Predictive Maintenance Technology to Reduce O&M Costs

Dr Tugan Eritenel, Senior Engineering Analyst
Dr John Coultate, Product Marketing Manager
Dr Ashley Crowther, VP - Engineering

PHM Society Conference - 2013
14-Oct-2013, New Orleans, LA

Summary

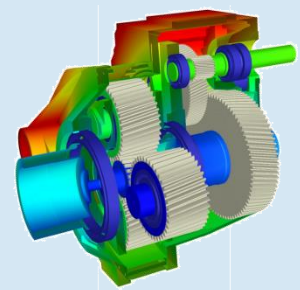
- Company introduction and background
  - Drivetrain and gearbox design and consultancy and RomaxDesigner CAE software
  - Wind turbine condition monitoring (Insight Health Management Services)

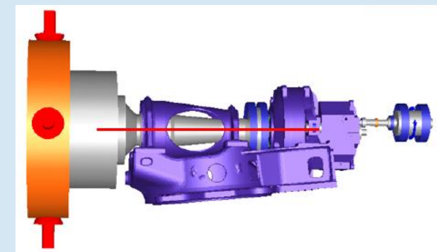
1. Vibration based condition monitoring
   - Mainstream use in aerospace, (HUMS), and other power plants
   - Can detect most main bearing and gearbox faults
   - If installed, must be actively watched for alarms
2. Business case for condition monitoring
   - Comparing estimated costs for a HSS bearing replacement scenario
   - Looking for a solution for a wind farm without CMS
3. Next generation predictive maintenance models (Insight)
   - Combines statistical methods, SCADA data, vibration data, and maintenance history

Romax Technology – what do we do?

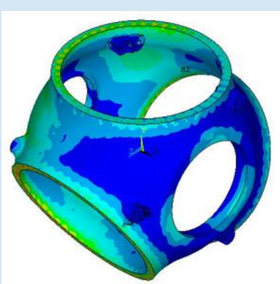
Drivetrain and gearbox design,
worldwide no. 1 independent wind turbine gearbox designer; 29 certified gearbox designs and 1.7 GW of gearboxes shipped

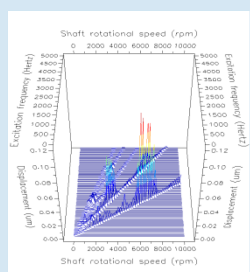
Drivetrain simulation software RomaxDESIGNER, virtual product development environment; dynamic analysis and bearing simulation



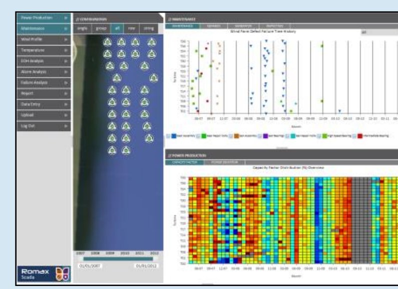


Engineering consultancy services,
analysis, certification support and failure investigation



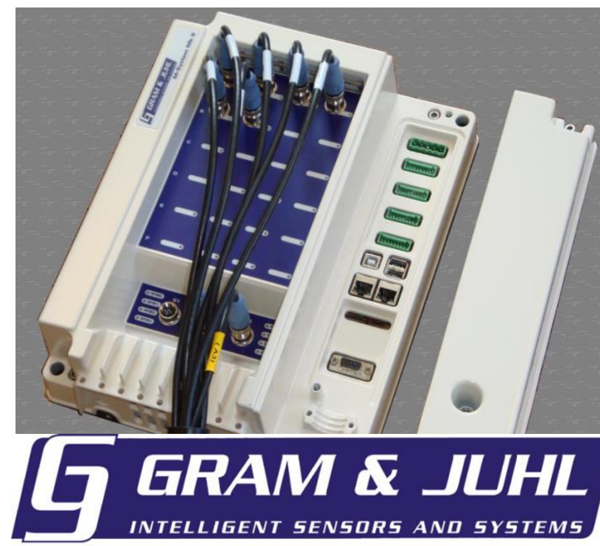


InSight health management solutions,
InSight software and technical services for optimising O&M



