality
 - Actively engaging partners to submit data.

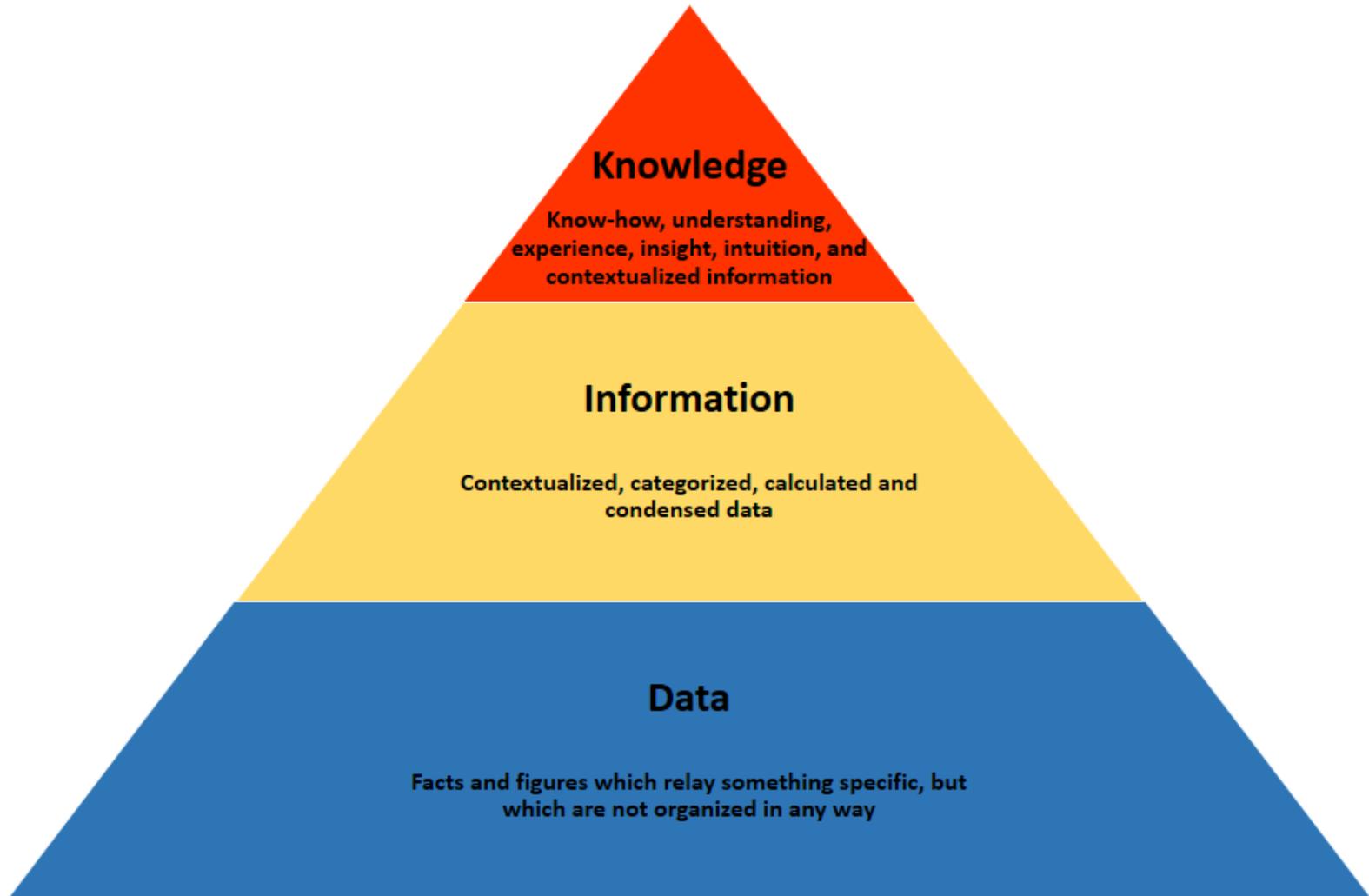
Project Plan

- Introduce a three-tier data-sharing mechanism:



- Launch remote data collection Web service
- Focus more on data collection and analysis
- Target a few dominant failure modes and release industry-wide statistics
- Expand the scope of the database to cover main shaft bearings and other major components/subsystems.

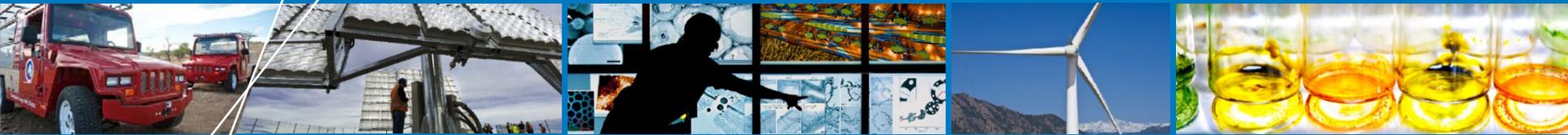
Thank You!



Data collection is the foundation to derive information and gain knowledge!

Acknowledgments

- U.S. Department of Energy Wind and Water Power Program
- Data-sharing partners
- The gearbox reliability database project team
 - NREL Technology Transfer office
 - Data collection tools developers
 - NREL colleagues handling logistics and communication tasks
- NREL Gearbox Reliability Collaborative project colleagues.



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