Connects For
A Better Life

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Smart Coach: Towards Predictive Maintenance

A comprehensive
Open Standards Implementation
of
Internet of Things Technology

on LHB coaches of Indian Railways.

A presentation to Esteemed Officer of Indian Railways on the Founders Day Celebration,2021
at IRIMEE

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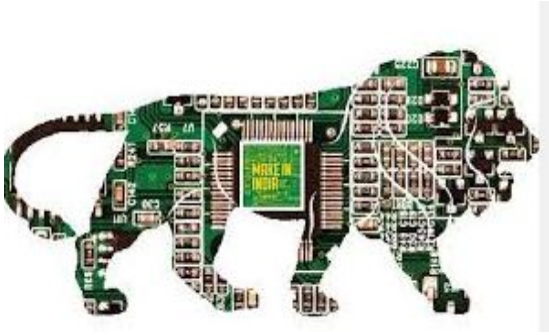
About Us

Connects For A Better Life

- 15 years of High-end Automation Systems to Railways.
- A 100% Indigenous R&D driven company.
- Strong Play in Railway Sector in India.
- Comprehensive capabilities
  - Design
  - Manufacture
  - Project Execution
  - Service support.
- National Presence.



The Awards

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sidbi
THE ECONOMIC TIMES
INDIA MSE AWARDS
FINDING BUSINESS LEADERS OF TOMORROW IN MICRO & SMALL ENTERPRISES SECTOR
KNOWLEDGE PARTNER CRISIL
An S&P Global Company

Tech Savvy MSE of the Year

Artificial Intelligence enabled IoT Solution
Smart Coach Systems, AC online Monitoring Solutions

Most Innovative MSE of the Year

Electronic Systems for Transport
Fogsafe GPS System, Passenger Information Systems for Railways and buses.

Rail Analysis™

Special Recognition Award for work on CCTV on trains

Infrastructure

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- Delhi : 7500 sq ft design and development facility.

- Faridabad: 35000 sq ft unit for Electronic Manufacturing.

The People

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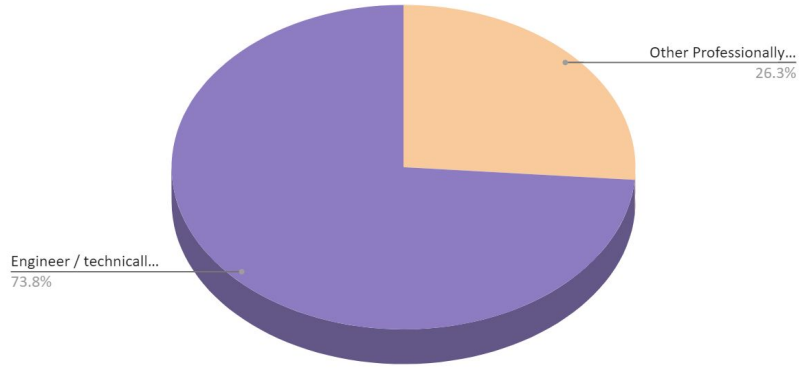
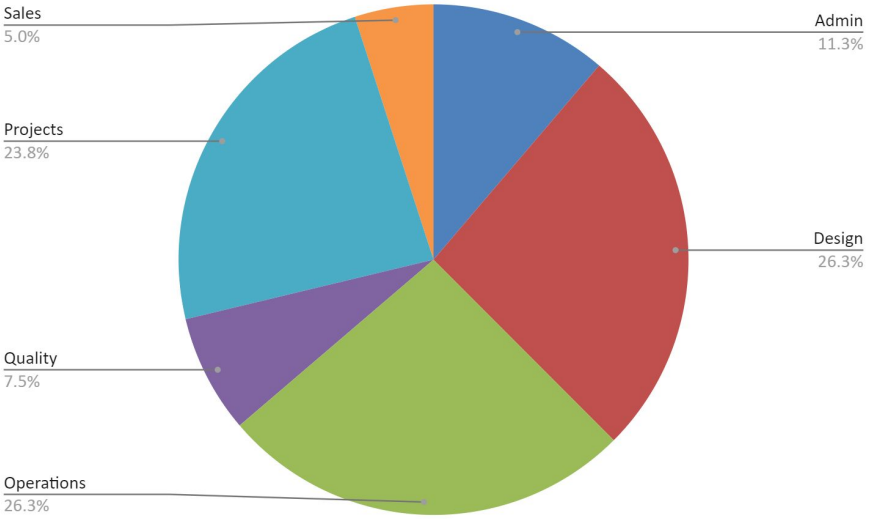
- 3 out of 4 people at A.Paul are Technically Qualified/ Engineers.
- Youthful Organisation
  Average Age <35
- On-Roll HeadCount (Aug 31)
  - Professionally Qualified other than Engineer: 21
  - Engineers: 59





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"A Good Product is what the customer loves to talk about"

Our
Design and Make in India
Success Story thus far.

GPS based Fogsafe System

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- A Customised Railway Navigation Device for drivers during dense foggy conditions.
- RDSO Approved.
- Hailed as a major success.

A Tweet by Sh. Piyush Goyal, Hon'ble Minister for Railways.

"Beating Fog, Ensuring Safety & Punctuality: Despite heavy fog, Indian Railways is clocking over 90% punctuality with the help of advanced devices in place. Railways has almost doubled installation of fog pass devices in the past 2 years."

Digital Destination Boards, Passenger Announcement and Information System

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- RDSO, ICF, RCF, MCF approved Source.
- Completely integration PA, PIS and Digital Destination Boards.
- Configurable over the Air.

PA-PIS for Trainsets/AC-EMU/ MEMU/DEMU

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Our Prestigious Clients

ICF Chennai

Crompton Greaves

Besco

BHEL

TITAGARH

BEML NEW FRONTIERS. NEW DREAMS

A proven 100% indigenous Solution

IoT enabled HVAC controllers for Trains

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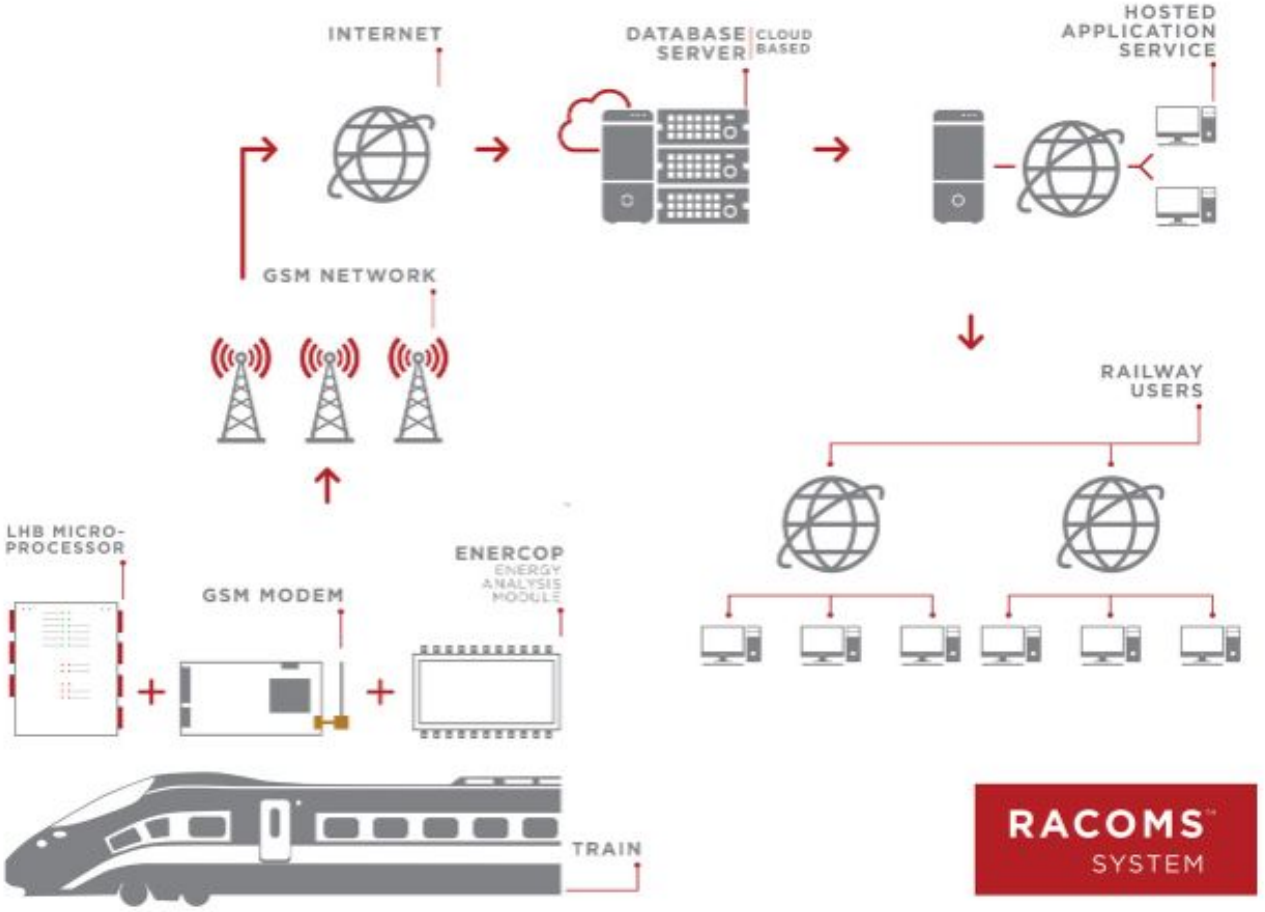
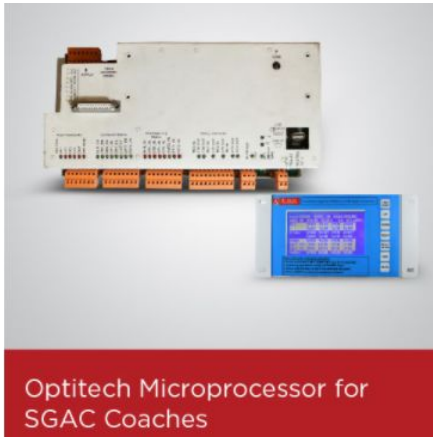


Optitech Microprocessor for LHB Coaches



Optitech Microprocessor for SGAC Coaches

CCTV Surveillance Systems for Trains.

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- 2015: First to Commission a rake; Shan-e-Punjab Inaugurated by Hon'ble Rail Minister.
- Video Analytics based Centralised CCTV viewing on the new Tejas in 2021.

IP based System for Train Sets

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- Passenger Wi-Fi
- Real-time passenger info
- Infotainment & CCTV
- Live vehicle tracking
- Smart ticket machines
- Smart ticketing & contactless payments

Crew Voice and Video Recording System
(CCVRS for Locomotives)

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Key Features

- Based on Industrial grade Compute System
- Highly Rugged design
- Audio-Video capabilities
  - Supports Noise Cancelling Mics
  - Supports Analog and Digital cameras
  - Video Analytics
  - 90+ days of storage

Infotainment System for Trains and Buses

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- OptiPlay Streaming Media Server.
- People In-seat Video on Demand on their Smartphones.
- Integrated media and gaming services.
- Android and IOS App for Mobile & Tab
- Enables on device announcements and Journey updates

Opti Play
Entertainment on the Go.

“ Predictive Maintenance is the Holy Grail that everyone wanted but no one knew how to build for.”

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Predictive Maintenance.
The Holy Grail of Maintenance Engineering

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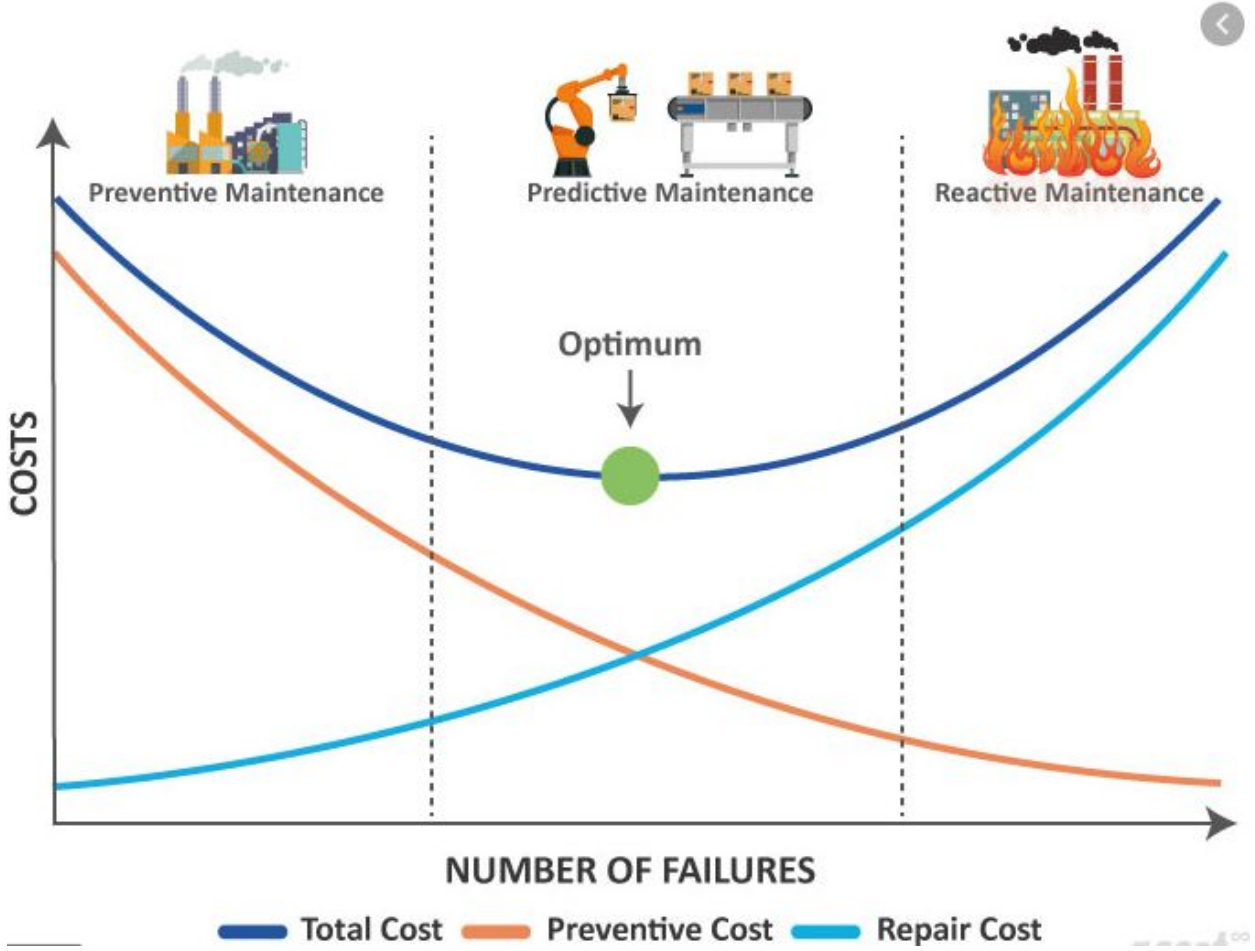
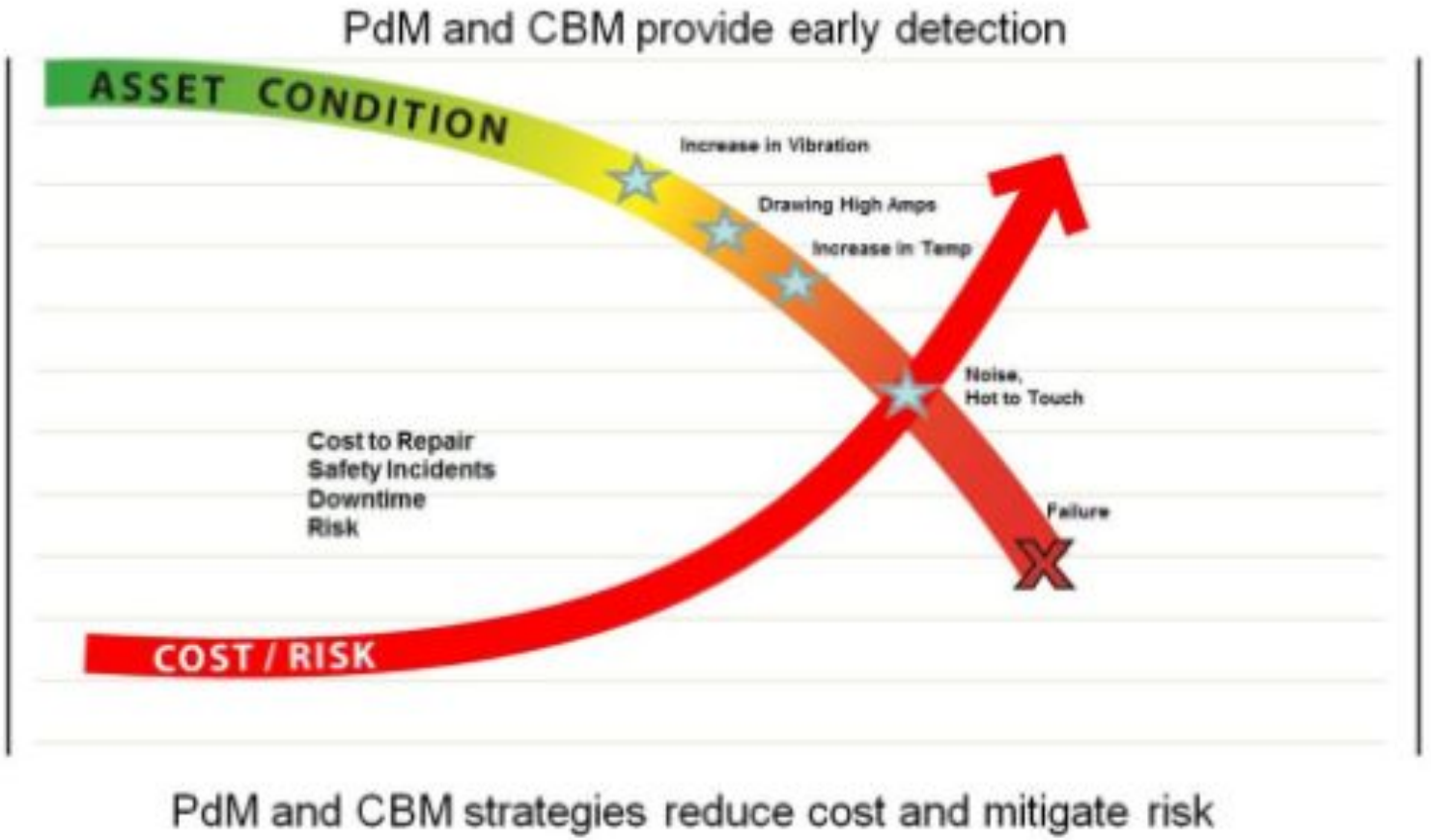


Preventive Maintenance
- Too Many Inspections,
- High Manpower.
- Higher Turnaround Time (TAT) for the Asset.

Predictive Maintenance
- Condition Based Maintenance.
- Low Manpower.
- Time to Plan Withdrawal From Service.
- Lowest TAT.

Reactive Maintenance
- Failures.
- High Cost
- Unpredictable TAT.
- Unplanned Withdrawals

Turn Around Time Minimisation is more Important than Cost Reduction.



Predictive Maintenance helps bring predictability to Operations.

Predictive Maintenance: A Mirage of the Past.

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Recurring Manual Readings

MANUAL METHODS

AUTOMATED / MANUAL METHODS

Manual Data collection and Capturing Processes, failed any Predictive Maintenance Regime, until arrival of IoT technologies.

