Wheel-Flat Dynamics Modeling and the WILD (Wheel Impact Load Detection) System

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Ministry for Railway
Government of India

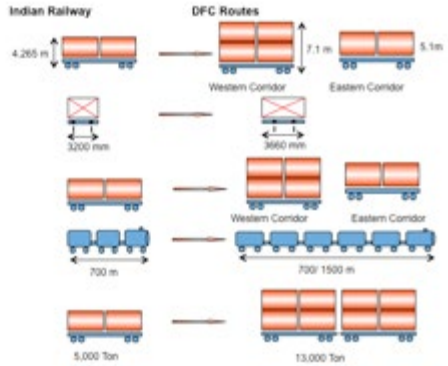
Indian Railways

Indian Railways (IR) is one of the largest transportation and logistics network of the world

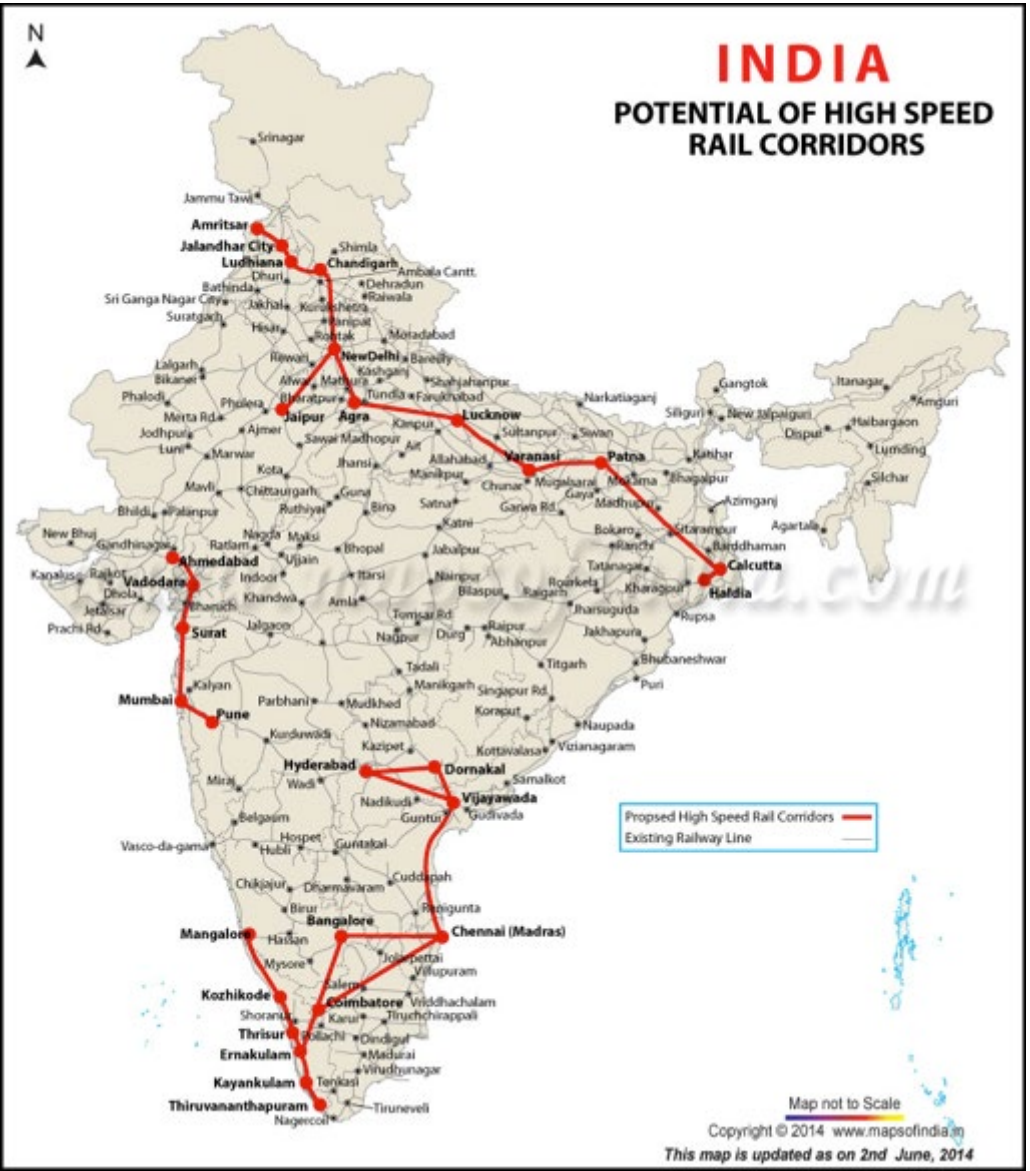
- network of 65,000 route kilometers is more than one and half times the circumference of the earth
- runs 19,000 trains
- runs 12,000 trains to carry over 23 million passengers per day
- connects about 8,000 stations
- runs more than 7,000 freight trains per day carrying about 3 million tonnes of freight every day