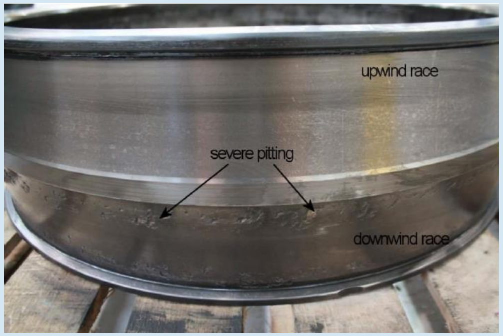
Monitoring and diagnostics track record

- **Over 3.0 GW** of data monitored and analysed to date using Romax InSight™
- Monitoring service – Romax are **currently monitoring over 1.5 GW**
- CMS hardware and software solutions
- Strategic offerings for existing Gram & Juhl users (e.g. Siemens turbine operators)



Drivetrain and rotating machinery failure examples

Main bearing failures



Gear failures

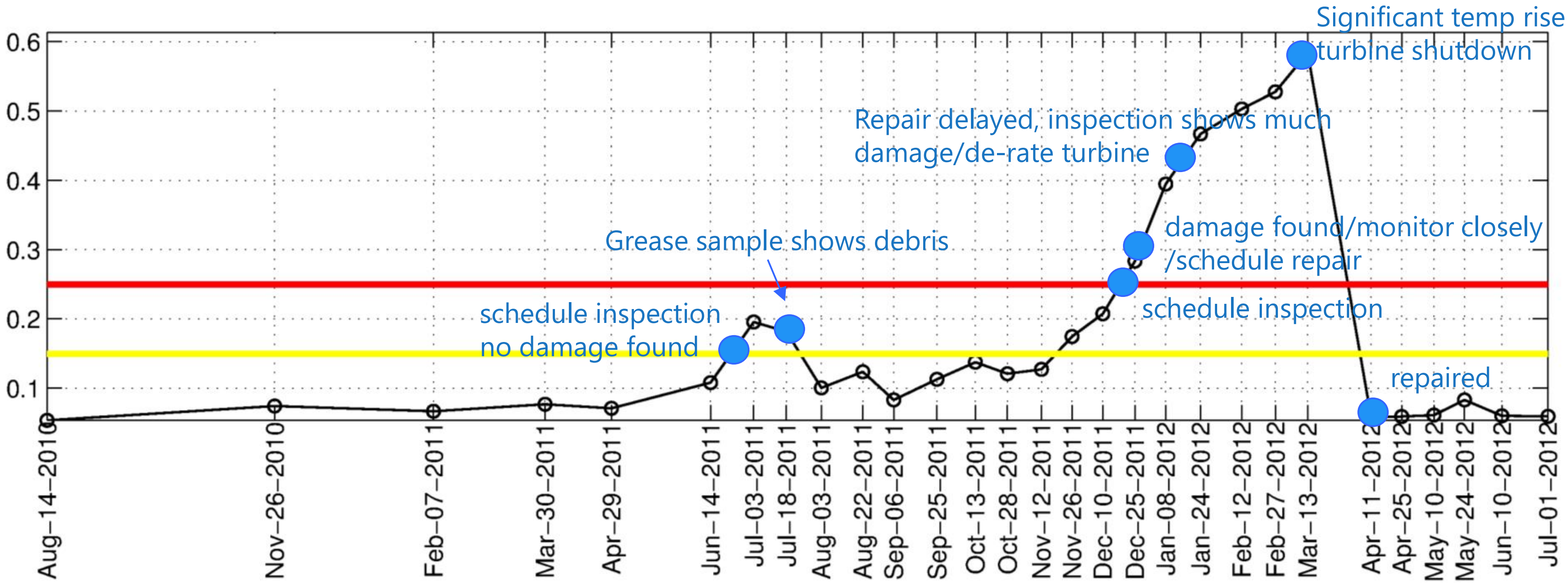
Yaw system failures

Coupling failures

Mount failures

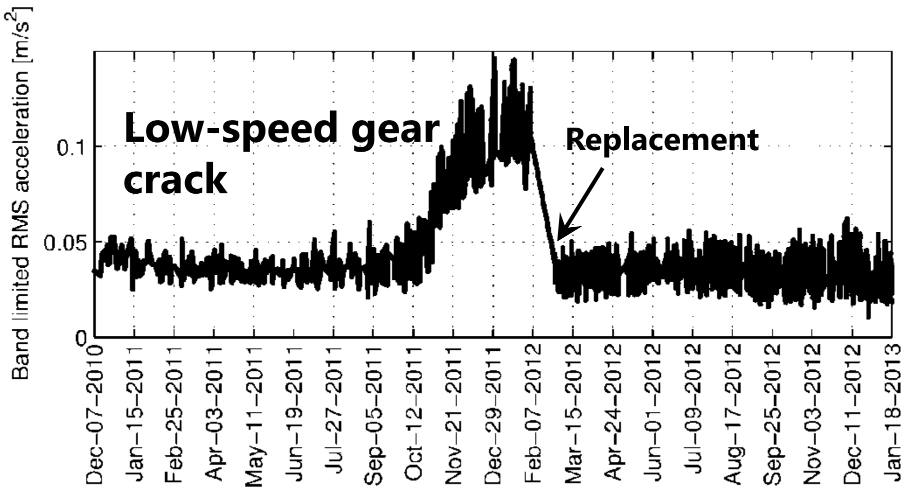
Generator and bearing failures

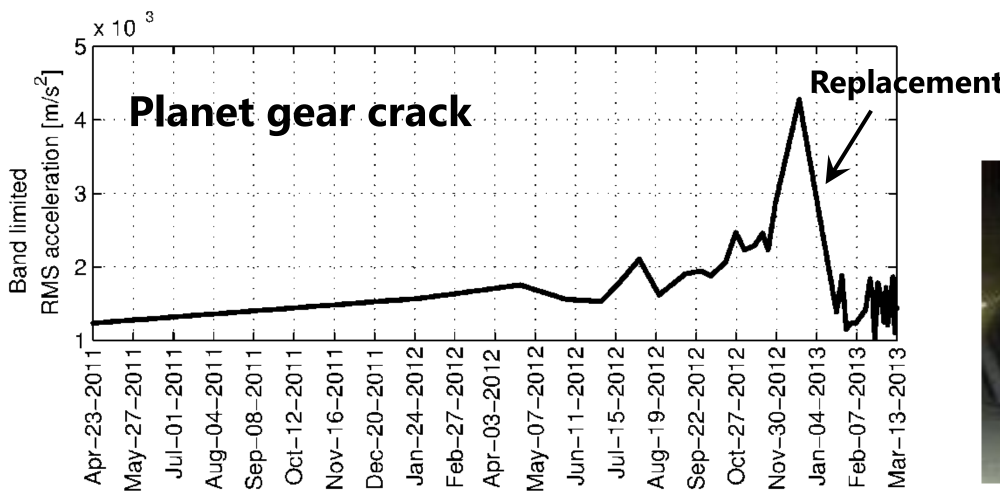
Case Studies



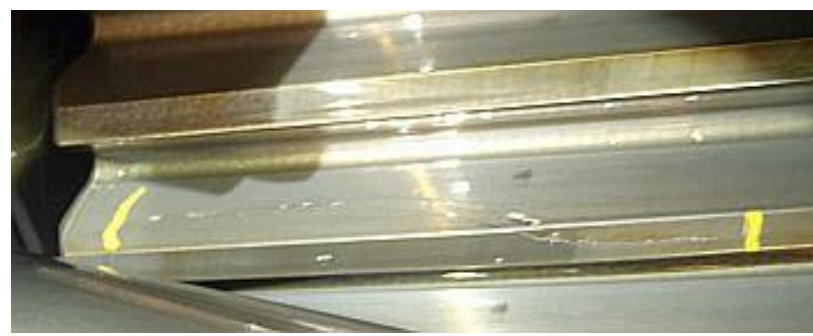
- Macro-pitting in main bearings
  - Timeline: 2-6 months
  - Replacement: Main bearing
  - **Hub needs to be craned in 3- point mount turbine designs**