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Predictive Maintenance: The IoT way

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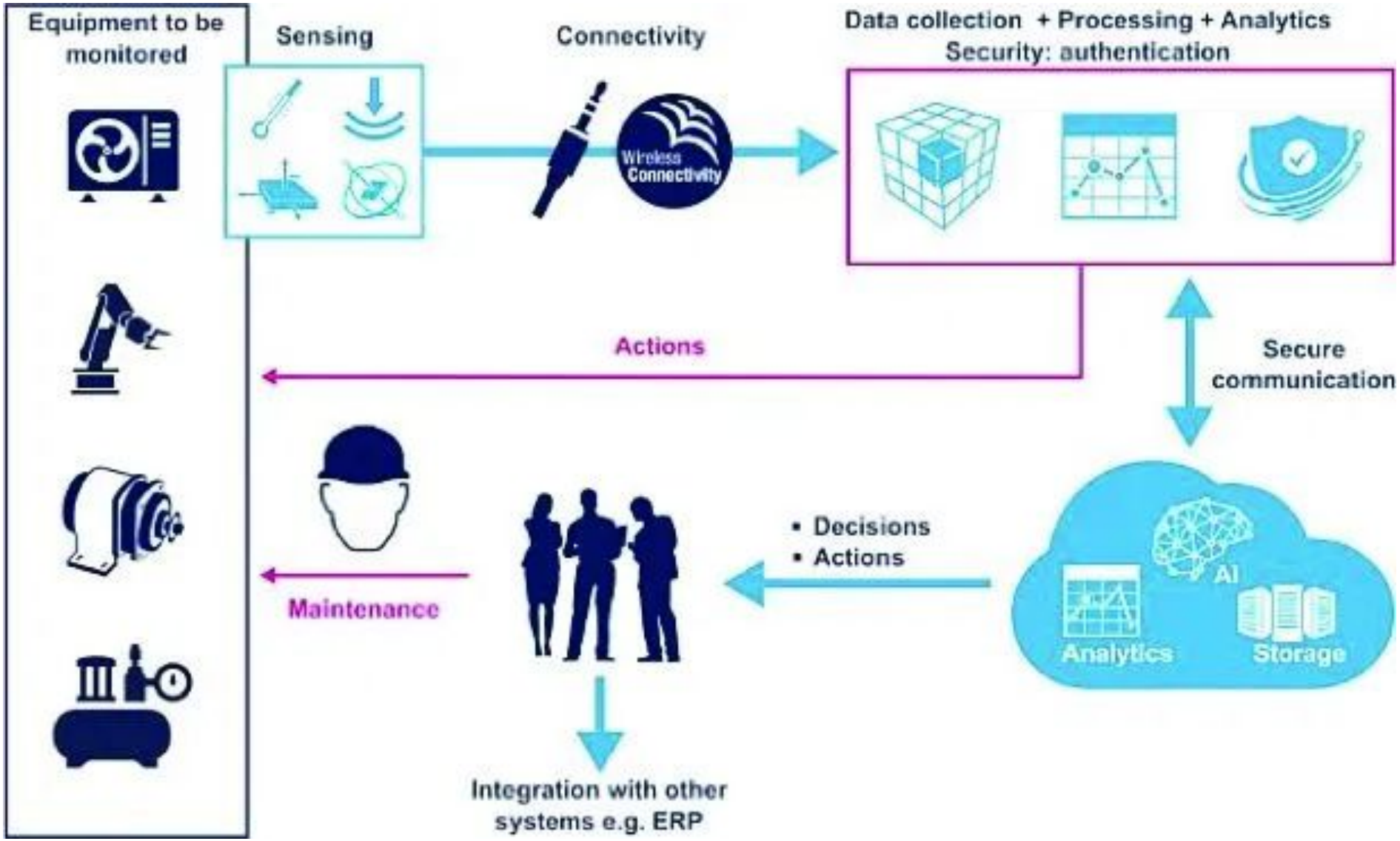

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Automated Data Collection from Rolling Stock.

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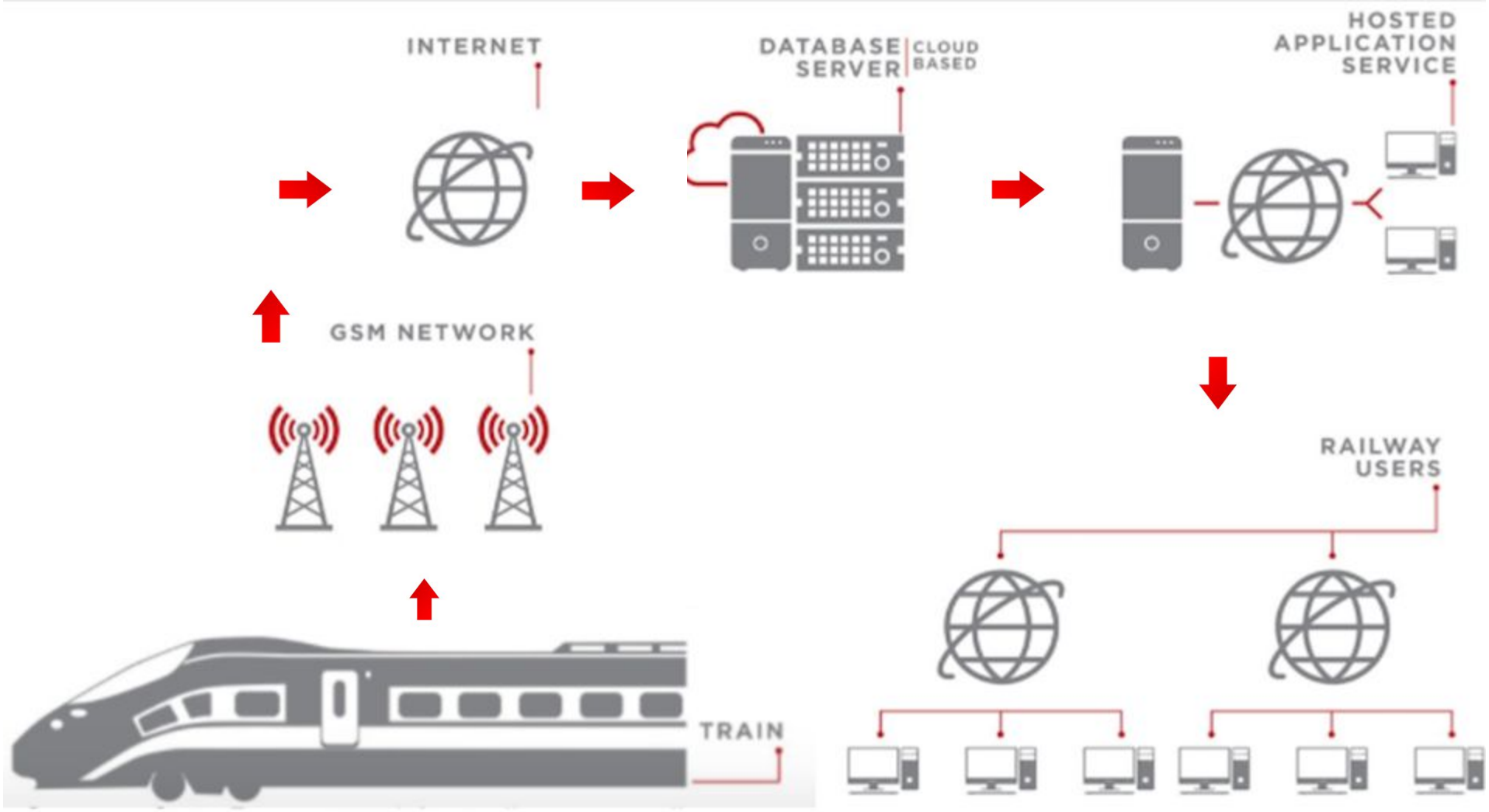

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Smart Coach:
A case study on an Open Architecture IoT System and upgrade in Passenger Services.

4 Major Differentiating Constructs

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4 Major Constructs that make a Coach Smart

IoT based Remote Monitoring System

Cloud based Control Center at HQ, IoT enabling of HVAC, Brake and Fire System

Ethernet Train Network

Train Wide Surveillance and Coach Health Monitoring System

On Board Condition Monitoring System

Wheel, Bearing and Health Monitoring

Upgrades in Passenger Amenities

IP based PA-PIS, Destination Board, Emergency Talk Back System and Next Gen CCTV

Other Minor Monitoring Sensors

Air Quality, VOC gas in toilets, Handicap friendly Panic Buttons

Brining new Generation Communication Systems and Passenger Amenities to LHB Rakes.

IoT enabling a Networked Train.

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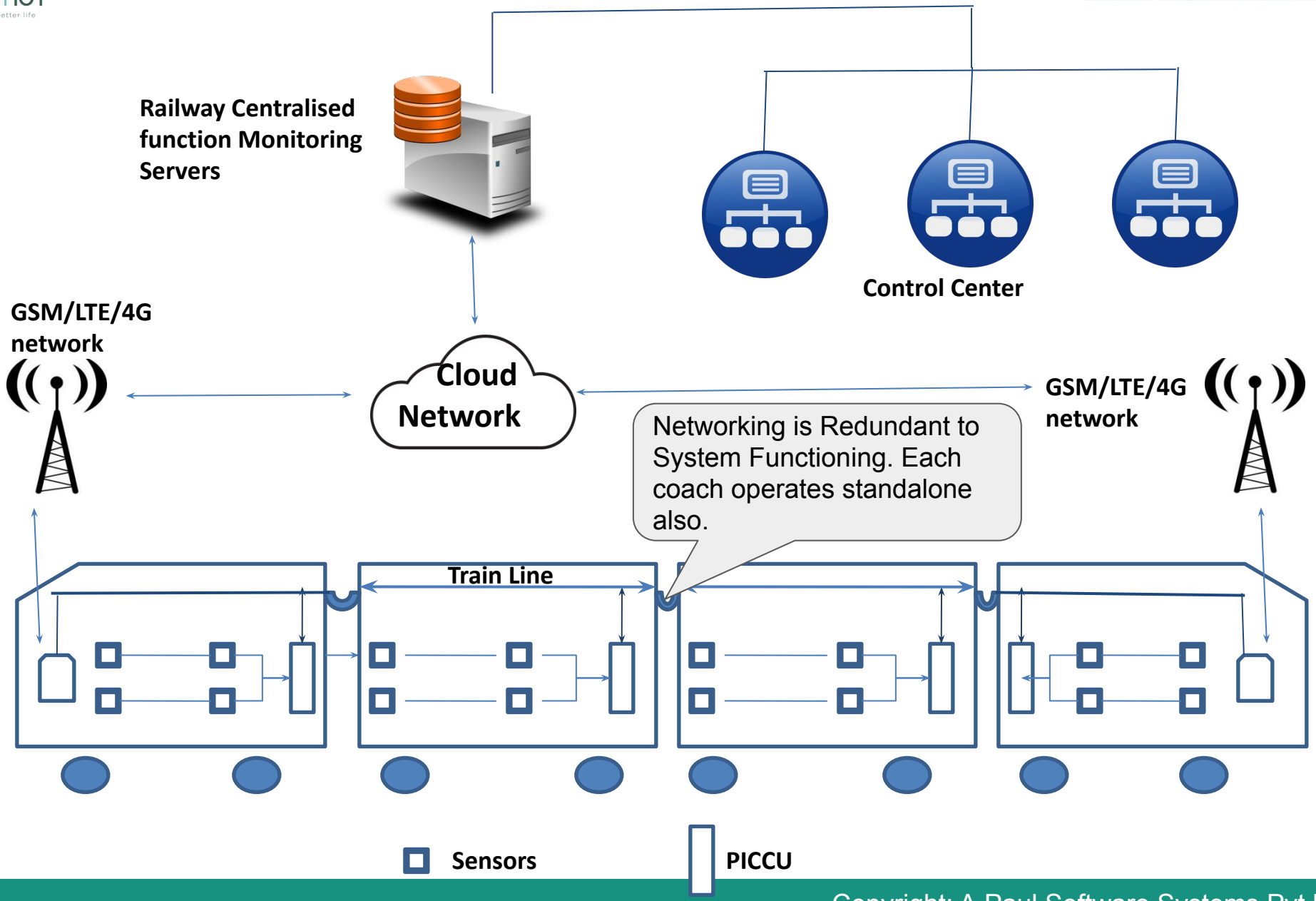

Systems integrated by Smart Coach IoT hub.

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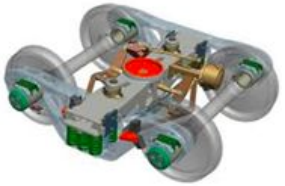
Wheel, Bearing and Bogie Monitoring

Air Conditioning System

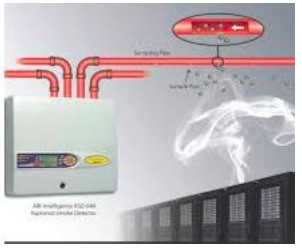
Electrical parameter Monitoring



WSPD

Toilet Sensing Module

Water level sensor



Fire and Smoke Detection System

Coach Battery Monitoring System

Remote Monitoring

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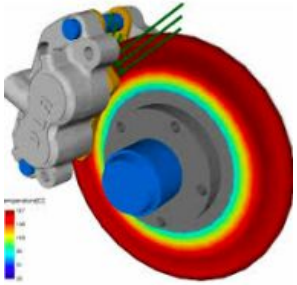
What it extends to:

A IoT enabled Data Aggregation Device

And

A Business Ecosystem



Brake System-WSPD

A Command and Control Center

Electric Control System

Perpetuum System

Air-Conditioning Controls

PICCU: The Brain Of A Smart Coach

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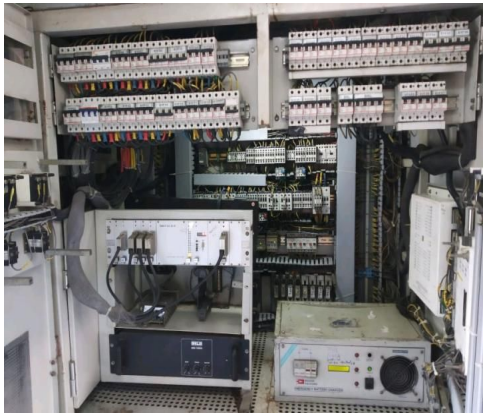
The Single Coach Computer

- Zero Modification Retro-fits in Existing Coaches.
- Indigenously Built, Industrial/ Mil Grade compute-system
  - Linux OS based Open Architecture.
- Multiple Applications – Single Host.



Passenger Amenities Upgrades

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Passenger Information system

CCTV Surveillance

PA System

Emergency Talkback system

Digital destination Board

Opti Play
Entertainment on the Go.

Infotainment on the go

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Internet Of Things

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IoT based Remote Monitoring System

1st First Train in India to be Monitored using a Cloud based Command and Control Center Software.

Realtime Remote Equipment Monitoring System

- 1st First IoT enabled Train in India.
- 1st First Train in India with 100% Remote Monitoring of HVAC system
- 1st First Train in India with Remote Monitoring of WSPD.
- 1st First Train in India with Real Time Water Level Monitoring.
- 1st First Train in India with Real Time Passenger Information And Destination Board Configuration and Management.

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Train Safety

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On Board Condition Monitoring System

20 Years Maintenance Free.

On Board Condition Monitoring System

- 1st First Indian Train with Automated Wheel Health Diagnostics.
- 1st First Indian Train with Automated Bearing Health Diagnostics
- 1st First Indian Train Track Health Monitoring System.

"No train Fitted with the Perpetuum System has ever had a Bearing or Wheel Defects while in service."

- Steve Turley, CEO, Perpetuum, UK

Train Ethernet Networking

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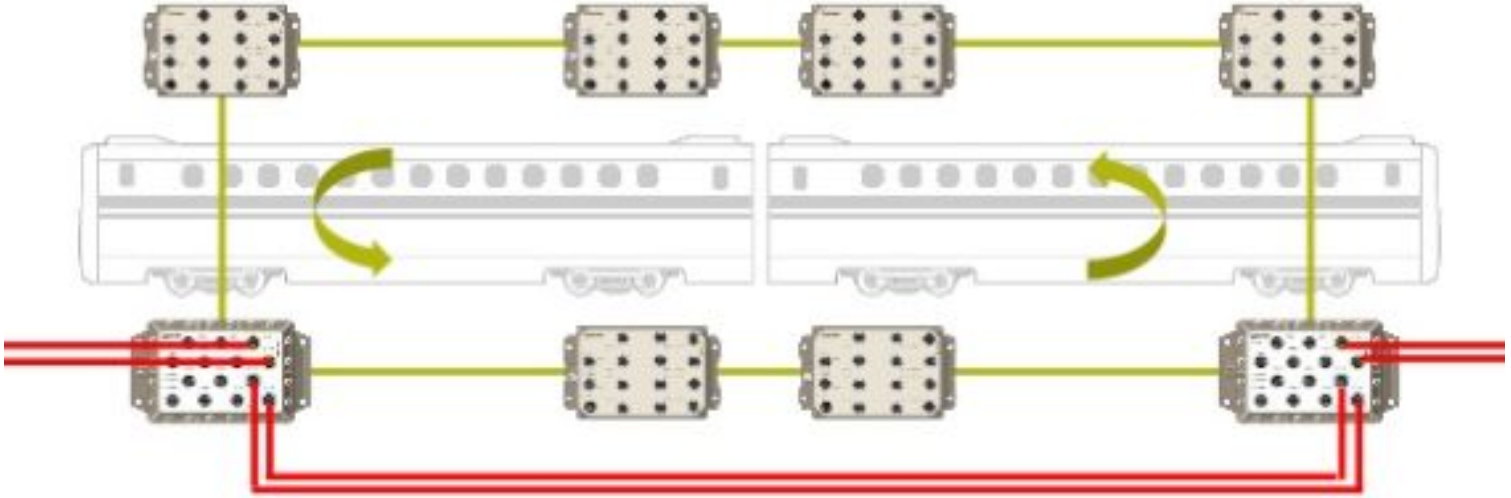
Ethernet Train Network

Train wide Ethernet Networking.

- 1st First LHB train with Train Wide Ethernet Networking.
- 1st First LHB train with Centralised “Train Monitoring System”
- 1st First LHB Train with Centralised Fault Monitoring System in Power Car.



Upgrades In Passenger Amenities

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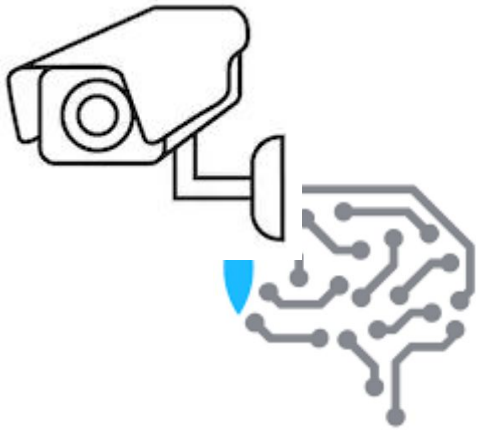
Upgrades in Passenger Amenities

Enhanced Passenger information System

- 1st First Train with GSM based Digital Destination Boards.
- 1st First Train with IP based Passenger Information and Announcement System.
- 1st First LHB Train with an Emergency Talk Back System.
- 1st First Train with Handicap Friendly Panic Button in Toilets



Next Generation CCTV surveillance System

- 1st First Train with Video Analytics based CCTV systems
- 1st First Train in India with an on-Train CCTV Monitoring Station
- 1st First Train in with Remote Viewing and retrieval of Coach CCTV Surveillance data

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Ensuring Happier Passengers

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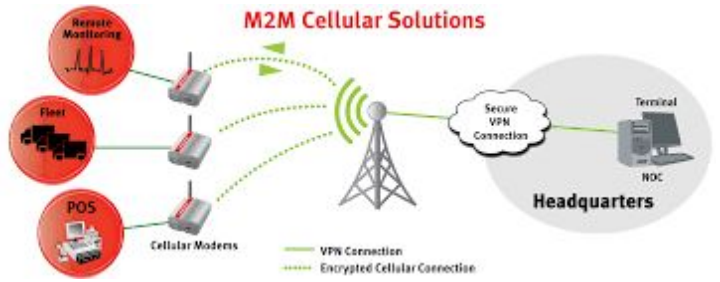
Comfort Application running on the PICCU

- Old System
  - GPS based Passenger information System (PIS)
  - No Control Center Function.

- Smart Coach System Add-Ons
  - Full Ethernet based System.
  - GSM based System Configuration and Management.
  - Wifi based Entertainment System.
  - Automated PA system
  - Emergency Talk Back System



LED Based Digital Destination Board

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- Flush Mounted: Automated cleaning System friendly.
- Requires no change in Coach Structure/ Coach Lines.
  - Recommended for Retrofitment.
  - Thin Display Developed for new coaches.
  - 45mm thick, Operates on 24V, IP66, High Brightness.

Passenger Communication

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Emergency Talk back System

- Reduce Chain Pulling during Passenger Emergency
- Present on all new Train Sets Globally (Train 18 in India).
- Talk to Guard.
- Integration to CCTV Surveillance.

IP based Displays.(Ethernet- TCP/IP based)

- Plays Rich Content, Videos, news, advertisements.
- Infotainment capable.
- Smart 10” Displays in FAC coupe.

IP based LCD displays

PA system

- Integrated Centralised Manual Announcement.
- Integrated Amplification System.
- Integrated Toilet Panic/ Fire Announcement.

Upgraded CCTV Surveillance System

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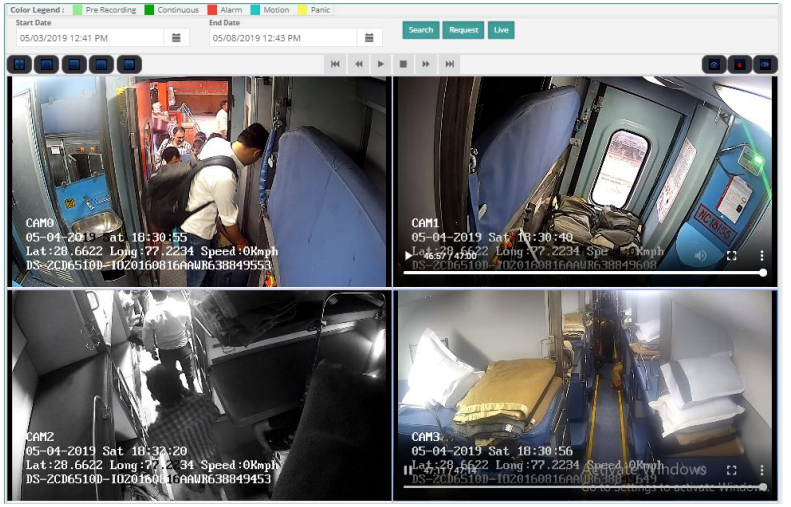
- Old System
  - Simple Low Cost Hardware Recorder from Chinese Sources.
  - No Centralised Monitoring on Train. No Remote Monitoring.
  - Prone to HDD Failures.
  - Requires Physical Visit for footage retrieval halting train operation.