Dedicated Freight Corridor

	Indian Railway	DFC Routes
Axle Load	22.9 t / 25 t	25 t (Bridges & formation designed for 32.5 t)
Maximum Speed	Predominently 75 Kmph	100 Kmph
Average speed	26.5 kmph	70 kmph
Grade	Upto 1 in 100	1 in 200
Station Spacing (Approx.)	7-10 Km	40 Km



High Speed Rail Mumbai Ahmedabad High Speed Railway Project (MAHSR)



Japan government is providing financial assistance for the project. India's first bullet train will run from Mumbai to Ahmadabad. The the time between these two places will be two hours seven minutes. As per the Nikkei Asian Review, the train will run at 320kph by 2023.

The high-speed Talgo train completed its trip, between Mumbai and Delhi as the final leg of speed trials undertaken by the Railways. The 'semi bullet train' beat the Rajdhani Express by nearly three hours, taking barely 13 hours to cover the Delhi-Mumbai distance. It clocked a speed of 130 kmph.

Technology Mission for Indian Railways

Indian Railways operate under vastly challenging circumstances of large population, low cost of travel, longer trains etc.

The challenges posed are also thus greater and varied and unique in nature.

They also provide enormous opportunities for mutual collaboration and sharing technical expertise and products.

Technology Mission for Indian Railways

A consortium of Ministry of Railways, Ministry of Human Resource Development, Ministry of Science & Technology and Industries on an Investment Sharing Model is being set up as part of **Technology Mission for Indian Railways** *to take up identified Railway projects for research.*

Focus

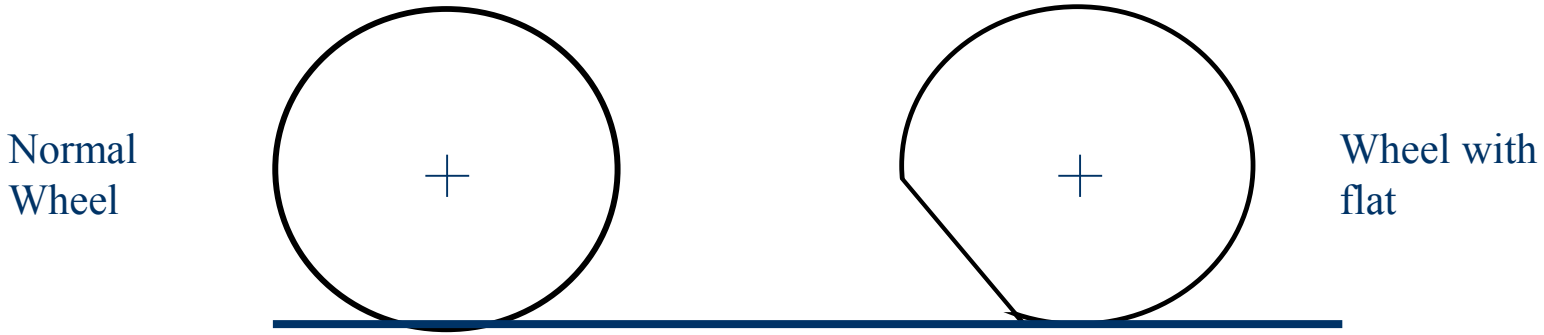
R & D Projects in
- Safety
- Heavy Haul
- High Speed
- Metro Rail
- Energy & Environment

