Lessons learned in Heavy Assets Predictive Maintenance

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Challenges

- Demand is increasing **while budgets are shrinking**
- Infrastructure and Rollong Stock are **under stress**
- Regulatory bodies are more demanding on **Quality of Service**
- Trains have to be on-time and mission ready
- MRO costs need to be drastically reduced
- Sacrificing Customer Service for Cost reduction is not an option
Maturity driven by safety, availability and TCO

<table>
<thead>
<tr>
<th></th>
<th>Safety</th>
<th>Availability</th>
<th>Costs</th>
<th>Maturity</th>
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</thead>
<tbody>
<tr>
<td>Air Forces</td>
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<td>Airlines</td>
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<td>Aircraft Manufacturer</td>
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<td>Aircraft Engines Manufacturer</td>
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<td>Railway Company</td>
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<td>Rolling Stock Manufacturer</td>
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<td>Turbine Manufacturer</td>
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<td>Truck / Tractor manufacturer</td>
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<tr>
<td>Manufacturing Process</td>
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<tr>
<td>Electrical Grid</td>
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<td>Telco</td>
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<tr>
<td>Mining Industry</td>
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<td>Facility Management</td>
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<td>Oil &amp; Gas</td>
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<tr>
<td>Car manufacturer</td>
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Even though Railway pays lot of attention to availability and TCO, it’s still lagging behind on predictive maintenance.

- Hard constraint
- Average constraint
- Soft Constraint
Use Cases

US Army
- Predictive Maintenance program has produced for a fleet of 120 helicopters:
  - 11% increase in fleet availability
  - 41,000 Maintenance Man Hours saved in a year

Navistar
- Telematics data is enabling
  - Failures prediction
  - Fleet operator notification
  - Proactive routing of spare parts
- Logistic response enhanced from 7 to 2 days

Caterpillar
- Monitoring and analysis of Truck engines sensor data has led to 100 M$ savings in executing Performance Based Contracts

Union Pacific
- 3350 trains/day on a 32,000 miles network
- Infrared sensors installed every 20 miles
  - 20 millions readings/day
  - Monitoring of mechanical wear, overheating and derailments
  - 1500 problems qualified every day
- Reduction of damages, delays and customers claims

More availability and 5-10% reduction in life cycle costs
Siemens Vision 2020

Teradata was named a Bronze Stevie Winner for the video "Siemens: Speeding Down the Path of a Successful Future with Big Data and Analytics" in the "sales & technology video" category.

http://www.teradata.com/Resources/Videos/Siemens-Capitalizing-on-Digitization,-the-In
Identifying risks and anticipating breakdowns

Predictive Maintenance

- Sensors continuously gather a breadth of data
- Most of the data is analysed on the fly
- Drafts are identified
- Alerts are triggered on abnormal situations

Benefits

- Performance-based-contracting
- One delay out of 2300 trips
- Valero Est the reliable RENFE High Speed Train
- Big market share on Madrid – Barcelone leg

Identifying risky situations

Market share: Railway vs Airlines
Prognostics & Health Management

- **Diagnostics**
- **Health** & **Performance Awareness**

**Failure cycle**
- Working OK
- Drift starts
- Precursor Faults
- Incipient Fault propagation
- Failure occurs
- Collateral damage

**Analytical functionality**
- Assess health
- Identify drifts
- Detect and isolate precursor faults
- Monitor and trend fault progression
- Predict Continuously Remaining Life
- Explore events prior to failure
- Unveil failure signature

Health & Performance Awareness

www.railway-asset-management.org
Impact of Predictive Maintenance

Before

Corrective

Preventive

After

Corrective

Preventive

Predictive

- Develop a deeper knowledge on equipment health and aging effects
- Improve Equipment reliability and maintainability
- Optimise Maintenance Planning and Execution
- Make better trade off between Repair vs. Leave in field with Partial Mission readiness
- Increase the sharing of equipment life cycle data
- Process Reengineering

The amount and mix of Maintenance workload will change
Focus on Predictive maintenance

- **Intelligent Asset Tracking**
  - Analyse asset demography

- **Health and performance Surveillance**
  - Scrutinise asset operations & pathologies

- **Maintenance Planning**
  - Fine tune the maintenance plan or maintenance process

- **Material Management**
  - Predict spare parts demand and align supply & inventories

- **Maintenance & Repair Efficiency**
  - Accelerate MRO tasks completion

- **LifeCycle Costing**
  - Planning and controlling MRO costs over the asset life

- **Asset Improvement & retrofit**
  - Upgrading and extending asset capabilities
Value first!