- Smart CCTV System.
  - Software Driven Feature Rich CCTV Surveillance System.
  - Feature Facial Recognition and Analytics.
  - Train wide Monitoring in Power Car.
  - Remote Connectivity and footage retrieval without visiting the train.
  - Emergency Talk Back System integration.



Know Your CCTV System health: Complete Camera, NVR and HDD Health Reporting on MCF Server.

Infotainment System

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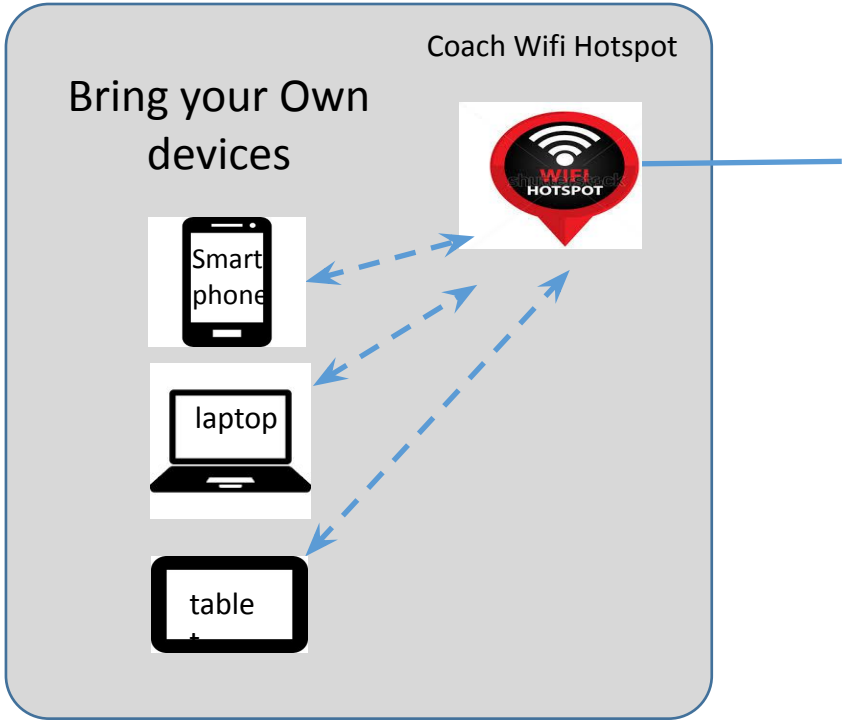
- OptiPlay Streaming Media Server.
- Video on Demand over local wifi on Smartphones.
- Integrated media and gaming services.
- Android and IOS App for Mobile & Tab.
- Seat Back 10.1” display options



Opti Play
Entertainment on the Go

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Compelling Value of Integration

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Similar Budget

Amazing Functionality.

The Train Walkthrough

Train wide Networked Surveillance

Power Car Surveillance

Sensors Deployed

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Sensors Used and Explained

- Choked Filter Sensor
- Air Quality- PM2.5/10 (Dust), VOC
- Tank Water Level
- Toilet Odour

SMART
Dust Sensor
SM-PWM-01C

Dust: PM2.5/PM10

- Laser Beam based.
- Laser intensity Attenuates in a higher dust environment.
- Digital Output for particle count by size.

Chock AC Filter Detection

Principle of Operation: Pressure drop across a choke filter is higher than usual.

Sensor Systems

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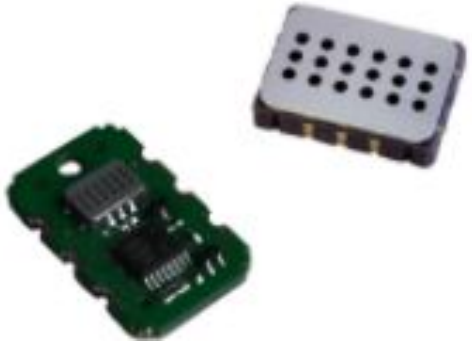
Water Level Sensing

Principle of Operation: Pressure Increases (cm of H2O) with water head over the sensor.



Odour, CO2 And VOC Sensors

Principle of Operation: Catalytic Element detects various gases, converting them into an electrical signal..

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Smart Coach.

Flawless Wheels, Bearings and Tracks

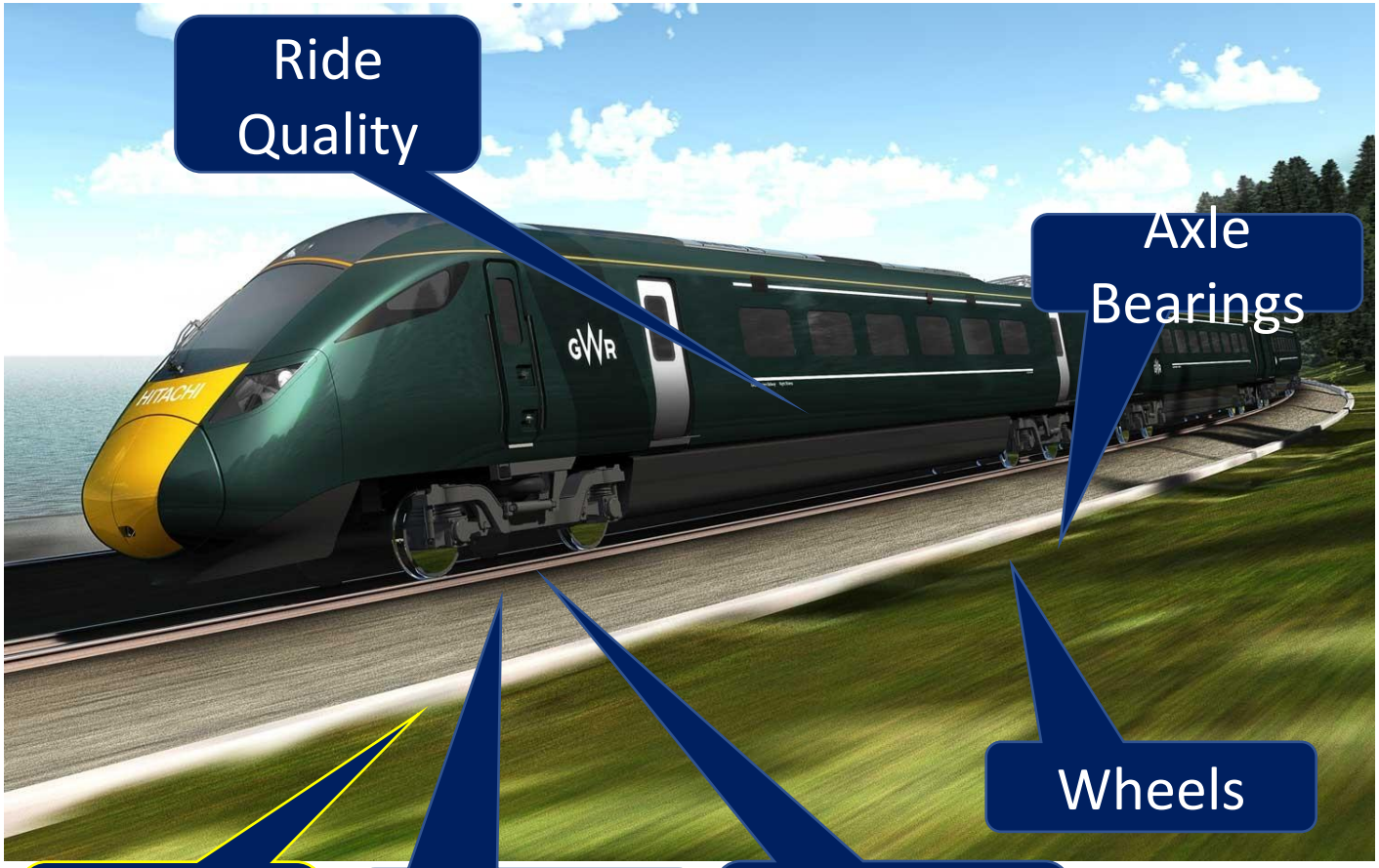
“Every Coach is a Track Surveyor.”

perpetuum

A University of Southampton UK Company founded in 2004

- 100% focussed on Rail industry globally
- 2012: First Order from Bombardier.
- 70% employees engineers and PHD's
- Shipped 25,000 sensors to global rail industry.
  - Europe, North America, India, China, Australia, Japan
  - Intercity, Commuter, Metro, Freight
- 2021: Perpetuum will be acquired by Hitachi Rail

The Intelligent Train ("In Flight Monitoring")

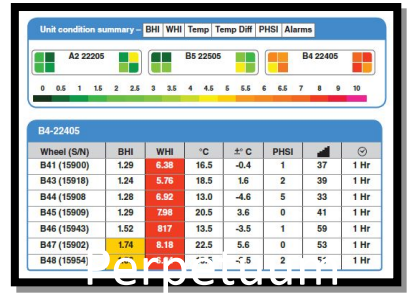


Data Concentrator with accurate GPS & “Bump Box”

Data Download Via Cellular Network

Perpetuum Algorithms

Reliable Actionable Information



Secure Analytics

Customer Specific Dashboard

Wireless Sensor N

43

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Wheel Bearing Monitoring System

Vibration based -Vibration Powered Condition Monitoring

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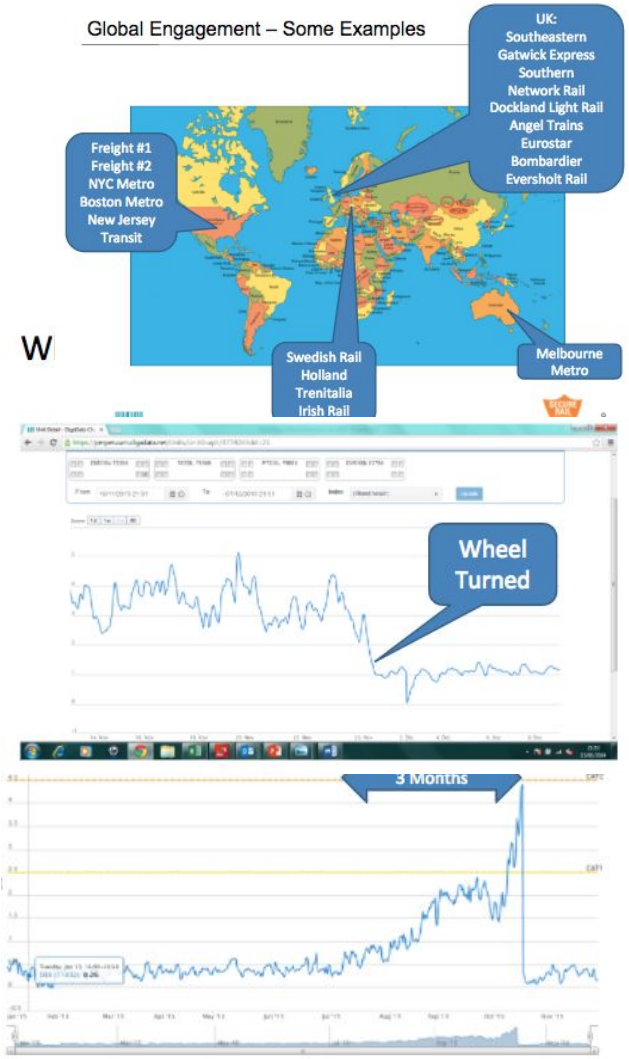
- Compact, self contained and sealed Sensors.
- Axle Mounted , On-Board Detection System
- Detect
  - Wheel Health - Turn when you Must.
  - Bearing Health - 3 months before total failure
  - Track Health- Rail Crack, Rail Break, Rail Twist etc.
- Correlate with Geolocation and Vehicle ID.



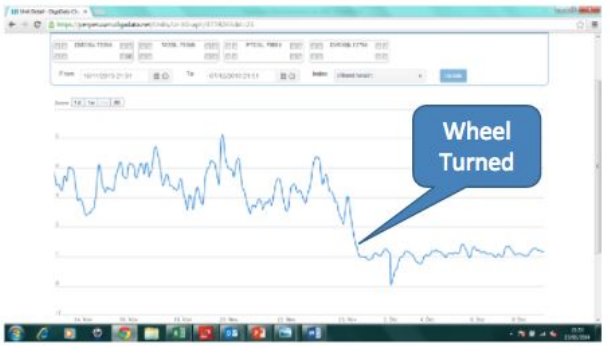
Online Application

Bearing, Wheel and Track Health Monitoring

Mature Solution

- Very High on Learning Curve with 25,000+ sensors.
- Sophisticated Algorithms optimised across multiple train types and conditions.
- Simple Reliable Actionable Information
- **Very early identification of damage**

Wheel Health



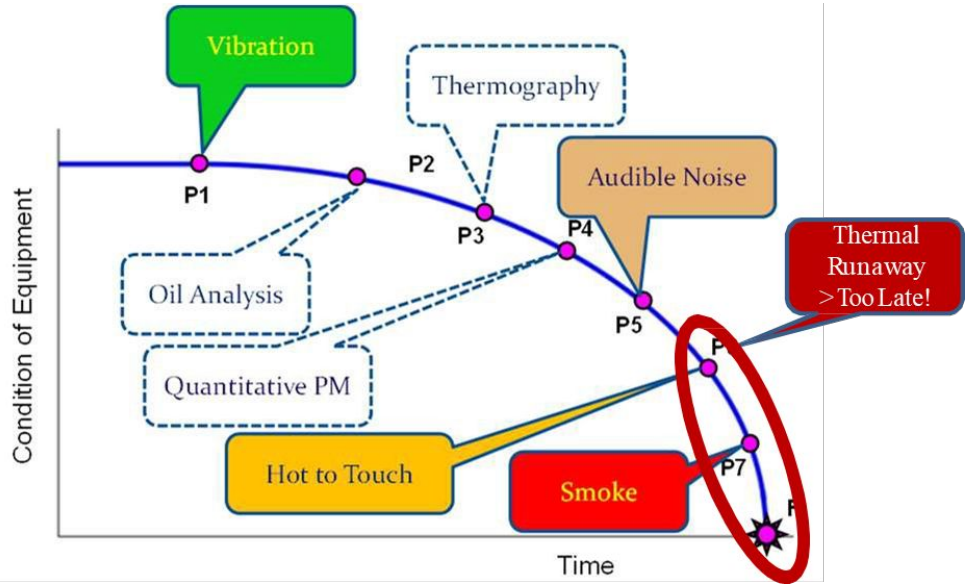
Value of Early Warning using Vibration Technology.

By the time you can hear the bearing, it's already too late.

- **Time to Failure for various detection methods.**
  - Vibration: 4-6 Months
  - Acoustic: Hours to Days
  - Temperature: Minutes to Hours.

- **Vibration is a very reliable measurement**
  - Sensor is in direct physical contact to source of damage
  - Immune to background noise like an acoustic sensor
  - On board repeated measurements every few minutes: accuracy and trending are extremely good

- **Early warning delivers massive operational benefits**
  - Allows maintenance to be planned well in advance and avoid reactive an inefficient responses
    - Maximise efficiency
    - Minimise downtime
  - Allows early intervention before problem gets worse and more expensive to repair
- **Avoids in service failures**



Energy Harvester Based Wireless Sensor Nodes

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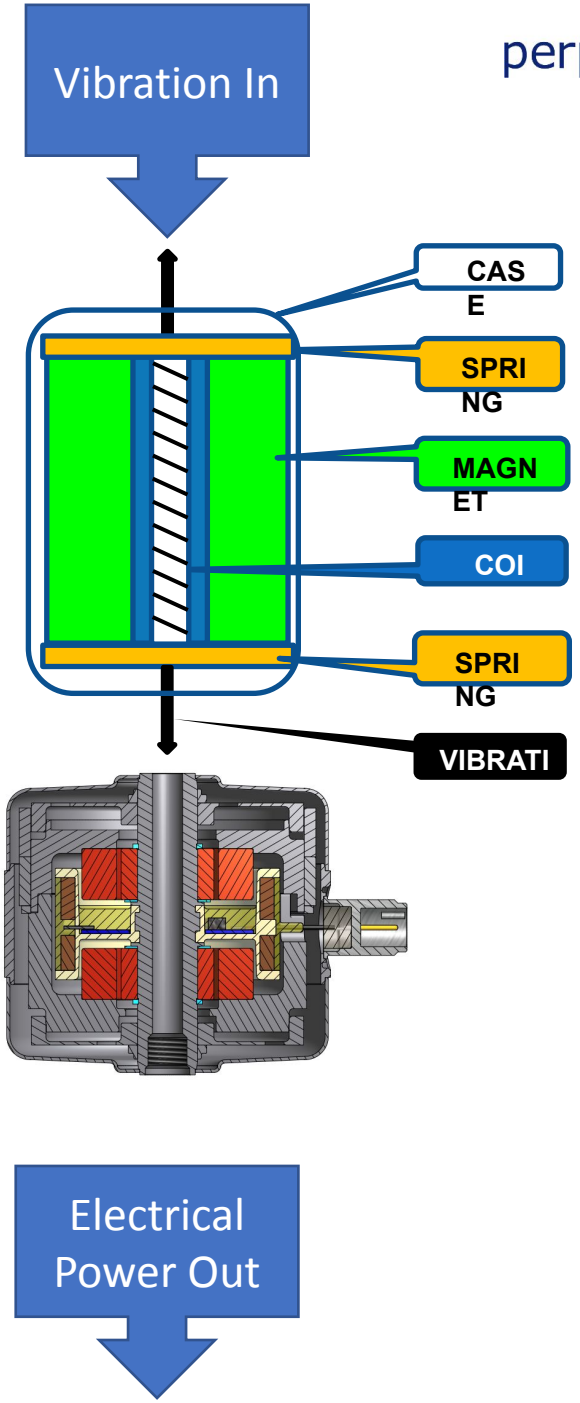
- Why Wireless?
  - Easy to fit / retrofit on any bogie.
  - Reliable & maintenance free.
  - No wires: no wiring faults.
  - Zero time wiring up the Bogies.
  - Lowered cost of ownership as no wiring maintenance required.
  - 10 minute tac time on production line.

20 Years Maintenance Free.

Vibration Energy Harvester Power

- Fit and Forget.
- Train Vibration Powered: No Wire, No Battery, No maintenance.
- 15 Minute Retrofittable on Track Side, No shunting Challenges to pit.
- No E-waste: Environment Friendly
- Why Electromagnetic Energy harvester?
  - Higher Energy Budget .
  - No Battery Replacements required
  - Eco-friendly solution
- Key Features
  - High resolution monitoring of track vibration. (not possible using battery).
  - Permits Track Health Monitoring.



Results

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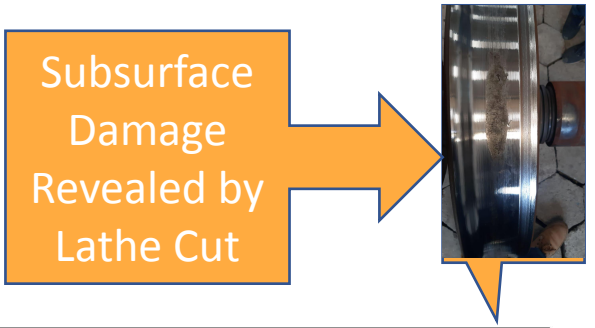
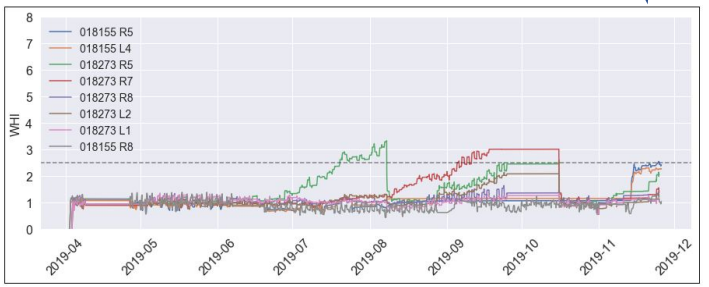
Monitor Wheel Health

- Detects early stage surface and **subsurface wheel damage**.
- Prevents Wheel Shelling by flagging only rogue wheels for turning.
- Non-Subjective determination of turning needs.



Monitor Bearing Health

- Up to 3 months advance notice of impending failures.