Case Studies – Gear Tooth Cracks

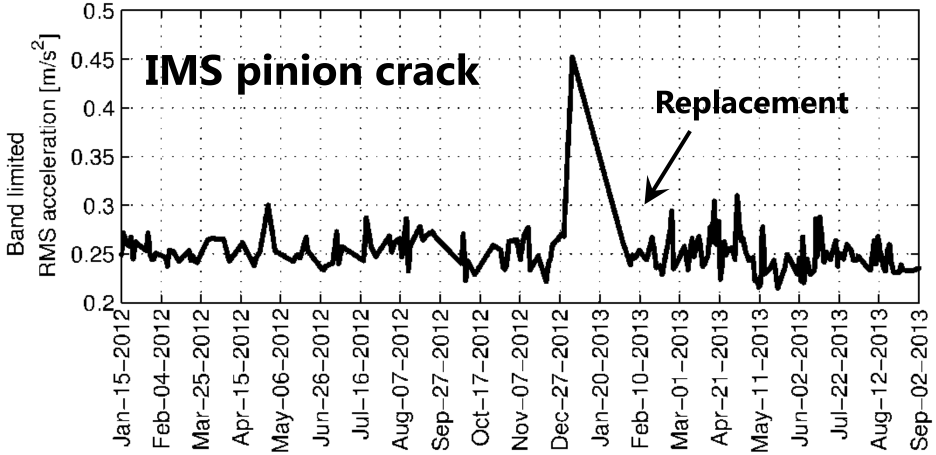


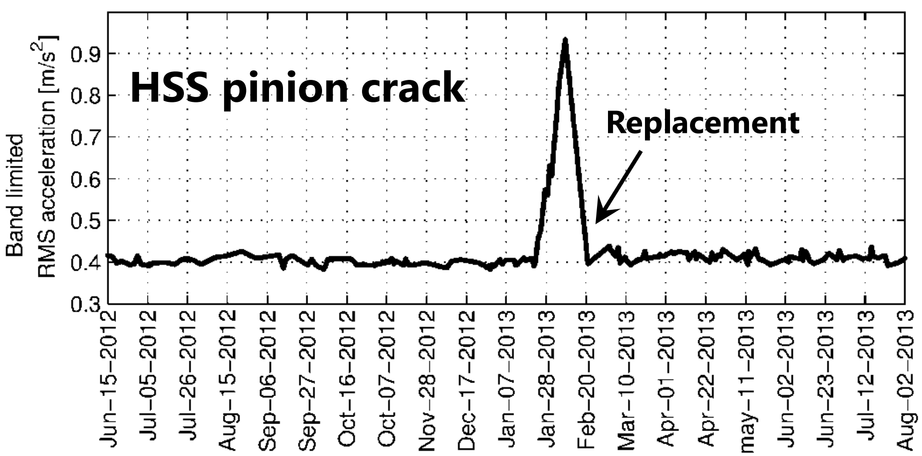


- Cracking in low-speed and planetary gears
  - Timeline: 5-90 days
  - Replacement: Gearbox
  - **Broken planet tooth can lodge between ring and planet gears and crack the gearbox housing**



