Self-powered, On-board, Wireless Condition, Preventive, & Predictive Monitoring

Keith J. Abate Sr.
SR. Dir. Business Development
Perpetuum Rail

2016 Rail Conference
Perpetuum Overview

- Global leader in the design and manufacture of the world’s most powerful *Vibration Energy Harvesting* technologies.
- Corporate HQ - Southampton UK --- U.S. HQ - Charleston, SC.
- Perpetuum uses its expertise and IP to design, manufacture & supply:
  - Vibration Energy Harvesters – Converts vibration to useable electrical energy.
  - Networked & Hosted Data Analytic Services.
Vibration Energy Harvester (VEH)

- Electromagnetic Construction:
  - Magnets, Coils & Springs
  - Power management
  - Temperature compensation

- Converts train vibration into electrical energy used to perpetually power on-board wireless sensors.

- No batteries, No wires ... No maintenance.

- Designed and tested for extreme environmental conditions.
Self-powered Wireless Sensor Node (WSN)

- Vibration Energy Harvester
- 3 Axis MEMs Accelerometer
- Temperature Sensor
- Energy Storage
- Power Management
- Microprocessor
- Wireless Transmitter

- Measures vibration in 3 axes.
- Sensitive to variations in vibration of 0.025g.
WSN Installed

“Fully Enabled Intelligent Rail Truck”

No Wires ... No Batteries ... No Maintenance
Installation Examples
Data Concentrator

- Collects data from on-board WSN’s
- Uploads collected data to Cloud.
- GPS (location & Speed)
Perpetuum Data Center

Data Analysis & Analytics
- Vibration Analysis
- Intelligent Algorithms
- Simple Health Index Output
  - BHI – Bearing Health Index
  - WHI – Wheel Health Index
  - THI – Track Health Index
  - Gearbox
  - Traction Motors
  - Others in development
System Overview:
Data Collection/Communication/Analysis

- Onboard Self-Powered Wireless Sensors
- Onboard Wireless Communication Network
- Data Concentrator
- Data Analytics

Perpetuum Secure Cloud

- Analysis
- Trending
- Status
- Alerts / Alarms
- Notifications
ACTIONABLE INTELLIGENCE

Collection

Focused Extraction And Process

Analyze and Distill
(based on YOUR Environment)

Relevant to you

High Quality & Resolution

Actionable

Asset and Life-cycle Analysis

Actions That Drive Improvement

Agency Specific
Simple Intuitive Displays

No learning curve or special training
Rail Intelligent Monitoring Modules (RIMMs)

WHEELS/WHEEL SETS (WHI):
- In-service Health, Performance & Predictive Monitoring
- Automated Daily Inspection
- Car, Truck, Axle and Wheel Identification & Severity
- Real-time Identification, Notification & location of RCF Issues
- Automated Alerts
- No False Positives / No Missed Exceptions

JOURNAL BEARINGS (BHI):
- In-service performance & predictive health monitoring
- Life cycle and Performance Analysis
- OEM design, life cycle and performance recommendation verification
- New OEM vendor qualification

TRACK Health Index (THI):
- Continuously updated real-time shock and vibration map
- GPS Correlation to Actual Track Route & Specified Locations
- Reports in-service changes to track condition
- Data from revenue trains & actual environmental conditions
- Absolute identification/differentiation of track vs. vehicle issue
- Report / Alert when operational/safety thresholds are exceeded
Gearbox/Traction Motor Monitoring
Wheel Health Index (WHI)

After Wheel Turned
Bearing Health Index (BHI)

Screenshot showing the bearing health signatures on unit 375906 MOSL vehicle 79036, note the increasing magnitude on the wheel 6 and then showing after the bearing change, the level reducing back to the baseline of the other bearings.

Bearing Replaced
Track Health Index (THI)

Same H/W used to detect track/rail problems
Simple Distilled Display

No Special Training

Click for Detailed Information

Top alerts are listed in map view

<table>
<thead>
<tr>
<th>Alerts</th>
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<tbody>
<tr>
<td>Ashford Down FAST 42m12c</td>
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<td>Chislehurst Up 42m12c</td>
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<td>Sevenoaks Up FAST 44m11c</td>
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<td>Tonbridge Up FAST 52m64c</td>
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Robust Suite of Analysis Tools
Various Levels of Resolution Detail

Zoomed in view of alert
Track Degradation Leading to Rail Break

Figure 3 – Surface plot of vibration level for vibration parameter 2 over time, at location of Feature 1 and nearby

18 Months

Rail Break

Increasing Vibration over many months
Evolution: Fully Monitored Assets

- Ride Quality
- Door Open/Closed
- Coach Temperature
- Gearbox and Traction Motor
- Brakes
- Suspension
- Compressor
- Pantograph
- 3rd Rail Shoe Impact
- Wheel/Rail Interface
- Wheels And Bearings
- Track
- Door Open/Closed
Deployed & Proven Solution

- 0% False Alerts for monitored components
- > 10,000 Assets being monitored
- > 1,800,000 data points collected per day
- > 1,000,000,000 miles of sensor database
- Production Rollouts - >20 fleets, 7 countries, 4 continents
- Bearings, Wheels, Track, Gearbox, Traction Motor, Ride quality
- Additional RIMMs in development
- Continuous tuning of Intelligent algorithms
- EMU, DMU, Loco, Coach
- Light, Heavy, Commuter & Freight Rail
Summary

• Self-Powered, Wireless, On-board Condition, Predictive & Preventive Monitoring
  • Powered by Vibration
  • No Wires, No Batteries, No Maintenance
  • On-board – Near Real Time & Continuous – In Revenue Service

• Actionable Intelligence – Actions that drive improvement
  • Focused Analytics to intelligently maintain your revenue assets & track
  • Perpetuum = Vibrational Analysis Experts
  • Eliminate “False” alarms or “No problem found”

• Optimized Transit Operations
  • Determine YOUR specific real-time operating health & performance conditions
  • Positive impacts on: Inspection, Repair or Replace, Overhaul, Spares, Scheduling
  • Maximize Safety, Availability, Reliability & Sustainability of rolling stock, track & people
Take Aways

- Improved Safety – Public, Employees, Assets & Property
- Maximized Quality of Service & Asset Utilization
- Enhanced Quality & Experience for Users
- Optimized Maintenance, R&R, Shop, Inventory and Overhaul Operations
- Reduce Time Revenue Assets spend in Shop
- Extend Rolling Stock and Linear Asset Life Cycles
- Unburden over extended/limited skilled workforce
- Supports State of Good Repair
- WSN provides Wheel, Bearing & Track monitoring
Technology Transporting You Beyond the Challenges of Tomorrow

Innovation in Motion