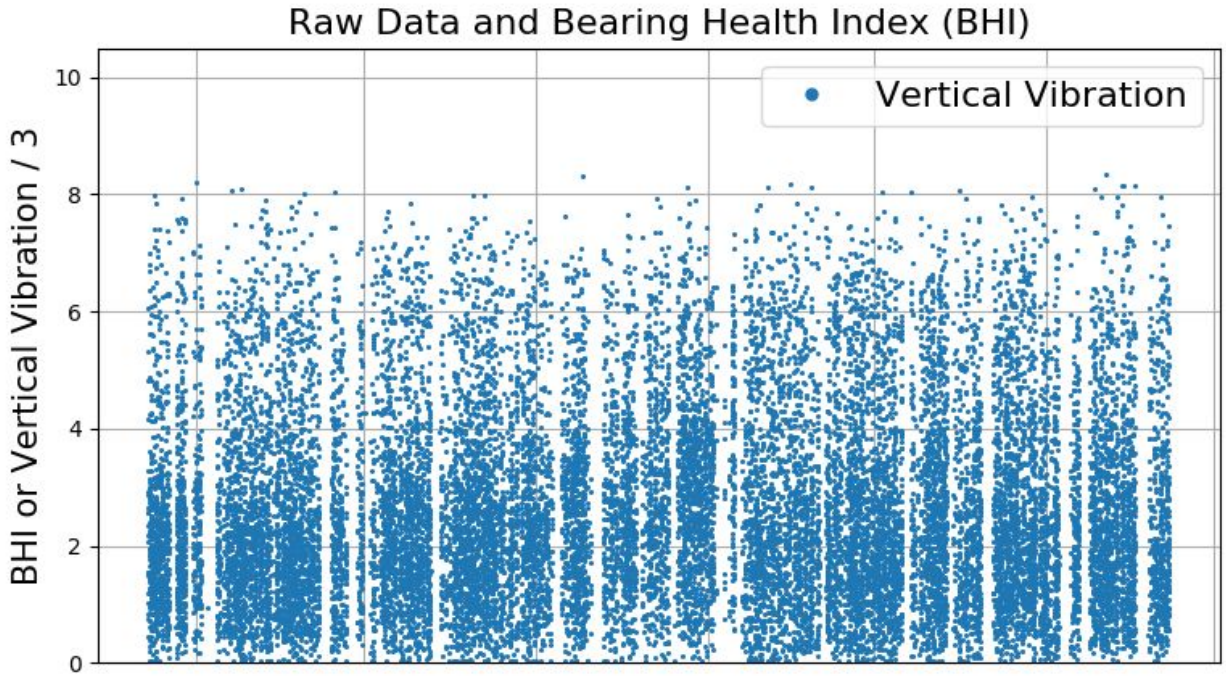


Identify Track Hot Spots

- Heat map of the track vibration.
- Specifies geo coordinates of track infrastructure needing repairs.
- High Power harvester allows high resolution measurements unachievable through battery.

Transforming Data into Information

Raw Data



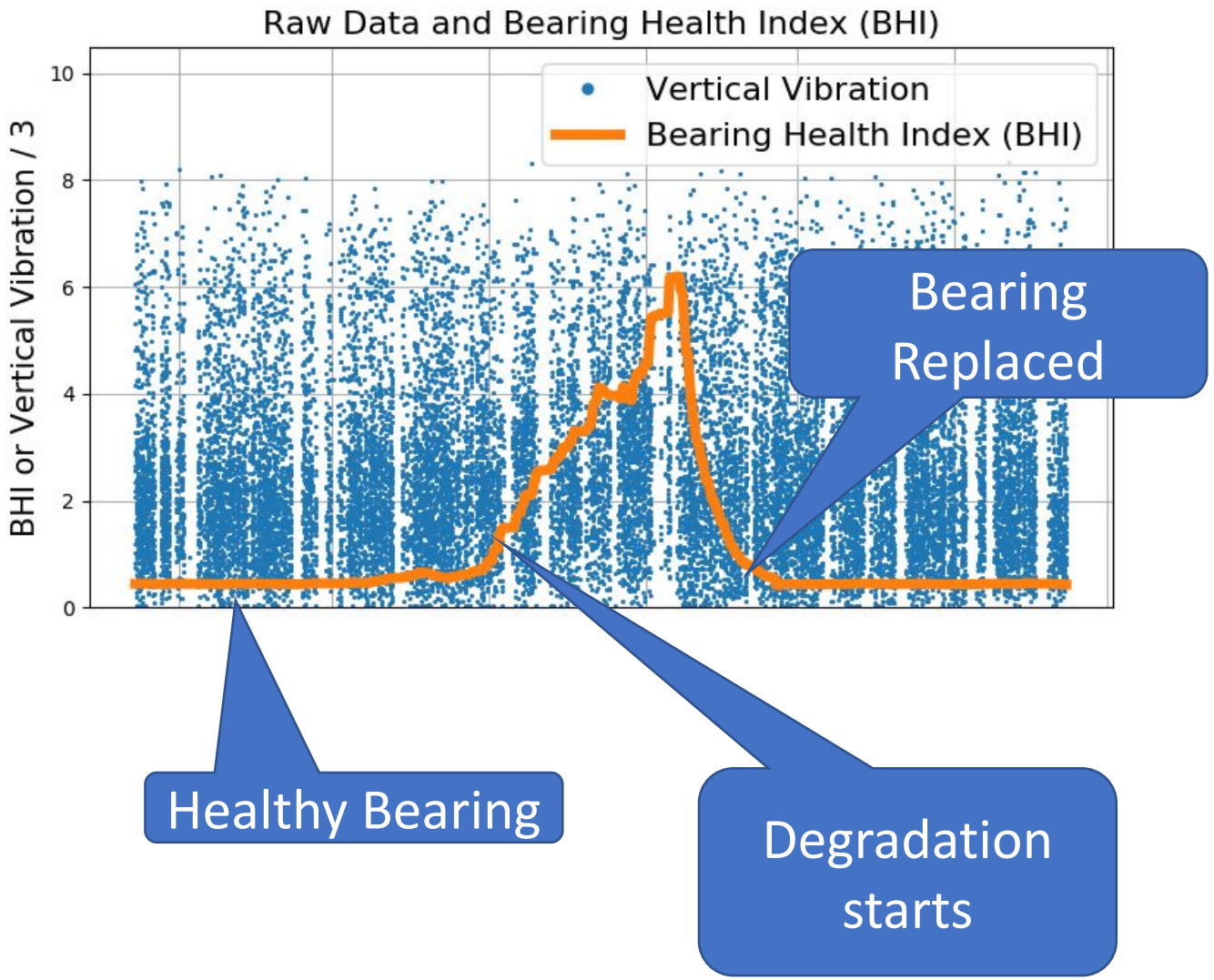
Time

Transforming Data into Information

Raw Data

Sophisticated Perpetuum Software Algorithms

Accurate, Reliable Actionable Information



Sophisticated Algorithms to Deliver Health Indices

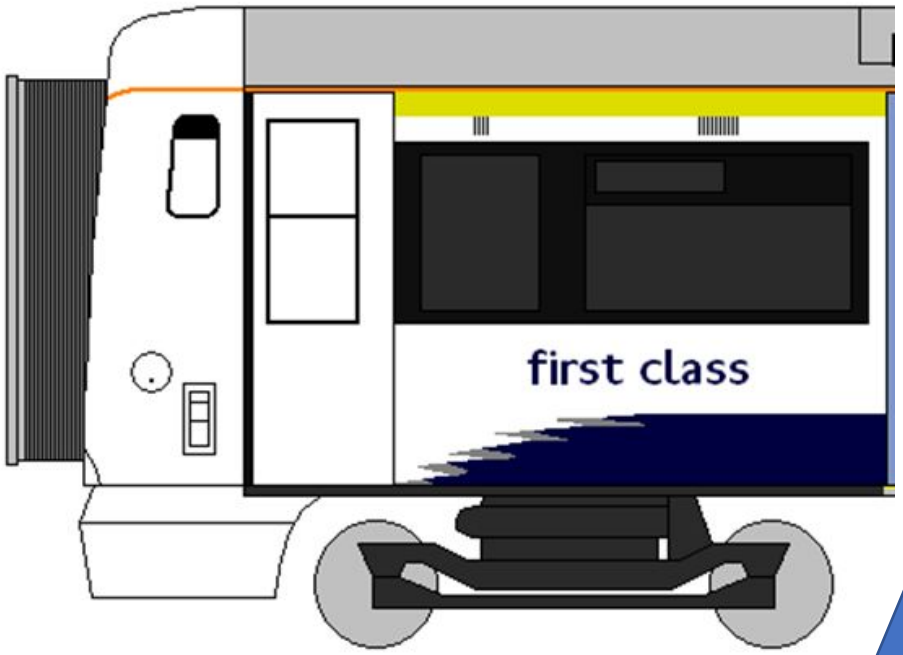
perpetuum

- **Vibration, temperature and GPS data are collected by the Wireless Sensor Node (WSN)**
- **Initial processing happens on the train:**
  - Reduce the noise
  - Add GPS data
  - Transmit off the train through the cellular network
- **The key processing is done in the cloud**
  - Allows greater processing power to be deployed
  - Allows comparison with rest of the fleet
  - Sophisticated algorithms translate raw data into a Health Index which gives the condition of the asset being monitored
  - Algorithms based on experience on 25,000 sensors globally since 2012
  - The data from the train is processed and translated
- **The software analytics are complex but the out put is simple i.e. “Actionable Information”**

The technology does the hard work to deliver a simple actionable solution

Health Monitoring – Same Hardware – Enhanced Analytics

perpetuum



One Sensor but many Sources of Vibration :

- Correlation with Wheel Dynamics
- Correlation with Bearing Dynamics
- Correlation with Train Location
- Random Vibration (Noise)

→ Wheel Health Index (WHI)

→ Bearing Health Index (BHI)

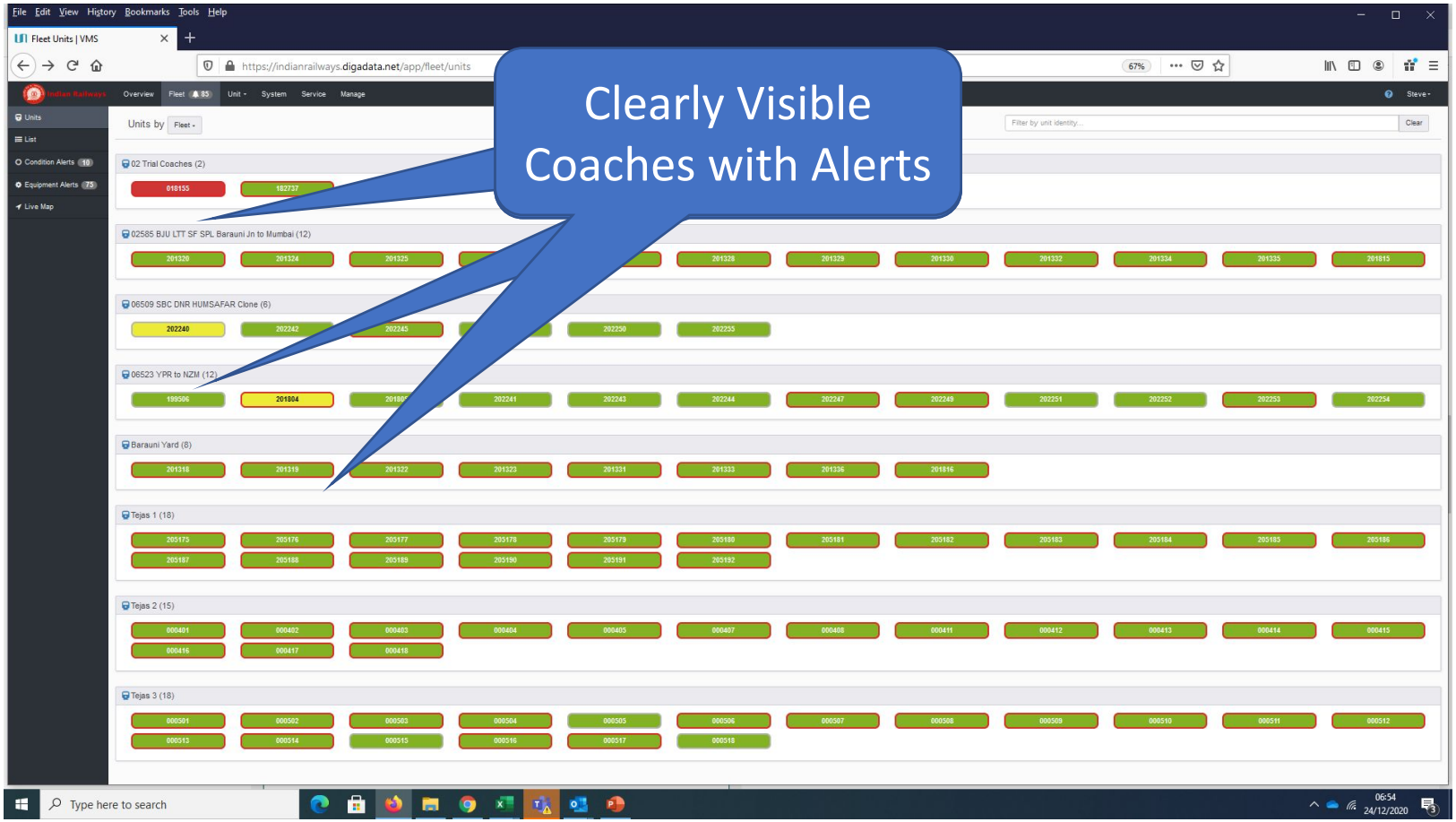
→ Track Health Index (THI)

→ Eliminate

Measuring Rail/Wheel Impact

Fleet Overview

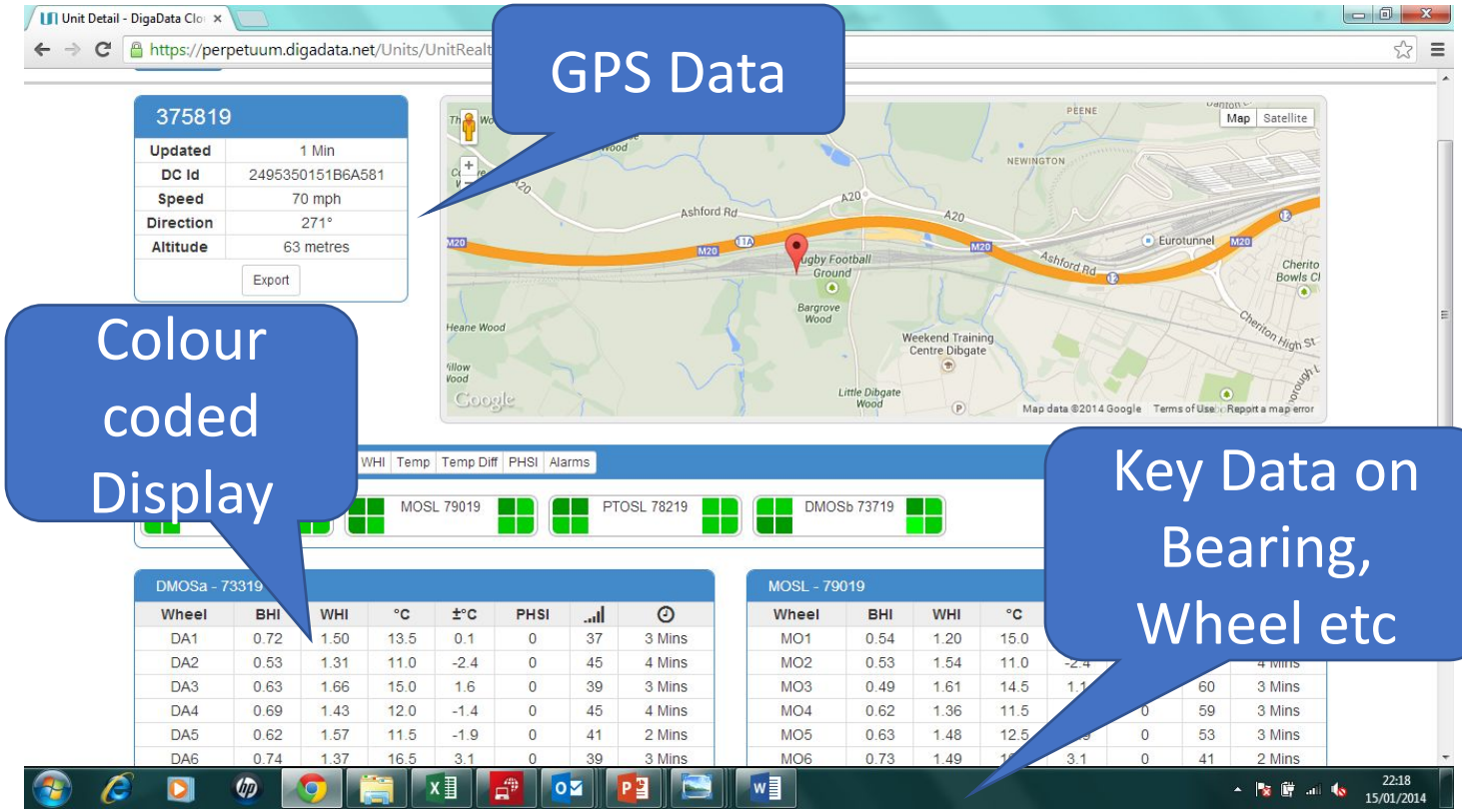
Fleet Overview in Perpetuum Vibration Monitoring System (VMS)



Data from Indian Railways Smart Coach Trial

L1

Simple Display of Key Information



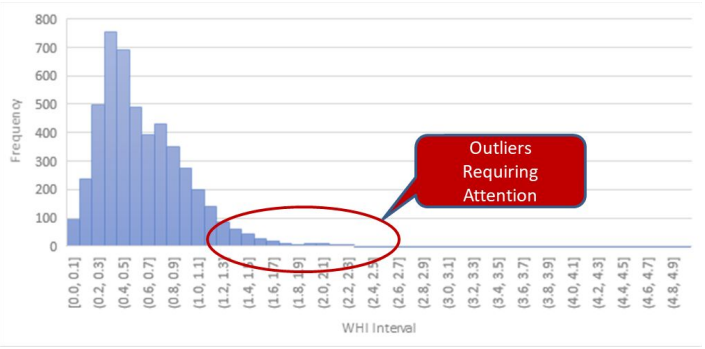
Wheel Health

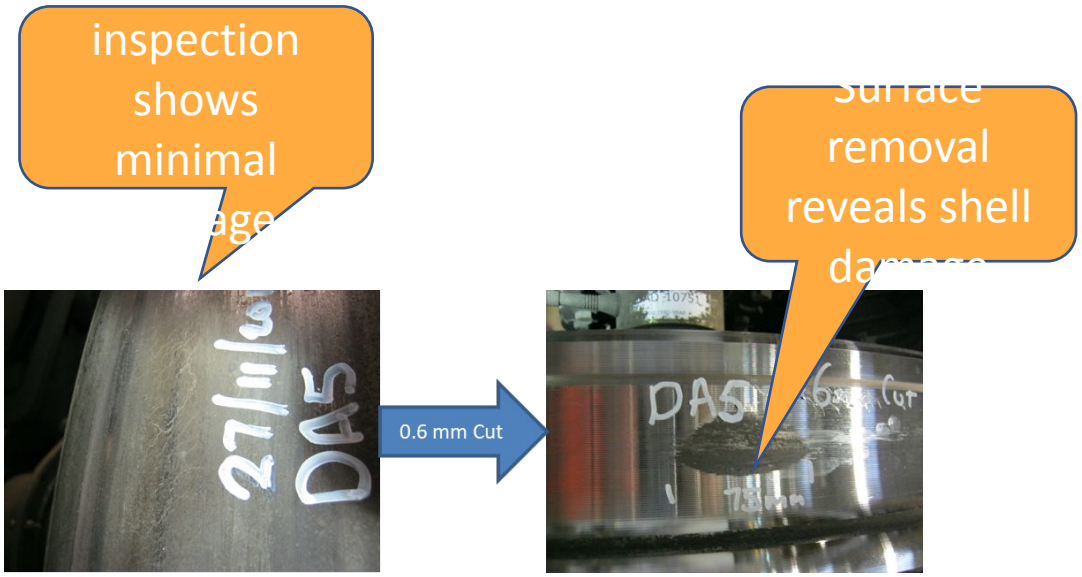
The Benefits - Dramatic Wheel Quality Improvement

Dramatic Improvement in Wheel Quality by Using Perpetuum OBCMS

Wheel Management

- Round wheels
  - Optimised rail/wheel contact
  - Maximum adhesion
- Damage e.g. flats
  - Initiates further damage
  - Reduction in wheel life grows exponentially with time.
  - Reduces adhesion as rail wheel contact is reduced
- Rolling Contact Fatigue (RCF)
  - Slow subsurface damage
  - Grows with time
  - Not easily visible from inspections
- Important to see both surface and subsurface damage





Case Study: Sub Surface Damage Detection

Connects For A Better Life

Coach 18273: Where Machine Detection proved superior to Visual inspection

MINISTRY OF RAILWAYS
आधुनिक रेल डिब्बा कारखाना, रायबरेली
MODERN COACH FACTORY, RAEBARELI

Rly. Ph. 039-61423
Tele Fax. 0535-2704331

No. RBL-MD54111 (Part-IV) Date: 26.09.2019

M/s, A Paul Instruments.
New Delhi.

Sub: - Turning of wheels of smart coach No - NR182737 running in train no 12429/12430 LKO-NDLS AC Superfast Exp.

Ref: 1- Email from Steve Turley (steve.turley@perpetuum.com) to PCME/MCF (pcmemcf@gmail.com), & CDE/MCF (cdemcfrbl@gmail.com) dated 24.09.2019.
2- DME/Sr.CDO/LKO/NR, L.No. RS/CDOLKO/Unusual/05 Dated 26.09.2019.