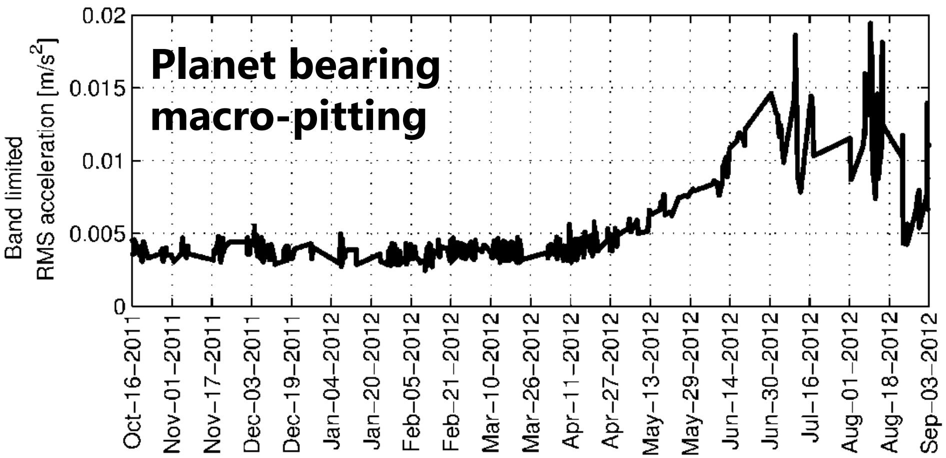
Case Studies – Gear Tooth Cracks

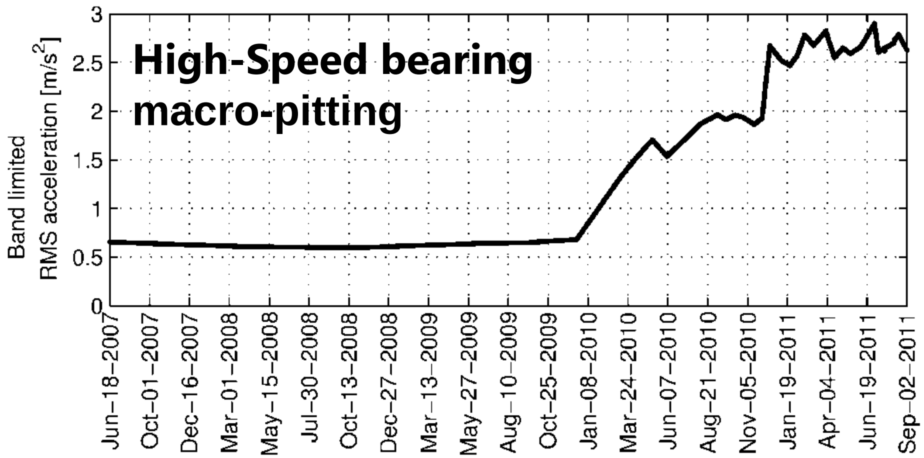




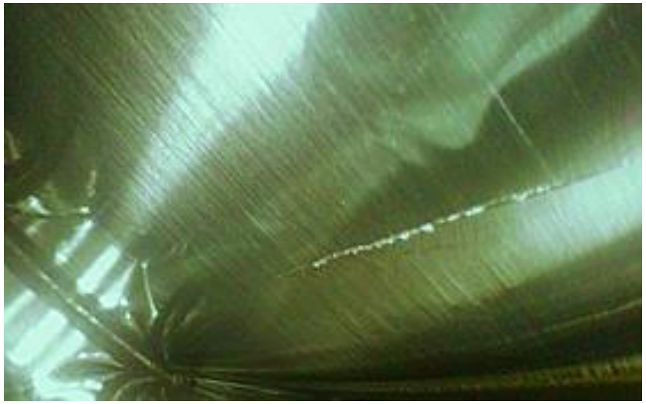
- Cracks in medium-high speed gears
  - Timeline: 2-7 days
  - Replacement: Shaft & gear
  - **Very good detection and repairs are usually ASAP.**
  - Occasionally, operators relief-grind the gear until replacement is convenient

Case Studies





- Macropitting and axial cracking in gearbox bearings
  - Timeline: 3-12 months
  - Replacement: Gearbox if planetary stage, bearing if high-speed stage
  - **Debris from bearing can dent gears and initiate cracks**