- Asset Life
- Logistic footprint
- Fleet size
- Maintenance Scheduling
- Over Maintenance
- False alarms & No Faults Found
- “Waiting for Parts”
- Operations interruptions
- CAPEX
- Gains
- Energy Consumption
- Maintenance Induced Damage
- Post Maintenance Test Hours
- Maintenance Man Hours
- Event Driven Maintenance
- Inspection Hours
- Collateral Damages
- Spares
- Obsolescence
- Inventory Sizing & Mix
- Supply Chain Pipe Line
- Repair vs. Replace
- Turn Around Times
- OPEX
- Turn Around Times
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- OPEX
- Turn Around Times
Focus first on organs that actually drive failures

- Shafts
- Gears
- Bearings
- Compressors, turbines, pumps, motors, etc
Leverage any kind of data

- Bearing Failure
  - ODM, EODM, EBM, VIBES, RLI, SWAN

- Bulk Oil Degradation
  - OCM, ODM, EBM

- Vapor Phase Coking
  - OCM, ODM, EODM, EBM

- Fan 1 Rotor Tip/Cracks
  - ECS, BVM, AFD, IDMS, EDM, VIBES, RLI, SWAN

- Overflowing/Blocked Fuel Nozzle
  - EDM, VIBES, RLI, SWAN

- Combustor/HPT Erosion
  - EDM

- LPT Blade Rub
  - EDM, VIBES, RLI, SWAN

- Gearbox Failure
  - VIBES, RLI, SWAN

- Bearing Failure
  - ODM, EBM, VIBES, RLI, SWAN

- Bulk Oil Contamination
  - OCM, EBM, ODM, EODM

- AFD
  - Acoustic FOD Detector

- BVMX
  - Blade Vibration Meter

- EBM
  - Electrostatic Bearing Monitor

- ECS
  - Eddy Current Blade Sensor

- EODM
  - Eletrosatatic Oil Debris Monitor

- EDMS
  - Engine Distress Monitoring

- IDMS
  - Ingested Debris Monitoring

- ODM
  - Oil Debris Monitor

- PZT
  - Piezoceramic Patch Crack Detection

- RLI
  - Robust LASER Interometer

- SWAN
  - Stress Wave Analysis

- VIBES
  - Vibrations sensor
Understand the dynamic of the machinery

<table>
<thead>
<tr>
<th>Failure modes</th>
<th>Sensor Data</th>
<th>Data characteristic</th>
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<tbody>
<tr>
<td><strong>Bearings</strong></td>
<td>• Vibration</td>
<td>• high noise in raw data</td>
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<tr>
<td>• Failure of outer/inner races, rollers or cage</td>
<td>• oil debris</td>
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<tr>
<td></td>
<td>• acoustic</td>
<td></td>
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<tr>
<td></td>
<td>• emission</td>
<td></td>
</tr>
<tr>
<td><strong>Gears</strong></td>
<td>• Vibration</td>
<td>• High noise</td>
</tr>
<tr>
<td>• Tooth pitting</td>
<td>• oil debris</td>
<td>• Signal modulation (coupling with bearing, shaft transmission path)</td>
</tr>
<tr>
<td>• Gear crack</td>
<td>• Acoustic emission</td>
<td></td>
</tr>
<tr>
<td>• Wear</td>
<td></td>
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</tr>
<tr>
<td><strong>Shafts</strong></td>
<td>• Vibrations</td>
<td>• Vibration signal is relatively clean and harmonic</td>
</tr>
<tr>
<td>• Misalignment</td>
<td></td>
<td>• frequency components of rotating speed can indicate the defects</td>
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<tr>
<td>• Unbalance</td>
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<td></td>
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<tr>
<td>• Bend</td>
<td></td>
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<tr>
<td>• Crack</td>
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<tr>
<td>• Rubbing</td>
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Pick and train relevant analytical technique

**Feature extraction**
- Fourier Transform Analysis
- STFT Analysis
- Wavelet Packet Decomposition
- Autoregressive Modeling

**Diagnosis**
- Feature Map
- Hidden Markov Model
- Bayesian Network
- Neural network

**Pattern Recognition**
- Logistic Regression
- Feature Map
- Statistical Pattern Recognition
- Hidden Markov Model

**Forecasting (Remaining Life)**
- Autoregressive Moving Average
- Match Matrix Prediction
- Fuzzy Logic Prediction
- Neural Network Prediction
Visualise and share

Accord

Flux

Hiérarchie

Affinité
Enlarge progressively your data scope
Adopt a step by step approach
Thank you!

Q & A