Vide email from Steve Turley to CDE/MCF dated 24.09.2019 unusual level of vibration were reported in Smart Coach No. NR 182737. The same coach was examined by DME/Sr. CDO/LKO/NR, visually, no cause was found that could attribute to it. However, the coach has been detached in sick line Lucknow for through examination.

In view of above, It is requested to kindly make a joint inspection so that root cause for this incidence can be established.

This is for your kind information & necessary action please.

26/09/19
(Kumar Sambhav)
Dy.CME/Design
MCF/RBL

Copy to: 1 - CDE/MCF - for kind information please.
2 - CRSE/NR -for kind information please.
3 - Sr. DME(C&W)/LKO/NR - for your kind information & necessary action please..

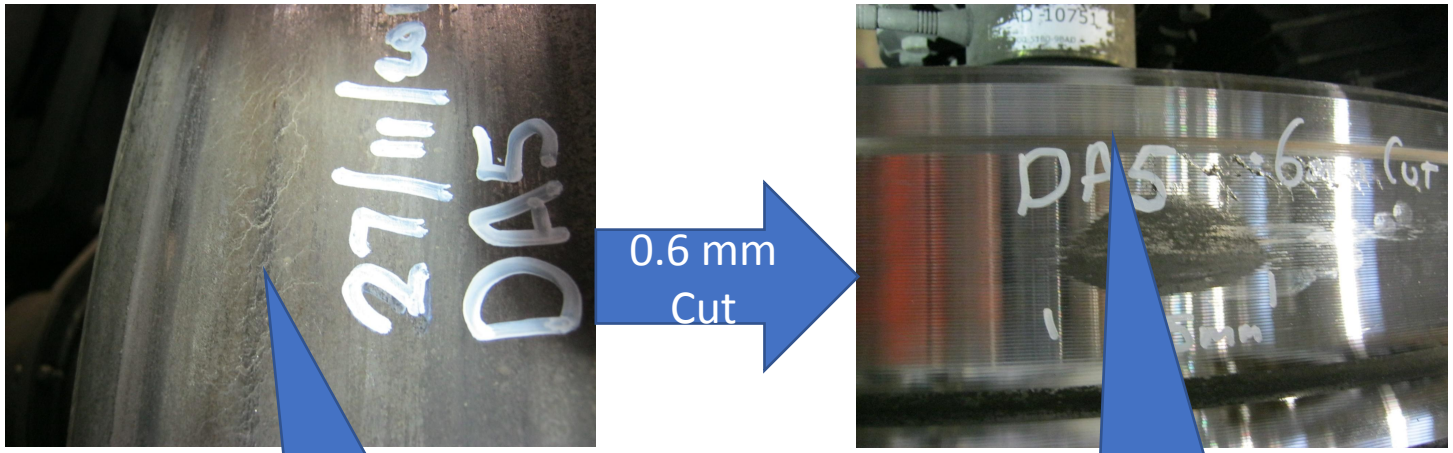
Since the start of September our analytical team have again identified a significant increase in vibration on the coach, climbing to Category 2 warning levels in the last day. Perpetuum suspect this to be significant rolling contact fatigue on the coach wheels, primarily L4, R5, R7 and L2.

Figure 1 below shows the Wheel Health Index since fitment in April to the present day, calculated using a bespoke algorithm developed for the Indian Railways Smart Coach:

Figure 1

Subsurface Damage Revealed

perpetuum



Initial inspection shows minimal damage

Surface removal reveals hidden damage

Early Intervention Results in Extended Wheel Life

Case Study: Sub Surface Damage Detection

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Coach 18273: Results on Wheel Turning Revealed extensive sub surface Damage.

Table 3-1: Summary of damaged regions found on each wheel of 018273 after wheel turn

Wheel	Number of damaged regions	Max. Length / mm	Comments
L4	7	90	High and increasing WHI
R5	5	58	High and increasing WHI
R7	2	20	High and increasing WHI
L2	1	45	High and increasing WHI
L1	2	12	Increasing WHI
L3	0	N/A	Stable WHI
R6	0	N/A	Stable WHI
R8	0	N/A	Stable WHI

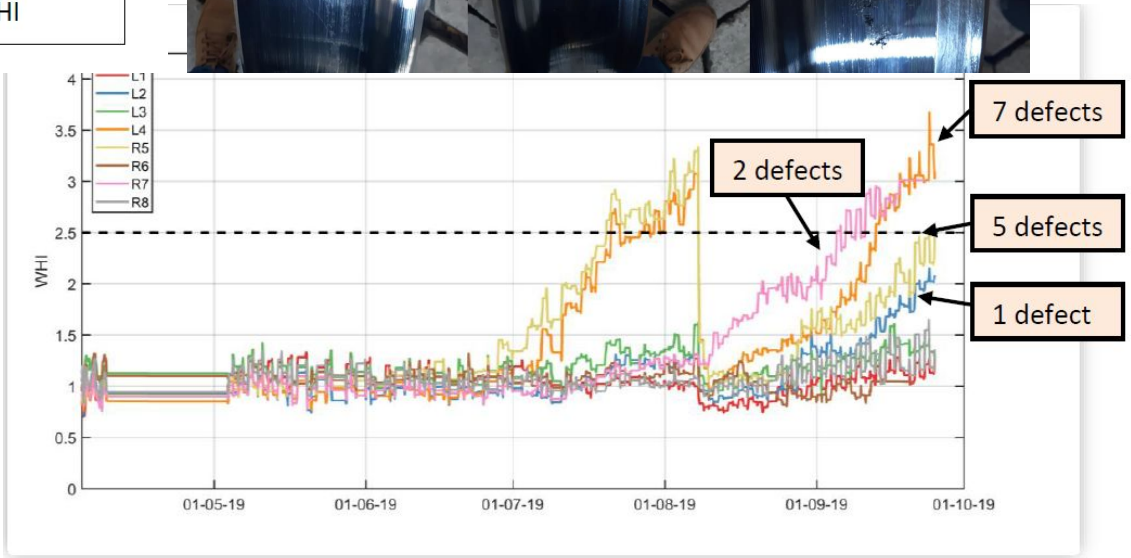
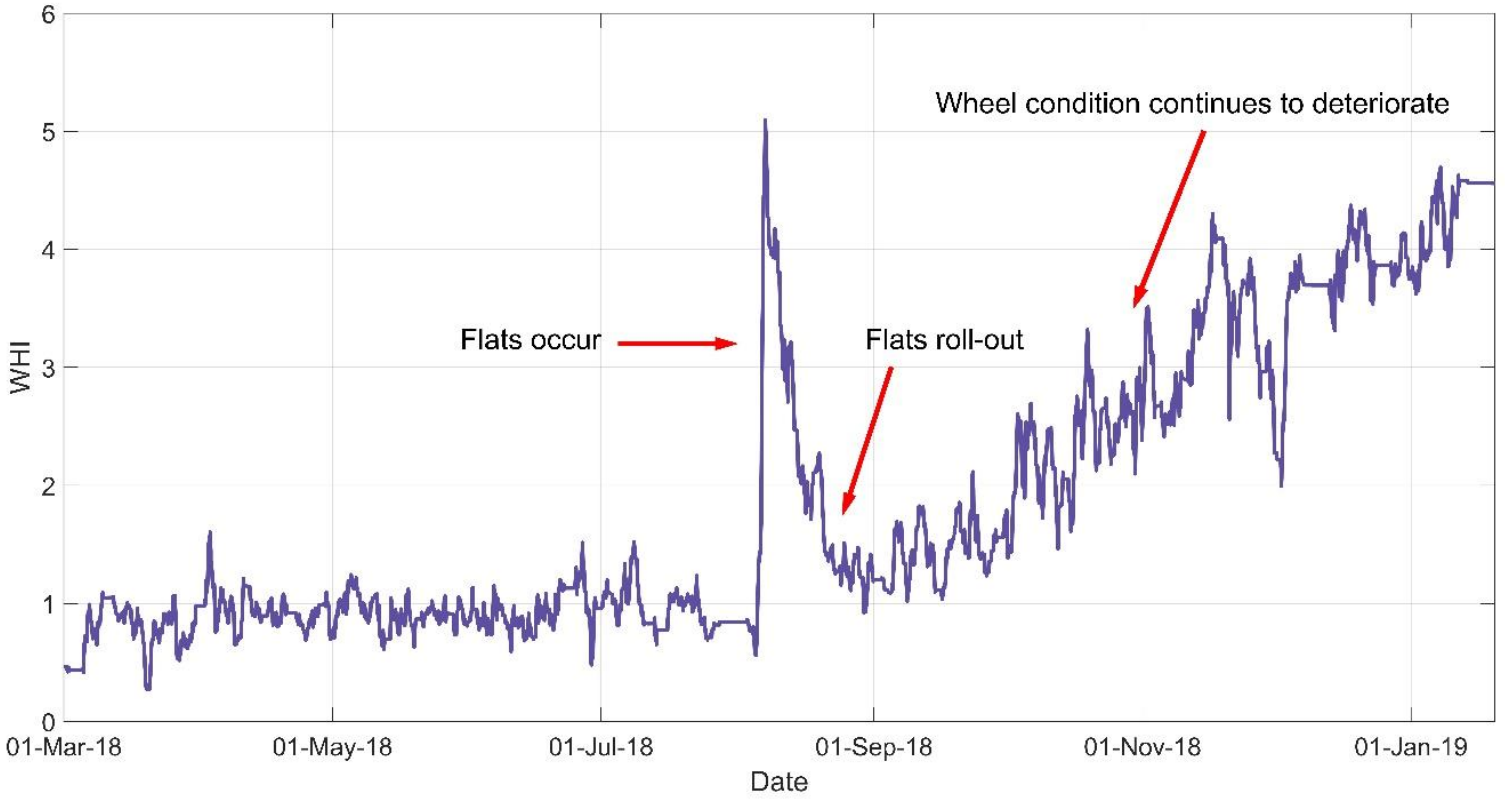
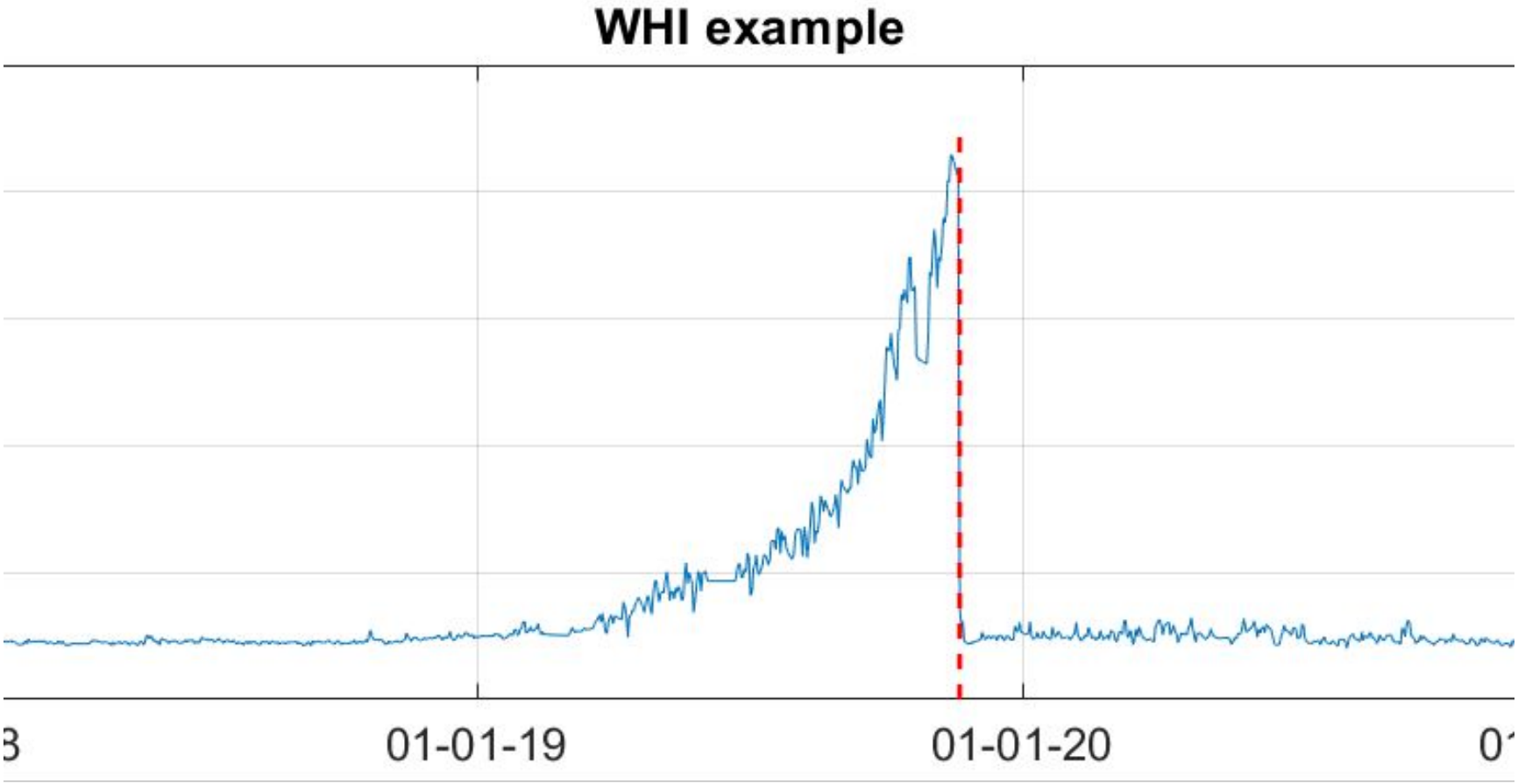


Figure 4-1:Wheel Health Index vs Inspection Data

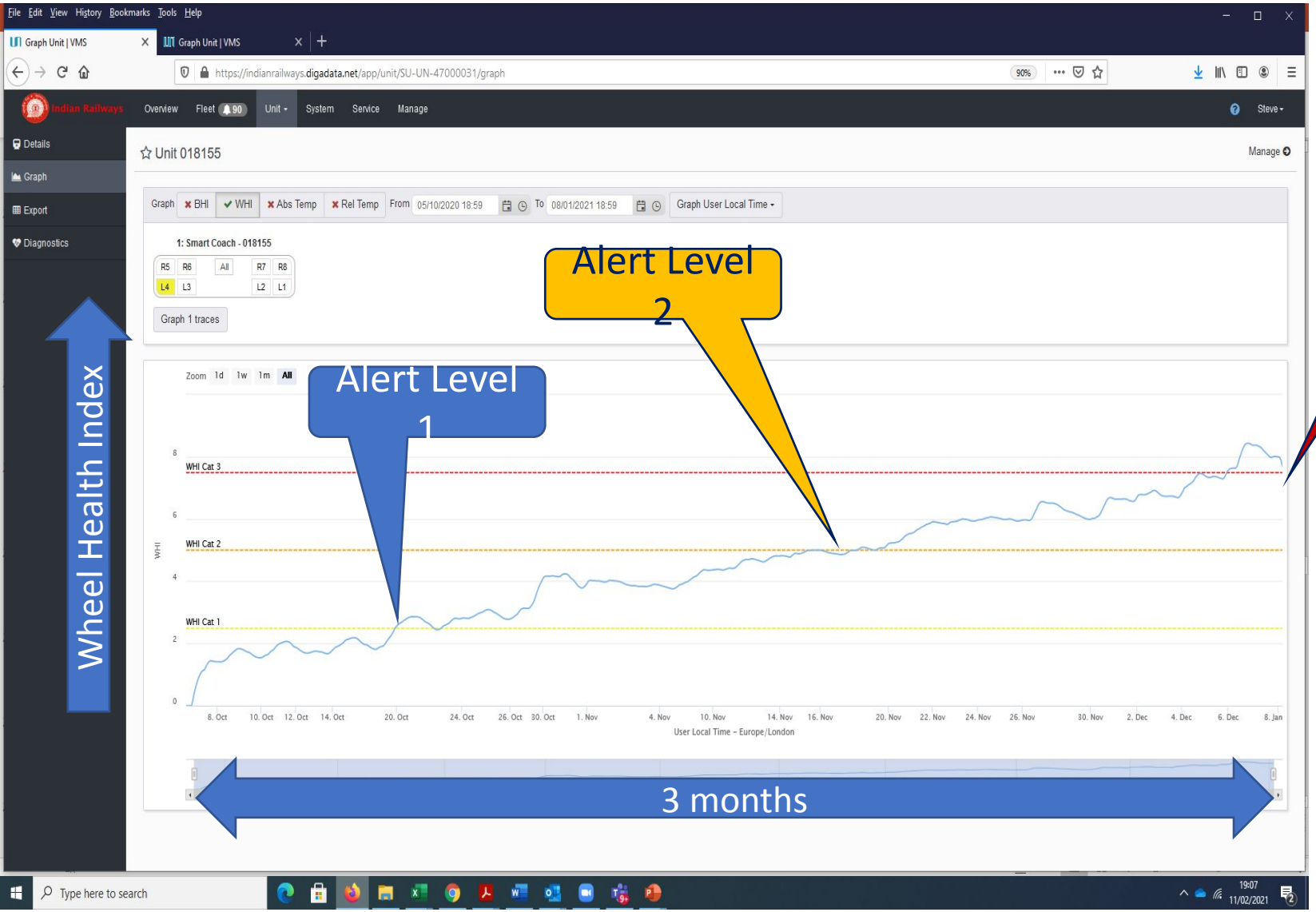
Wheel Damage (Flats) & Subsequent RCA



Example of WHI Reduction after Lathe



Degradation of Wheel Condition



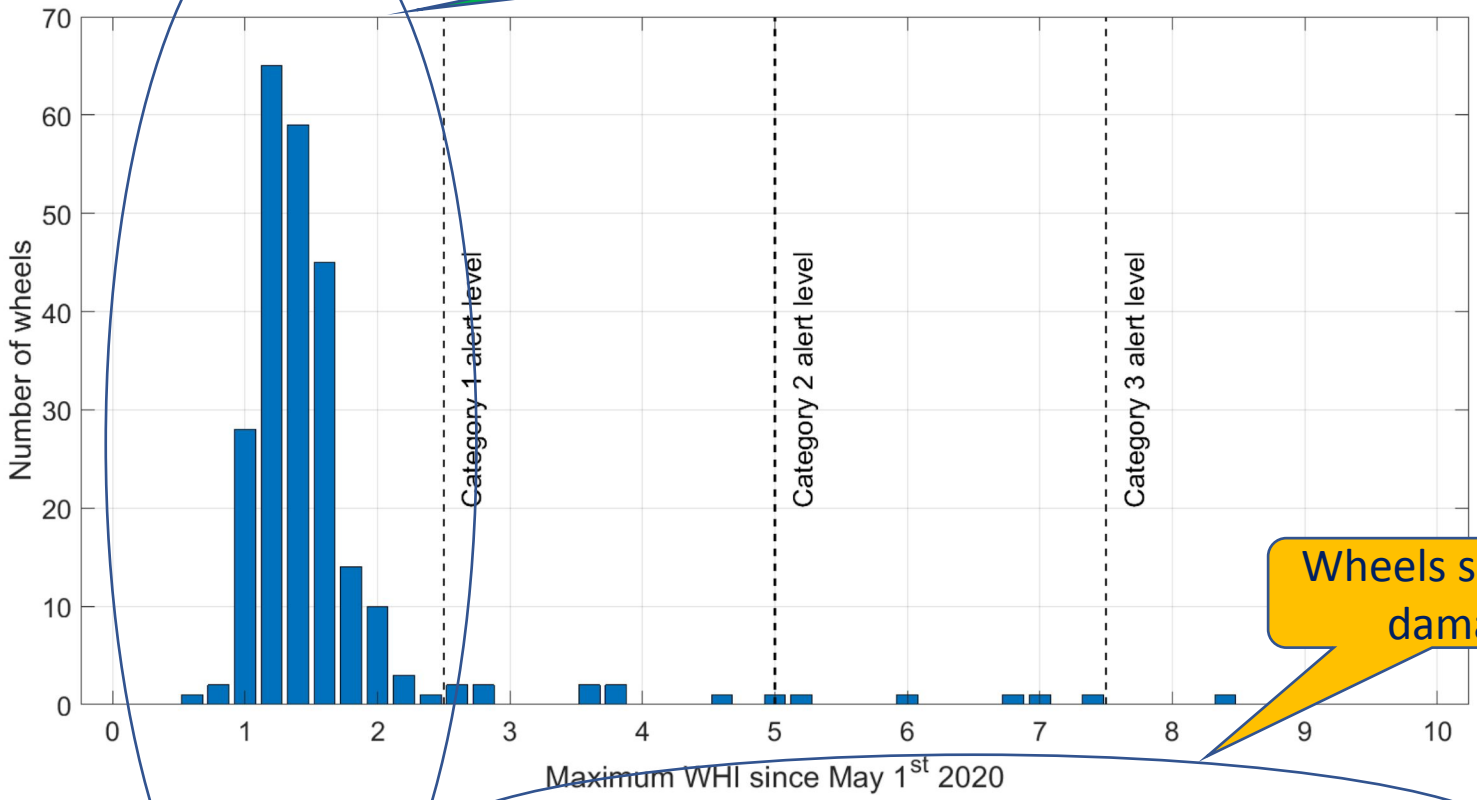
Levels set by Indian Railways according to Operational Condition