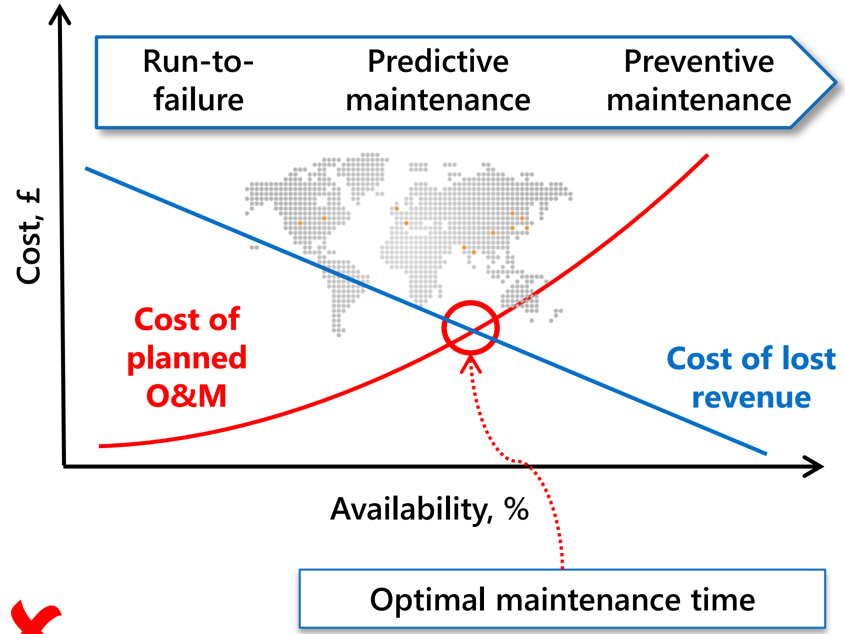
Business Case for Condition Monitoring

Example For a gearbox bearing failure requiring down-tower repair:

Predictive maintenance	Reactive maintenance
Bearing macro-pitting detected early with vibration based CMS	Bearing fails, from macro-pitting developed into cracks. CMS does not exist, or not being watched.
Visual (endoscope) inspection, confirmation of damage, action plan	Damage assessment.
Assess how long bearing can operate, combine repairs with other turbines. Wait for low-wind season.	Gearbox has secondary damage or completely fails. Debris dents on gears and bearing, cracked housing.
New parts and labor ≈$70k.	New gearbox and labor ≈ $200-500k.
Downtime is $5-10k per turbine. (for ≈ 5-10 days)	Downtime >≈ $20k. (depending on season and availability)
Cranes and service cost ≈ $100k.	Cranes and service cost ≈ $100k.
TOTAL COST ≈$180k.	**TYPICAL TOTAL COST ≈ $320k.**

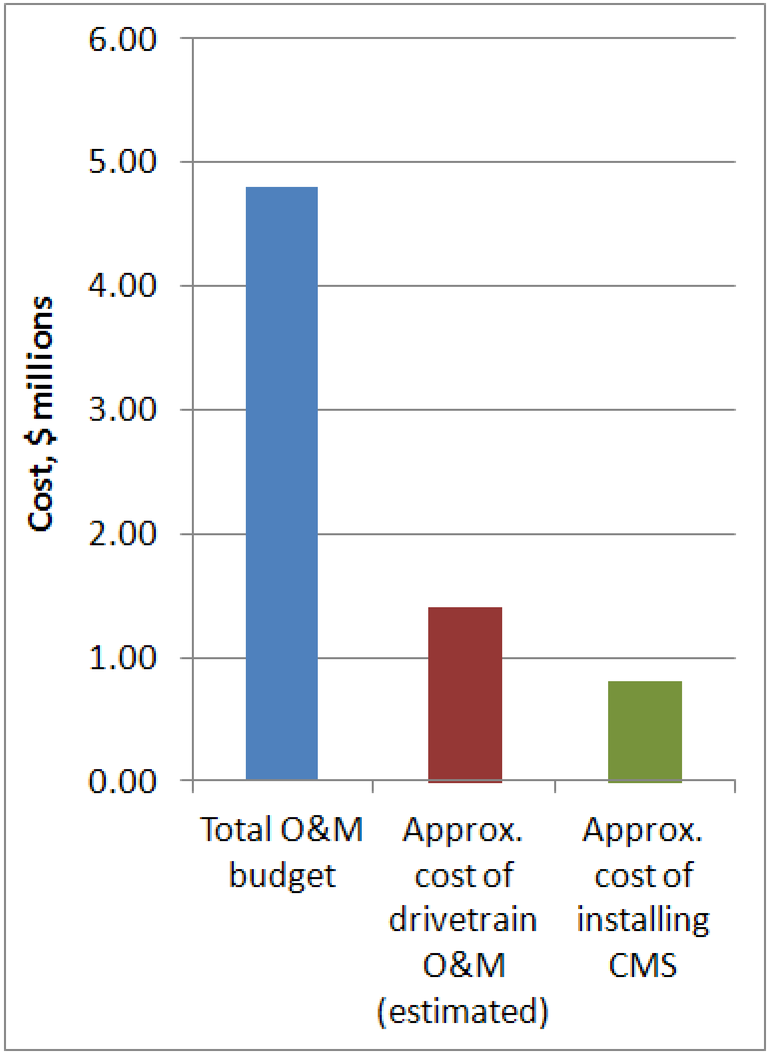
Striking a Balance

- **Reactive maintenance:**
  - Run to failure
  - Often expensive
- **Preventive maintenance:**
  - Fix everything prematurely
  - 100s of routine maintenance operations
  - Too expensive!
- **Predictive maintenance:**
  - Optimised cost
  - Enabled by key technologies – e.g. predictive models



Enabling predictive maintenance without CMS

- Example: out of warranty wind farm, 80 x 1.5 MW class wind turbines
  - O&M budget = approx. $4.8m per year
  - The site has no CMS – a major barrier to predictive maintenance
  - **Cost of installing CMS is prohibitively high for this operator**.
    - Approx. $800,000 initial outlay with no CAPEX budget available
    - ≈$10,000 per CMS unit



Enabling predictive maintenance without CMS

- Solution: **portable vibration sweeps**
  - Annual or quarterly drivetrain condition assessments using portable equipment: vibration analysis
  - More cost effective in the short term
    - Example: End-of-Warranty vibration sweep

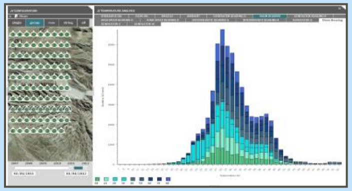
1. Install temporary monitoring equipment

2. Romax monitoring team analyse measured data

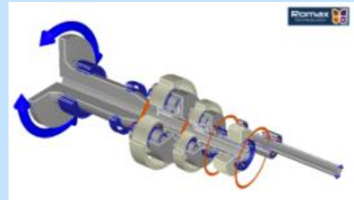
3. Vibration assessment report

3. Recommendations for further actions or inspections

Enabling technologies for predictive maintenance

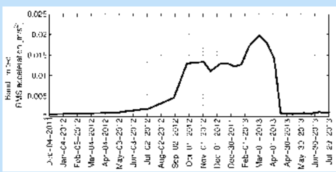


SCADA analysis



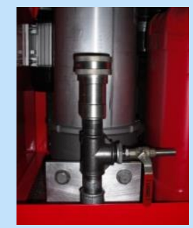
Predictive life models

Full scale testing and failure data



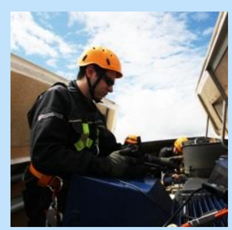
CMS data analysis (e.g. vibration; oil particles)