Data from Indian Railways Smart Coach Trial

Health Distribution Analysis: Example for Wheel Health

Wheels in good condition

Data from Indian Railways Smart Coach Trial



Wheels suffering damage

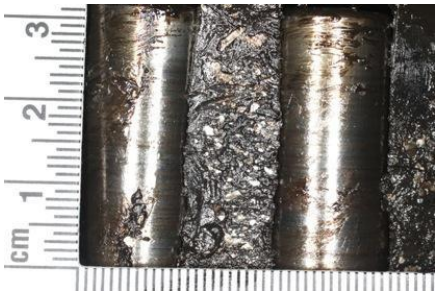
Distribution of Wheel Health Index (WHI) clearly shows outliers with degrading Wheel Quality

Bearing Health

Early Warning of Damage: Example for Journal Bearings

Levels set by Indian Railways according to Operational Condition

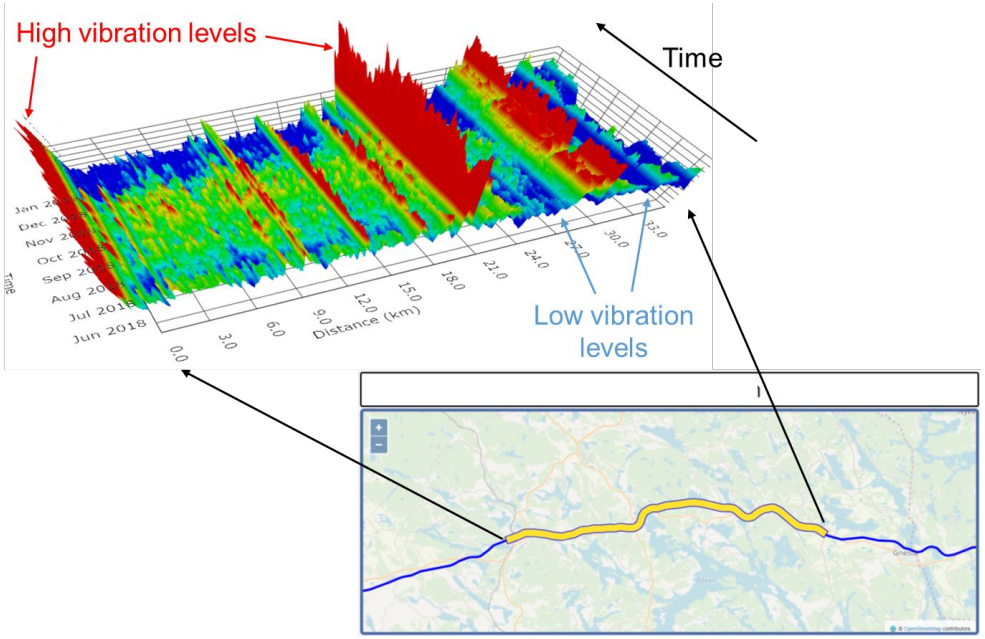
Damaged bearings

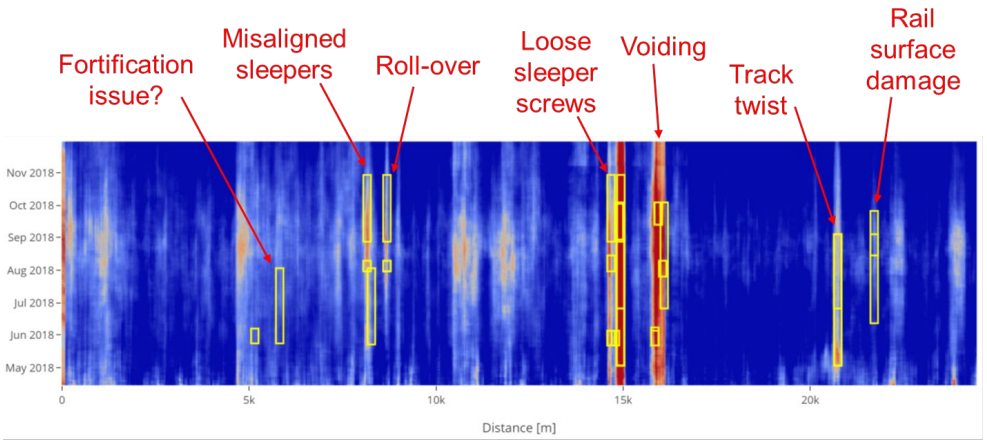


Track Monitoring

Rough Ride and Track Condition Monitoring

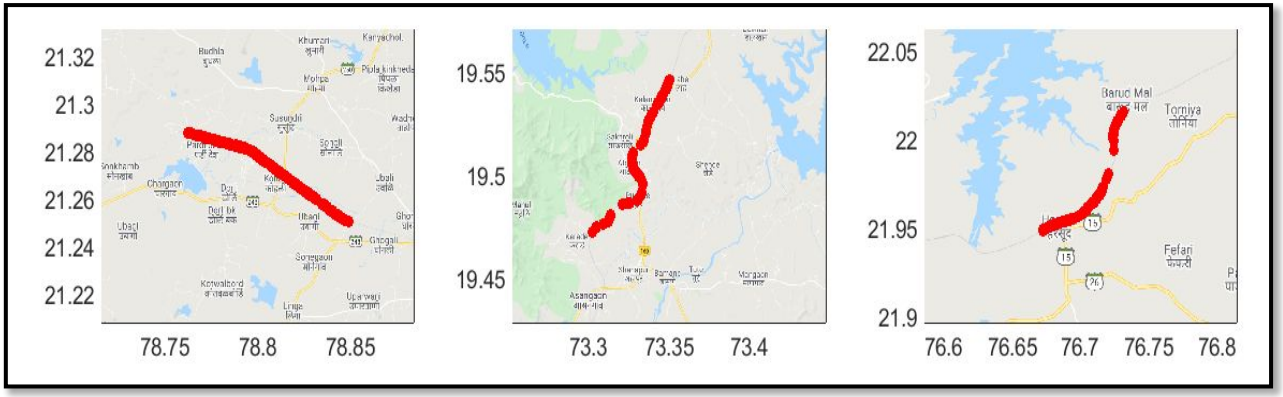
- Accelerometer and gyroscope are fitted in the data concentrator in the coach
- Large shocks are located on the track using GPS or Wi-Fi node interpolation
- System delivers real-time map of shock and vibration in the infrastructure
- Visibility of coach dynamics also provided
- Location of problem areas can be located on the map
- Rough ride analysis allows track and rolling stock contributions to be analysed

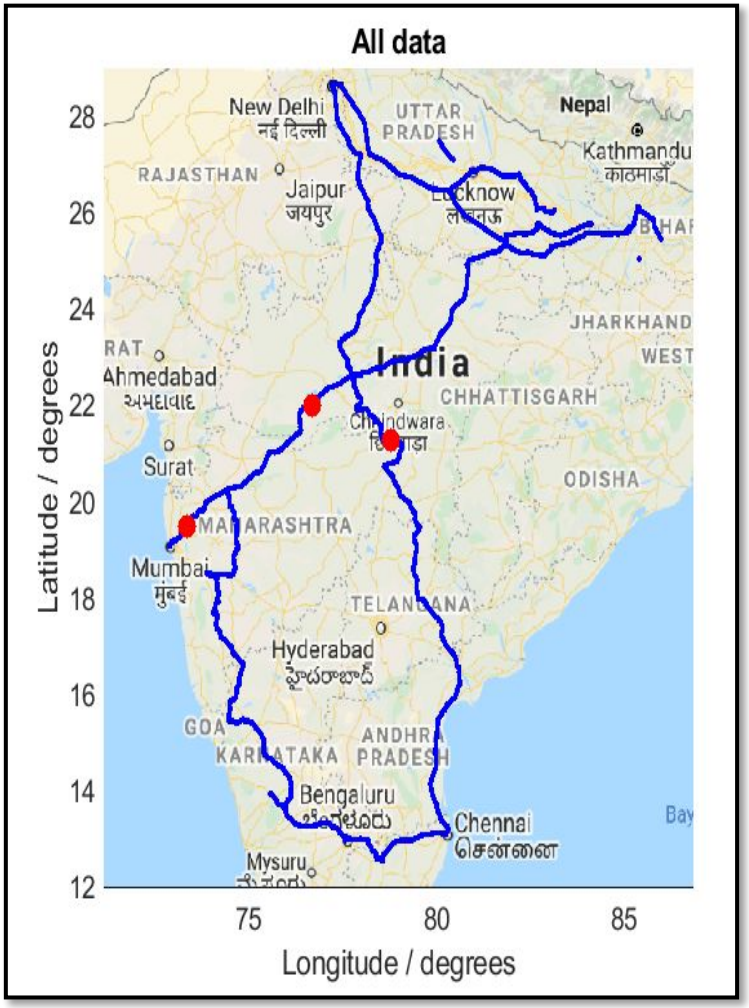




Concentrations of High Vibrations

- Several locations where high vibrations seems to be more likely.
- These will be investigated in more detail when the track website is expanded to covert the new routes.





Data from Indian Railways Smart Coach Trial

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Third Party Device Integrations

PICCU as a Open Platform Data Aggregator

- Air Conditioning System,
- Wheel Slip Protection Device,
- Fire Detection System,
- Switchboard Cabinet

RMPU Controller Integration

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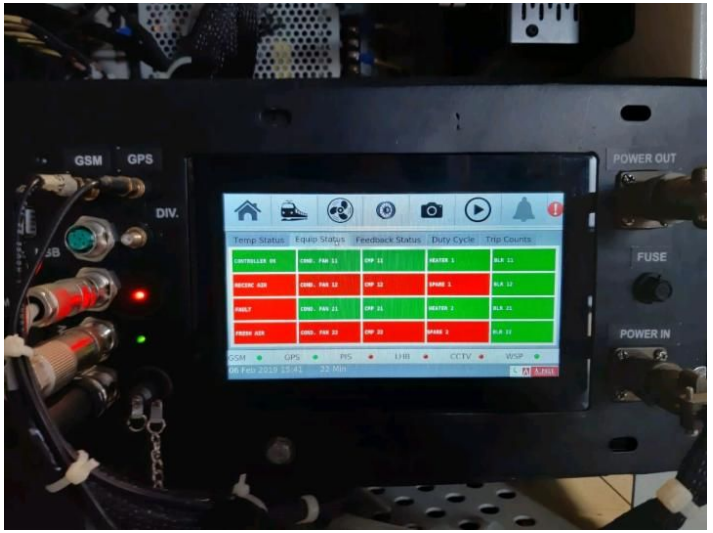
- RMPU Data Monitored online via PICCU
- Choked Filter Sensors Added In Coach
- Successful integration despite challenges.
  - Microprocessors all follow proprietary protocols
  - Not all Makes Microprocessor provide this data.
  - Low Update rate of data from Microprocessors (once every 2 minutes)



Wheel Slip Protection Device

- Data Monitored
  - Trippings and Faults only as per fault list of OEM.
  - Can port any data provided by OEM.
- Interfacing
  - Knorr and Faiveley: Ethernet.
  - Escorts: USB.
  - Interfacing done with Knorr and Escorts.

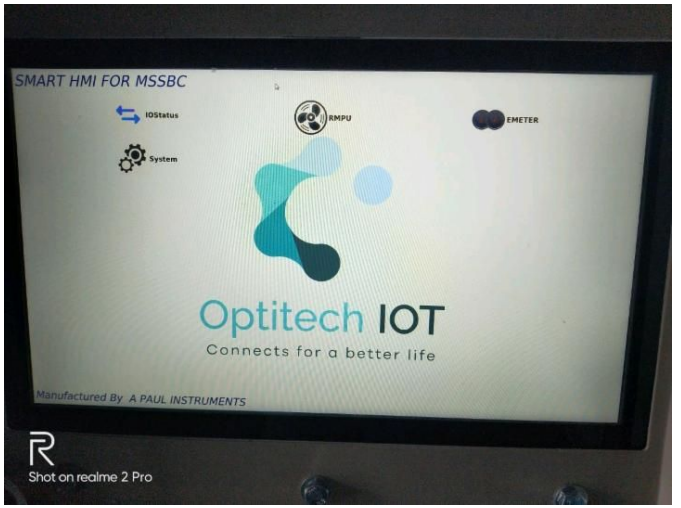
Smart Switch Board Cabinet Controller

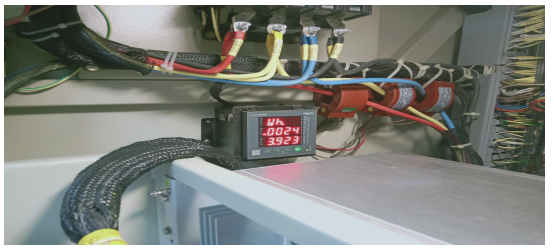
Connects For A Better Life

- Monitoring Coach Energy consumption using a smart meter.
- All new Master Smart Switch board Cabinet Controller.
  - Much Slimmer - Space for other amenities
  - 18.5” TFT display with touch
  - Integration to SSBC switchgear.
  - Touch based on-Off control of loads.
  - Integrated withPICCU: programmable coach shut down at end of journey.
  - WRA integration.

Retrofitting the MSSBC

- Retrofit requires changing door structure.
- Requires extensive rewiring.
- Old Rolling Stock upgrade difficulties.





PICCU As Coach Management Unit

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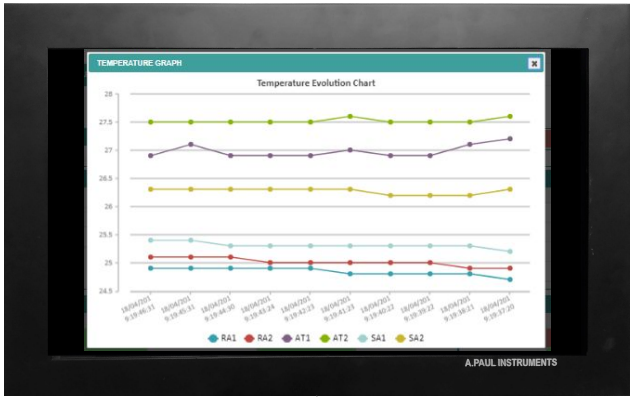
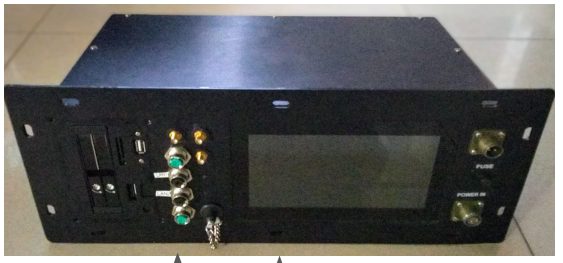
Remote Monitoring Server.



PICCU



TASI

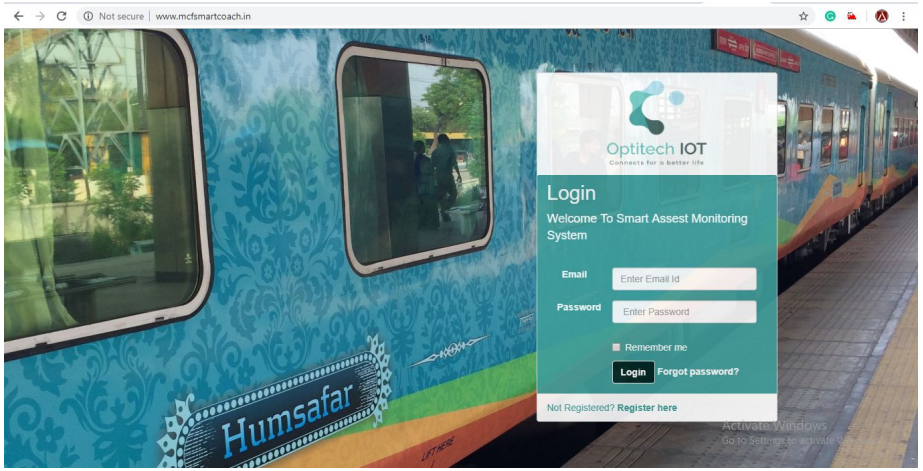
PA System

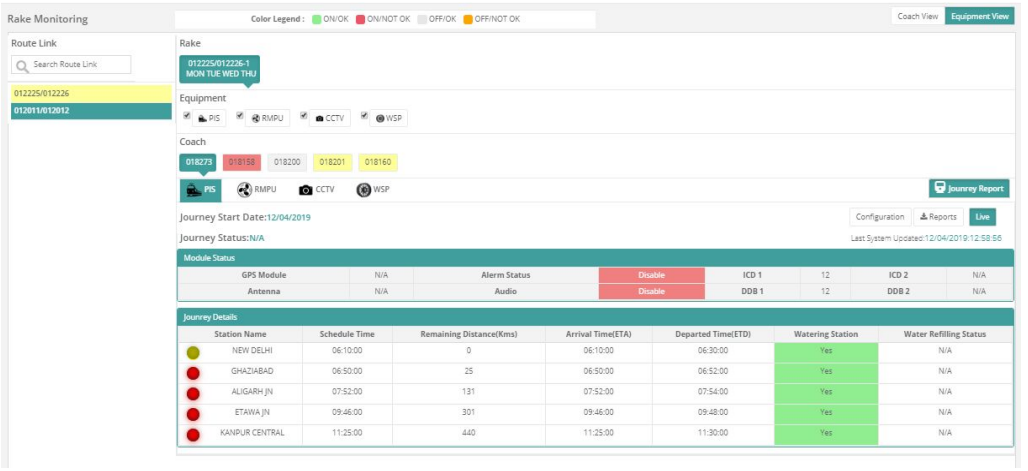
Water sensor

Online Smart Asset Management Tools

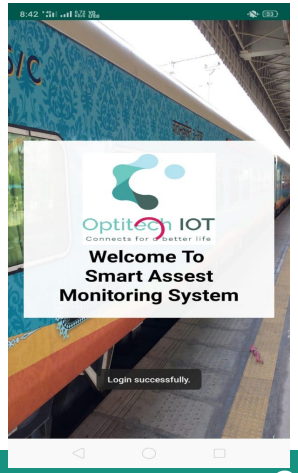
Connects For A Better Life

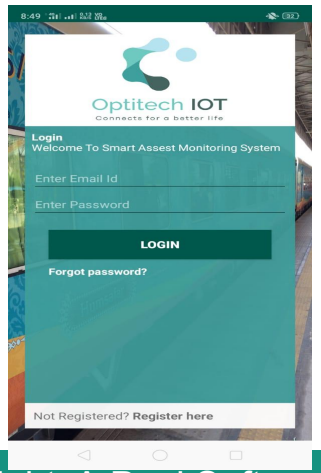
1. PC based Application Software

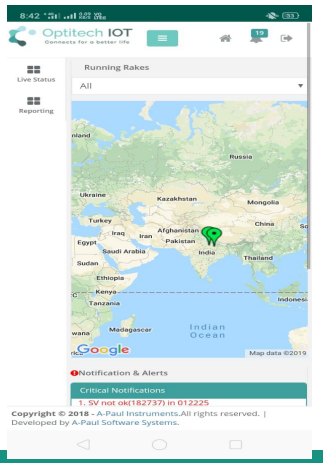




2. Mobile based Android/IOS app







Web Based Management

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Multiple Authorised Logins

Major Gains

- View system wide defects needing attention.
- Coach level and Rake level Configuration
- Online retrieval of CCTV Recordings.
- View Alerts as they are generated.
- SMS alert generation for faults
- Defect rate Analysis
- Assuring loop closures
- Detailed action and service Reports
- Overall Process development