Predictive maintenance solutions

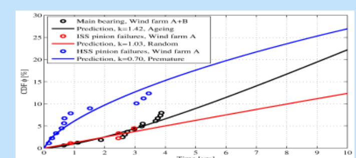


Lubrication monitoring & upgrades

Maintenance and inspections history



Vibration sweeps



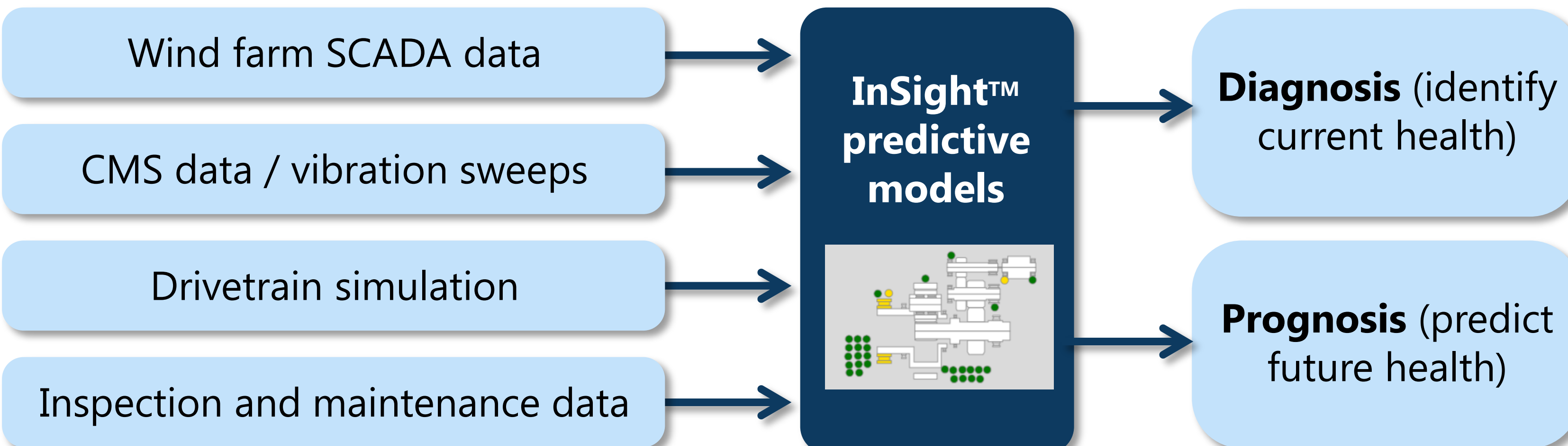
Statistical reliability analysis

Close up: predictive life models

- The aim of a predictive model is to **prioritise** and **schedule** maintenance and inspections
- For many years, predictive life models have been utilized for maintenance scheduling:
    - Aerospace – aero engine monitoring
    - Power production – steam and gas turbines
    - Helicopters – ‘Health and Usage Monitoring Systems’ (HUMS)

Close up: predictive maintenance models

- In a fleet of wind turbines, predictive models work in conjunction with CMS to give the longest lead time for identifying faults
- Huge cost savings come from scheduling large crane operations simultaneously – e.g. Romax regularly save US operators money supporting main bearing repairs



Conclusions

1) Predictive maintenance reduces costs for O&M, if done properly.
   - Existing CMS: must be usable by operators and be watched.
   - CMS does not exist and cost is prohibitive: intelligent tools (portable vibration sweep) can be used.
   - This is Romax's experience. Comments from operators?
2) Innovative software tools are being developed and tried.
   - Inspection and maintenance data: reports, replacements.
     - Statistical analysis, failure rates of each gear and assembly.
   - SCADA data analysis: power, wind speed, yaw, pitch, temperature, alarms, …
     - Usage: How long a bearing spent above 70°C.
   - Vibration analysis: Gear, bearing, shaft, coupling faults