Rake Performance Monitoring

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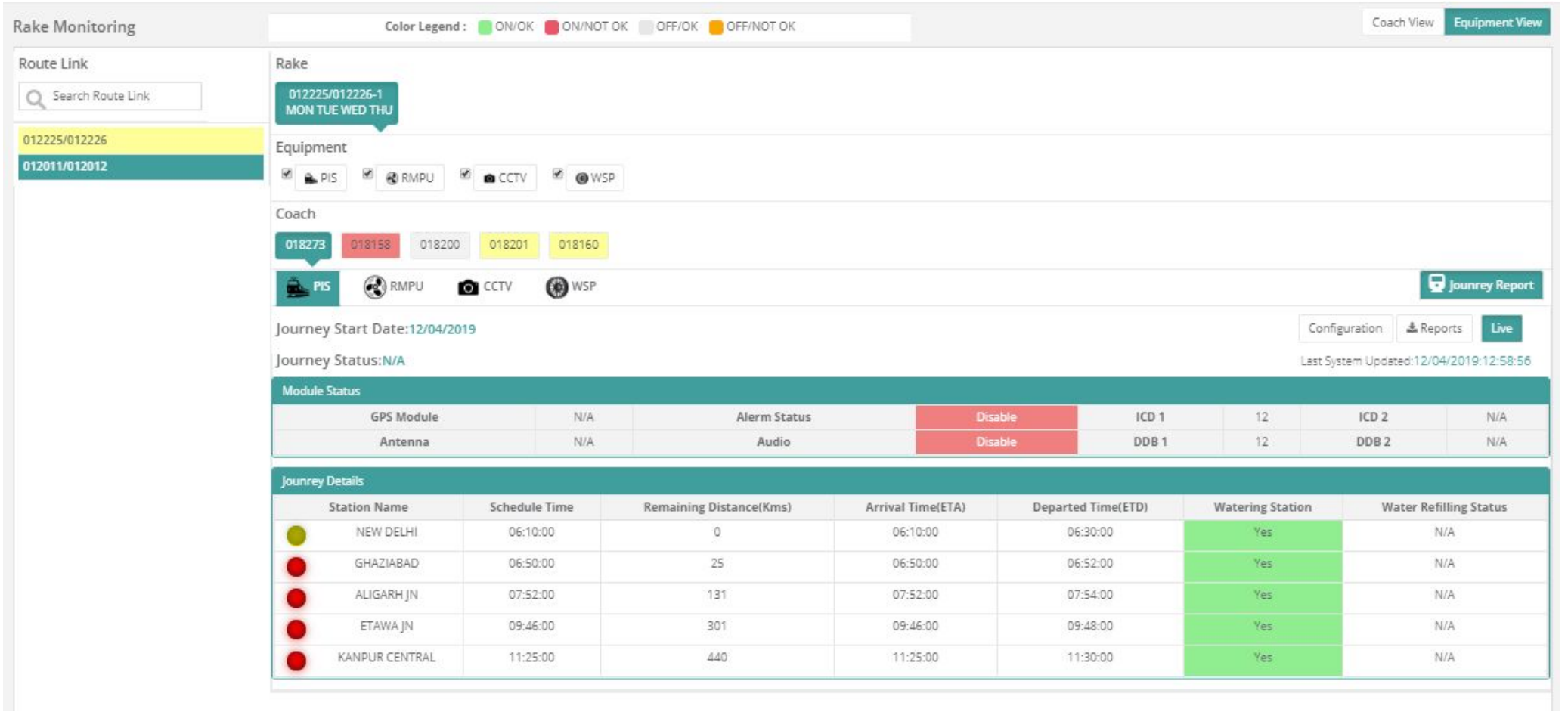

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Application View Tabs

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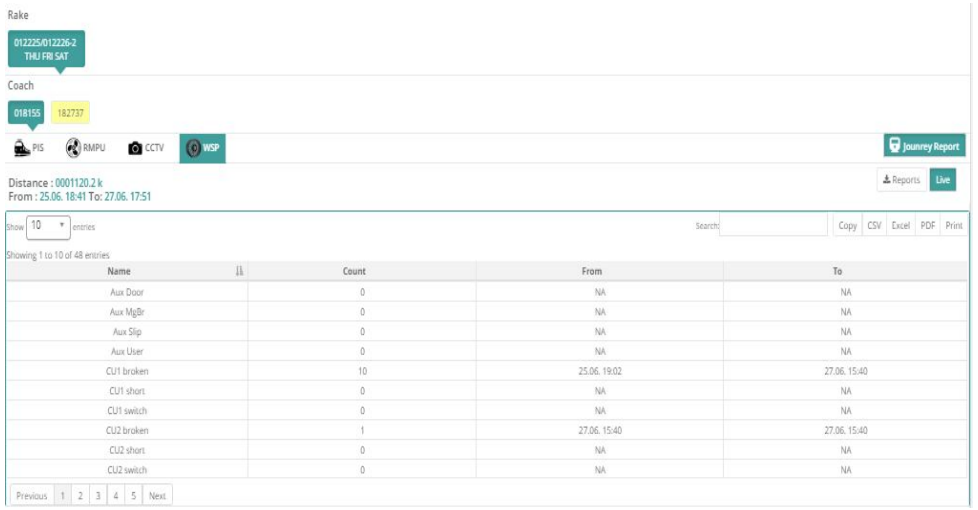

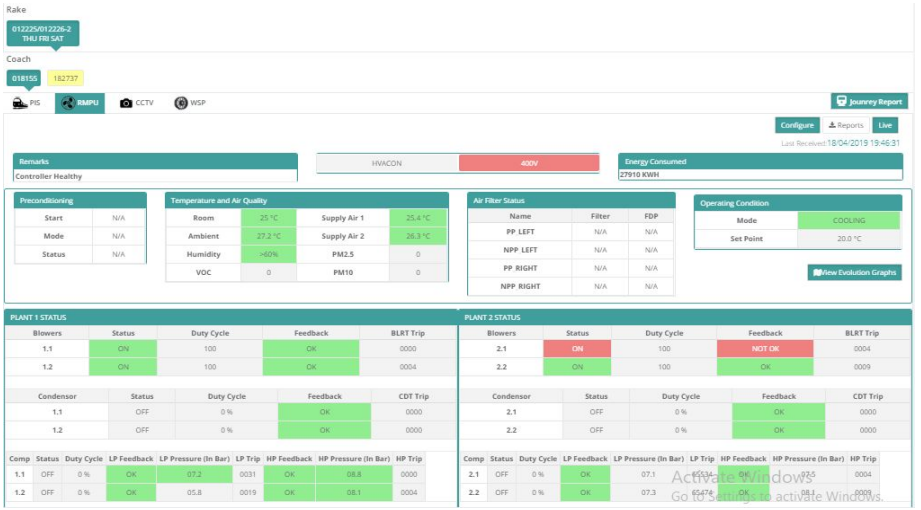

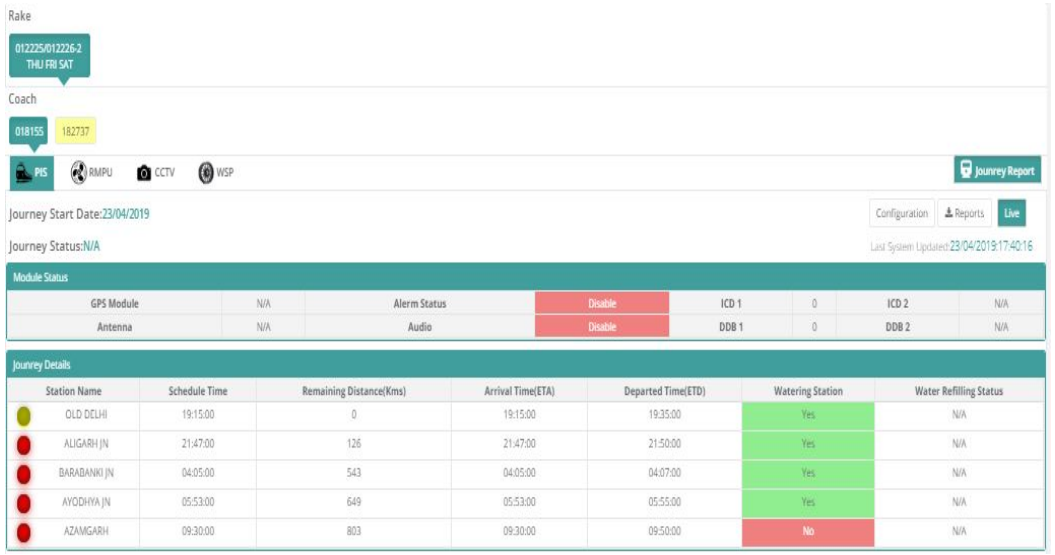

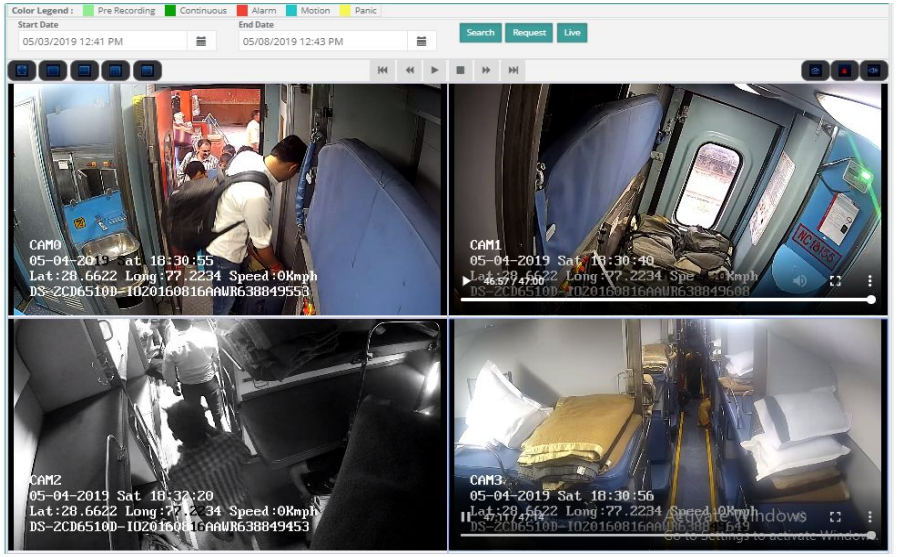

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Reports

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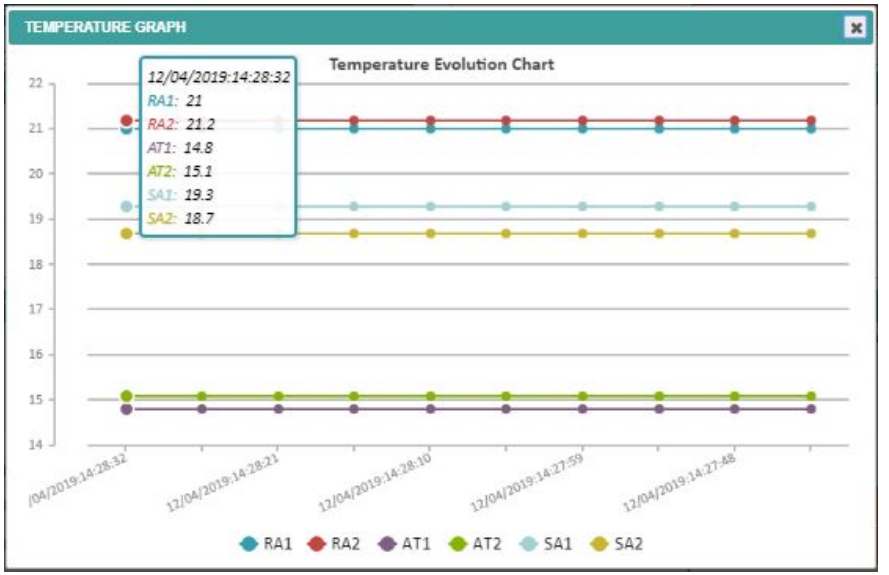
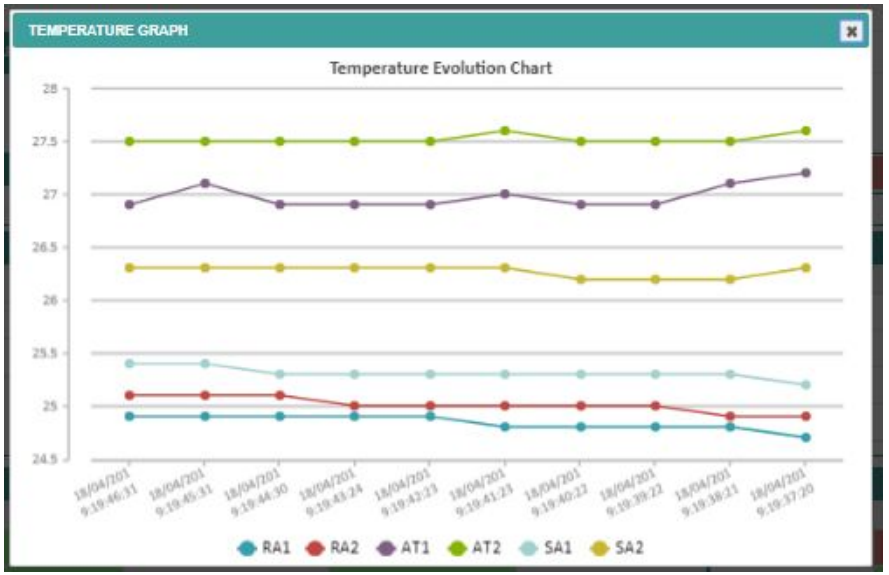
SMART ASSET MONITORING SYSTEM | RakeMonitoring

Name	Count	From	To
Aux Door	0	NA	NA
Aux MgBr	0	NA	NA
Aux Slip	0	NA	NA
Aux User	0	NA	NA
CU1 broken	10	25.06. 19:02	27.06. 15:40
CU1 short	0	NA	NA
CU1 switch	0	NA	NA
CU2 broken	1	27.06. 15:40	27.06. 15:40
CU2 short	0	NA	NA
CU2 switch	0	NA	NA
CU3 broken	10	25.06. 19:02	27.06. 15:40
CU3 short	0	NA	NA
CU3 switch	0	NA	NA
CU4 broken	10	25.06. 19:02	27.06. 15:40
CU4 short	0	NA	NA
CU4 switch	0	NA	NA
EX1 broken	10	25.06. 19:02	27.06. 15:40
EX1 short	0	NA	NA
EX1 switch	0	NA	NA
EX2 broken	1	27.06. 15:40	27.06. 15:40
EX2 short	0	NA	NA
EX2 switch	0	NA	NA
EX3 broken	10	25.06. 19:02	27.06. 15:40
EX3 short	0	NA	NA
EX3 switch	0	NA	NA
EX4 broken	10	25.06. 19:02	27.06. 15:40
EX4 short	0	NA	NA
EX4 switch	0	NA	NA
Reg axle 1	2509	25.06. 19:17	27.06. 11:34
Reg axle 2	2542	25.06. 19:17	27.06. 11:34
Reg axle 3	2542	25.06. 19:17	27.06. 11:34
Reg axle 4	2542	25.06. 19:17	27.06. 11:34
SL1 long	5	25.06. 19:19	27.06. 11:31
SL2 long	0	NA	NA
SL3 long	0	NA	NA
SL4 long	0	NA	NA
TG1 broken	1	27.06. 15:40	27.06. 15:40





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Connects For A Better Life

Bridging The Data Islands on The Coach

Achieving Coach Level Standardisation.

- PICCU suppliers to build API/ Drivers for all third party eqpt on shared protocol.
- PICCU uses Structured and Unstructured Databases for data aggregation..
- Communication to Railway Servers over API's.

Necessity of Enabling Policy Decisions.

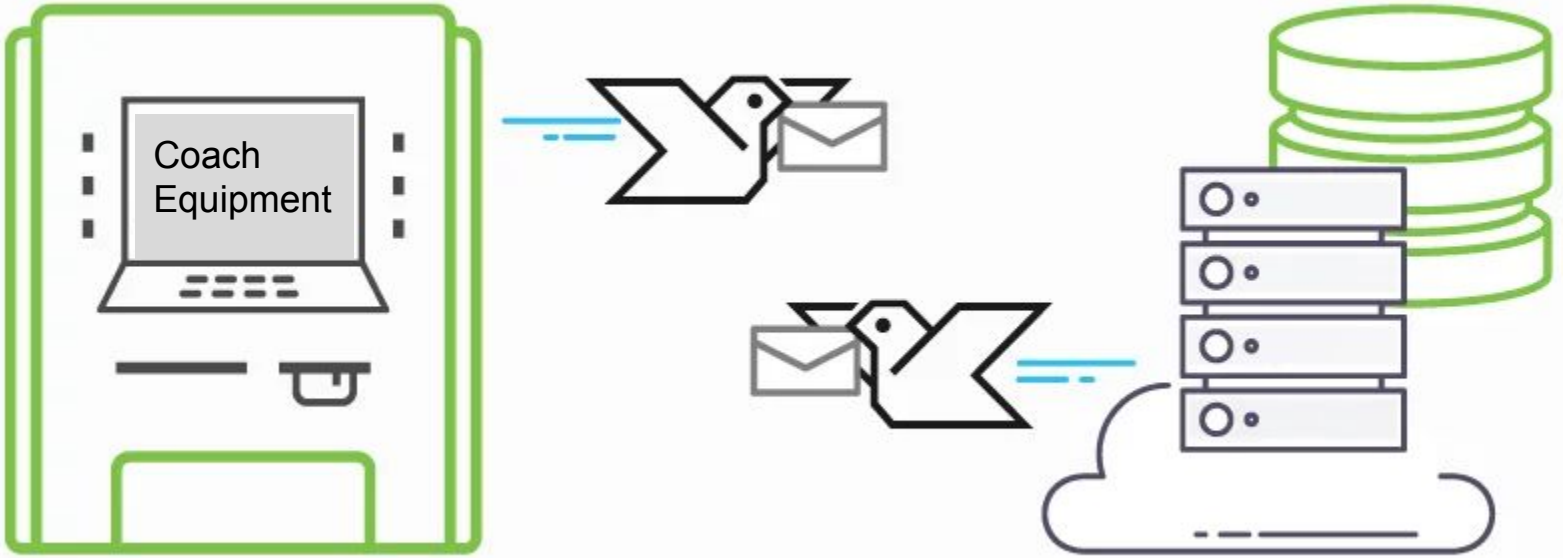
- Retrospective Mandatory protocol sharing as precondition to approval for all equipments.
- IT Server System to be developed Independent of PICCU suppliers to support multi-vendorism.
- For future, adopt
  - Mandatory Ethernet(TCP/IP) interface on all complex controllers.
  - Industry Standard MVB/ modbus Protocols for simpler non-TCP/IP cable simple systems.

How to Make It All OPEN On The Coach

Connects For A Better Life

Working of API: Application Programming Interface.

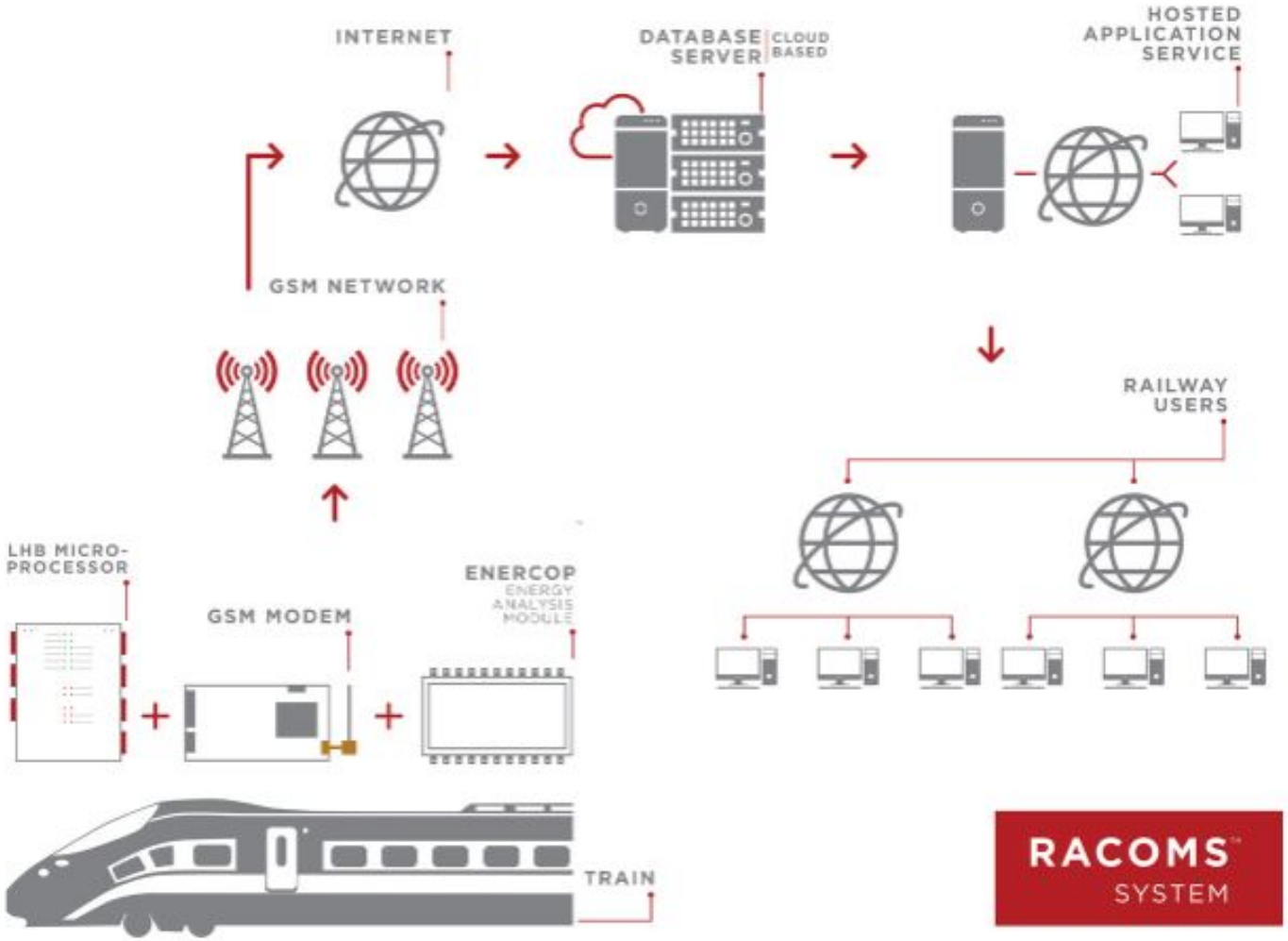
- Data interchange between devices and servers with safety, security and Openness
- Software Technique Responsible for Openness of the Internet.
- uses Standard technologies such as XML,



Other IoT application at A.Paul

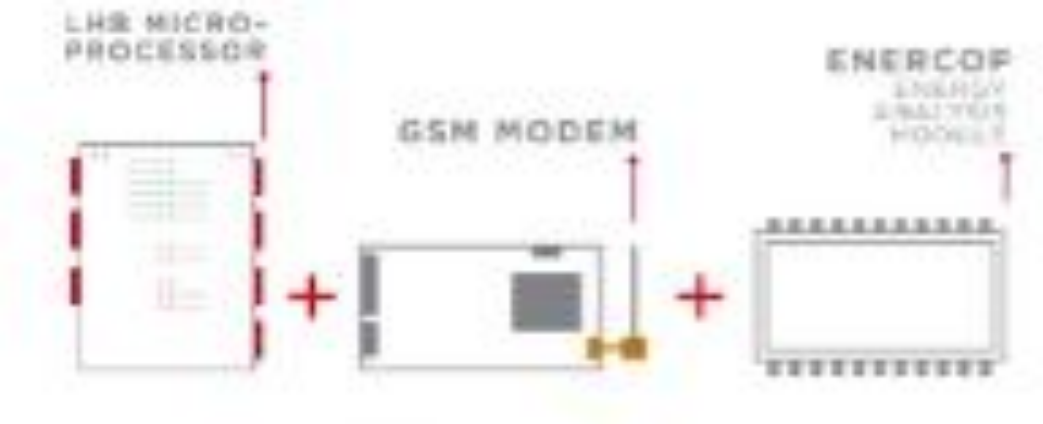
- Stand Alone RMPU Health Monitoring System.
- Pantograph Predictive Health Monitoring System

Condition Monitoring For Air-conditioning Coaches



Optitech Microprocessor for LHB Coaches

Enabling a Predictive Regime



- Minimum Basics
  - RDSO approved Microprocessor with IoT software. (Available in most cases)
  - 4G GSM modem + Bypass Monitor.
  - Energy Meter Module.

Value Add-ons

- Choked Filter Detector
- Air Quality Sensor
- Gas Leakage Detection

Upgrading the HVAC Controller

- IOT Features- Software Capability to interface with servers.
  - Remote Monitoring of complete system over GSM/GPRS.
  - Interfacing With Energy Meters
- New Advanced Algorithms
  - Gas Leakage Detection.
  - Manual Bypass Detection
- New Device Interfaces
  - Energy Module
  - Choked Filter Detection.*
  - Monitoring of Air Quality.*

Air Conditioning control And Monitoring

Connects For
A Better Life

Optitech IOT

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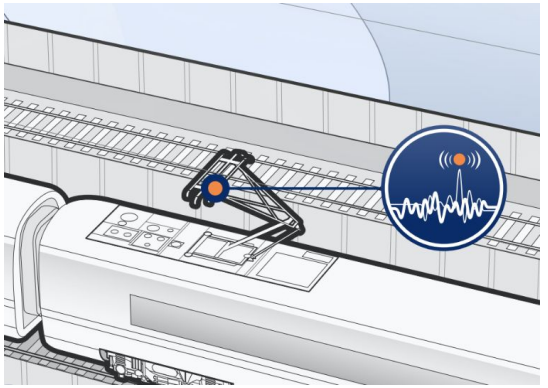
Other IoT application at A.Paul

Pantograph Predictive Health Monitoring System

Overview



- Typical applications
  - Predictive overhead line maintenance
    - 24/7 overhead line monitoring through regular trains
  - Contact force regulated pantograph
    - High speed applications
  - Homologation and testing of pantograph (EN50317)
- Measured and computed values
  - Vertical contact force
  - Vertical acceleration
  - Sideway position computed from contact forces
- Specifics
  - Purely optical
    - No electromagnetic influences
  - Force transducer and accelerometer design results in high accuracy
  - Allows easy and flexible integration with adapter holding plates
  - Very good long-term results
  - Patent pending

Optitech iOT
Connects for a better life

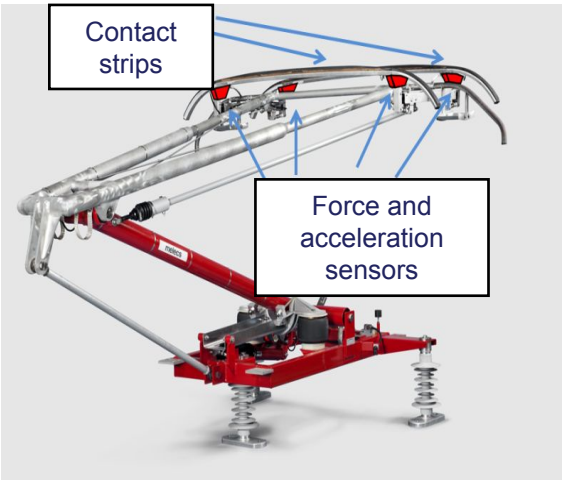
Connects For A Better Life

FiberSensing HBM

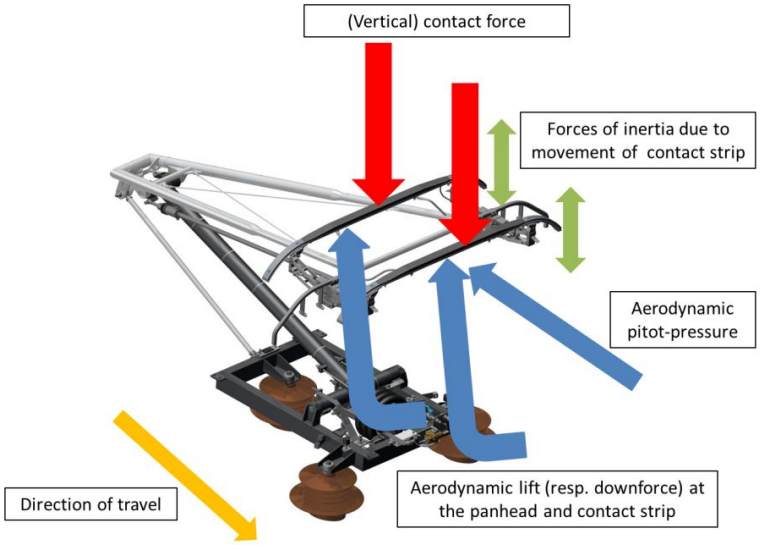
Contact force measurement

PUBLIC

Contact force measurement



- Force measurement on four positions of pantograph
  - Two for each panhead



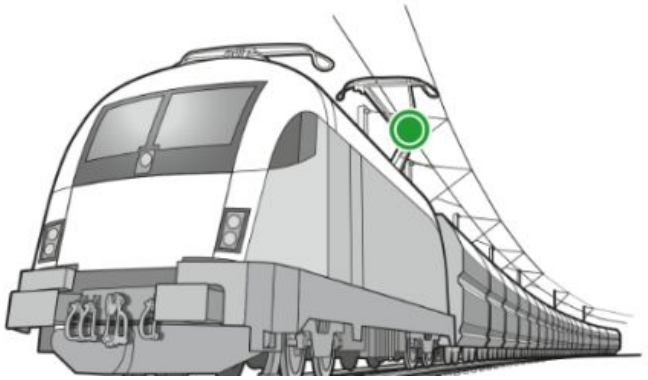
FORCES ON PANTOGRAPH

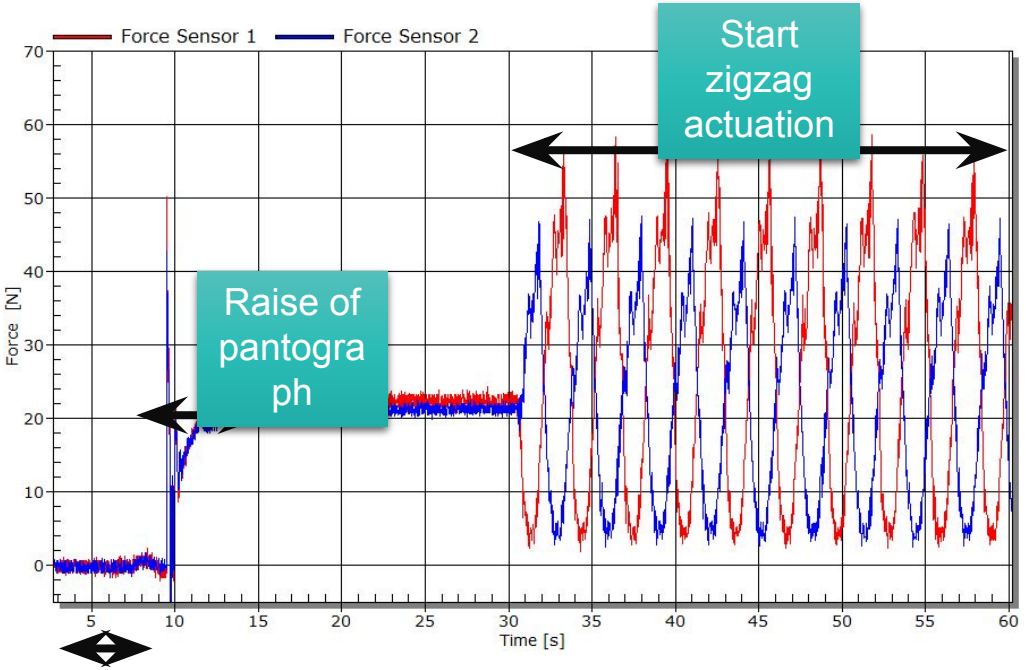
$$F_c = \sum_{i=1}^{k_f} F_{Sensor,i} + \frac{m_{above}}{k_a} \sum_{i=1}^{k_a} a_{Sensor,i} + F_{corr,aero}$$

F_c = contact force
$F_{Sensor;i}$ = measured force at sensor i
$a_{Sensor;i}$ = measured acceleration at sensor i
k_f = number of force sensors
k_a = number of acceleration sensors
m_{above} = mass of the panhead located above the force sensors
$F_{corr;aero}$ = aerodynamic correction force
(velocity dependent, retrieved from lookup table)

Contact force measurement

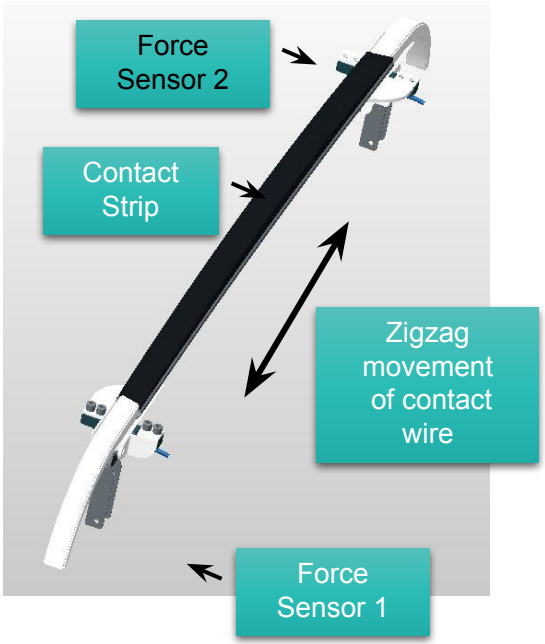
- Force measurement results
  - Force under zigzag actuation scenario





- Force measurement results
  - Position of contact line – from the force values the position of contact wire can be deduced

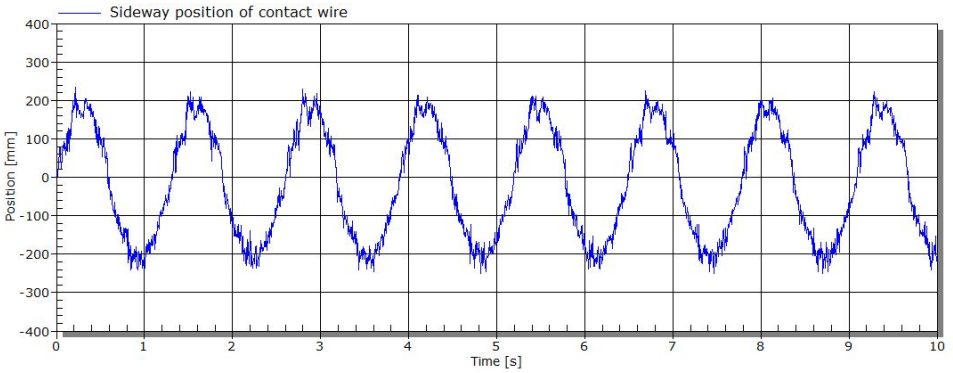
PANHEAD



$$x = \frac{F_2}{F_1 + F_2} L - L/2$$

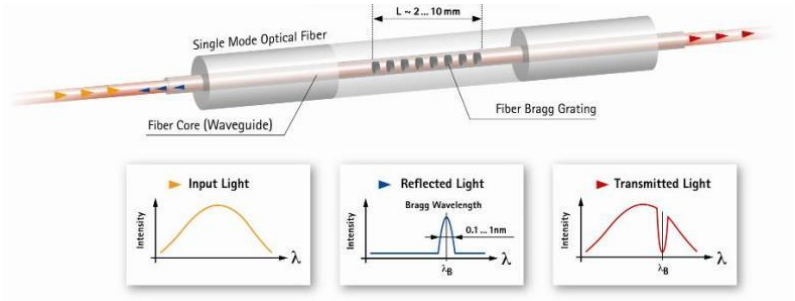
With:

x = 0 middle position
L distance between force sensors



Optical technology

- Fiber Bragg Grating (FBG) technology
  - FBGs inscribed in optical fiber reflect light at certain wavelengths
  - Changes in strain or temperature alter FBG and affect reflected light
  - Measurements obtained from wavelength shifts in reflected peaks (nm)
  - Sensors can operate in HV environment (0.6 to 25 kV, up to 8000 A)



- Bragg's Law $\lambda_B = 2n_{eff}\Lambda$ $\Lambda = \frac{\Lambda_m}{2}$
- Temperature

$$\frac{\Delta\lambda_B}{\lambda_B} = (\alpha + \varsigma)\Delta T = \beta_T \Delta T \qquad \frac{\Delta\lambda_B}{\Delta T} = 10\ \text{pm/°C}$$

@ 1.55 mm

- Strain

$$\frac{\Delta\lambda_B}{\lambda_B} = (1 + p_e)\Delta\varepsilon = \beta_\varepsilon \Delta\varepsilon \qquad \frac{\Delta\lambda_B}{\Delta\varepsilon} = 1.2\ \text{pm/με}$$

@ 1.55 mm

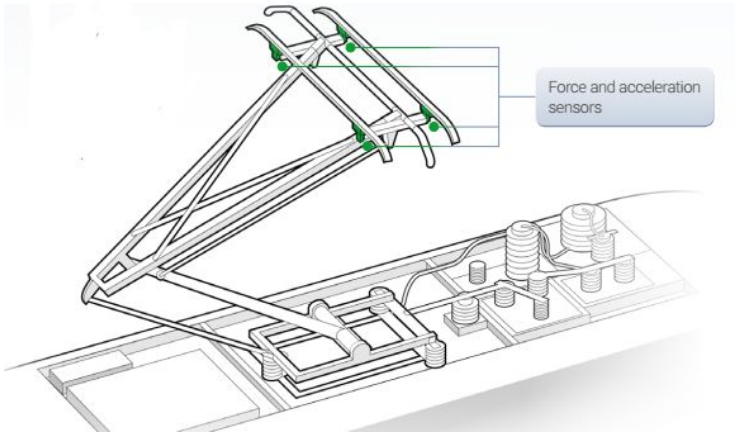
FB G

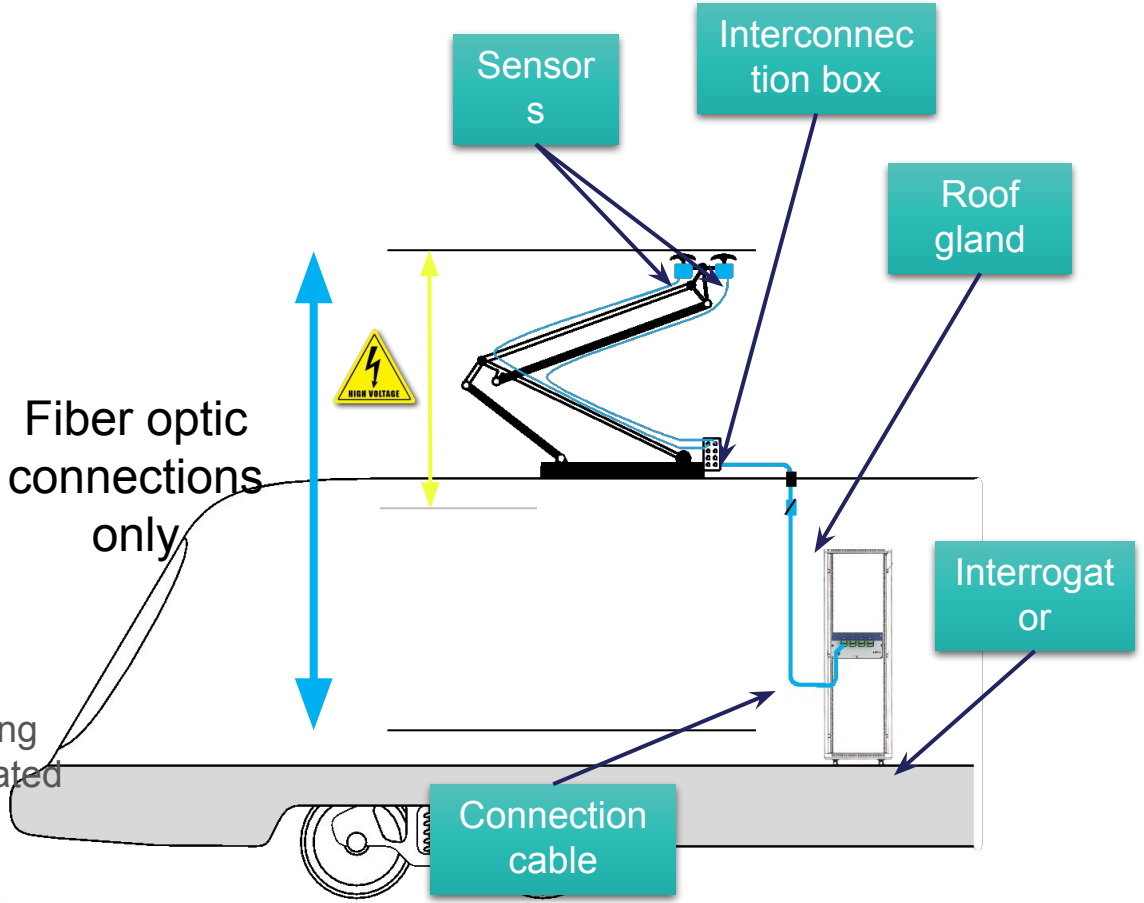
$$\frac{\Delta\lambda_B}{\lambda_B} = 0.78 \cdot \Delta\varepsilon$$

Strain gauge

$$\frac{\Delta R}{R} = 2 \cdot \Delta\varepsilon$$

System general architecture



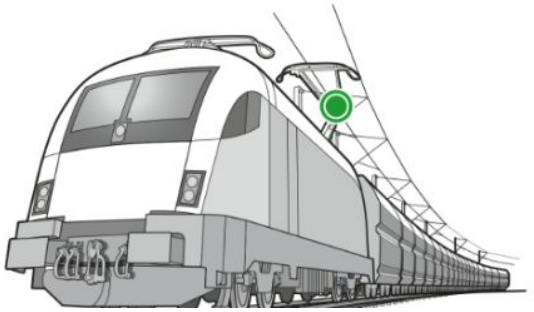


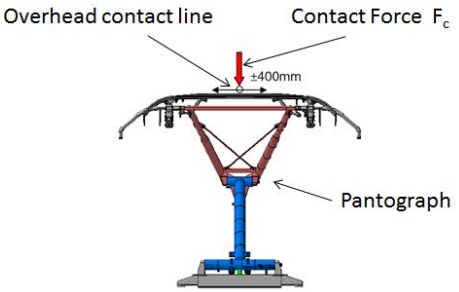
Fiber optic connections only

All cables, including on sensors, are rated for railway applications (manufactured by Huber+Suhner)

Application to predictive overhead line maintenance

- Design criteria – a measurement pantograph incorporating a fiber optic sensing system must…
  - … measure the side way movement of the contact wire
  - … detect undesired peaks in contact force
  - … detect contact force relief of the pantograph
  - … localize the obtained results on railway track (via GPS, +/-1 m position accuracy)
  - … monitor thresholds and give alarm immediately to operator in case a critical condition is detected
  - … ensure continuous 24/7 operation
  - … be in compliance with EN 50317 (standard for measuring the pantograph-contact line interaction)
  - … have minimum influence in vehicle maintenance (standard contact strips)





Installation reference

- Pictures taken after one year operation
  - Force sensors

Installation reference

- Pictures taken after one year operation
  - Accelerometers

Thank You.