Platforms

- Centres of Excellence
- Research Programs
- Post Graduate Program
- International Collaboration

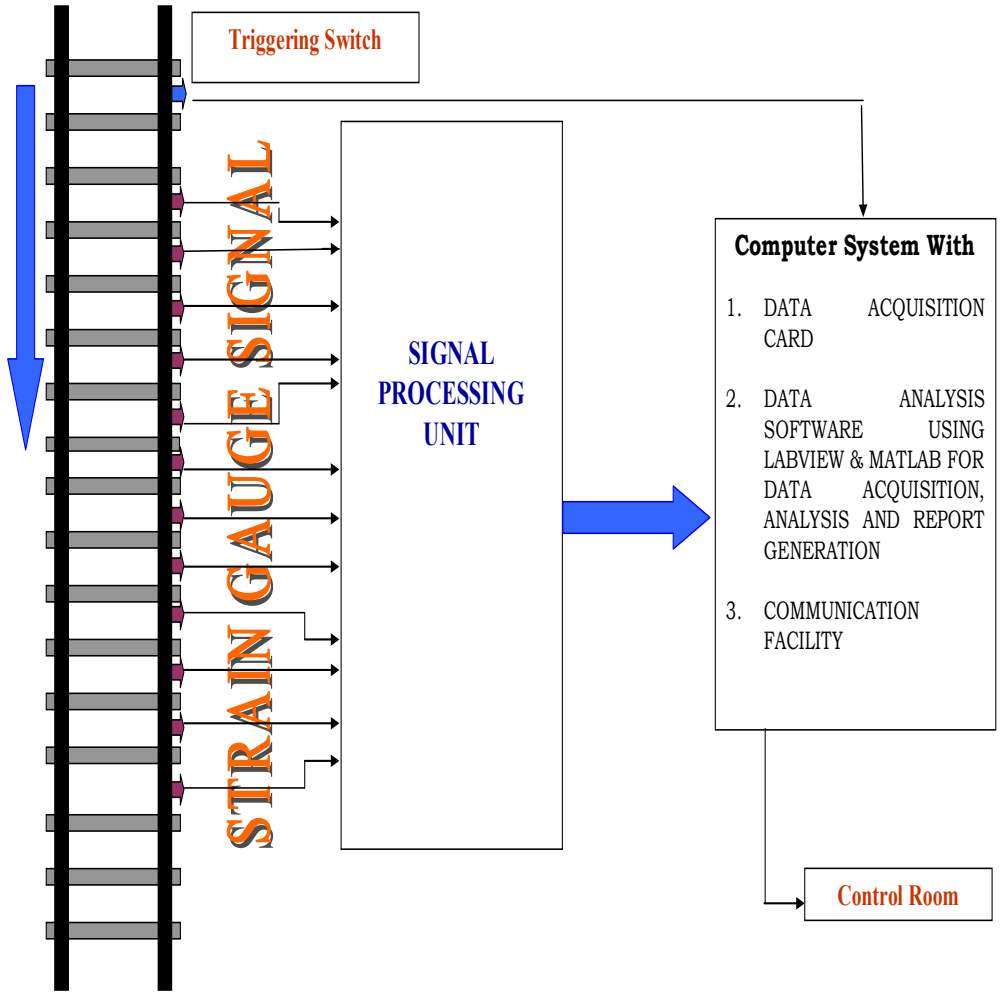
The Problem

A severe type of out of roundness is the wheel flat, which is a flat zone on the wheel tread caused by unintentional sliding of the wheel on the rail when the brake locks.

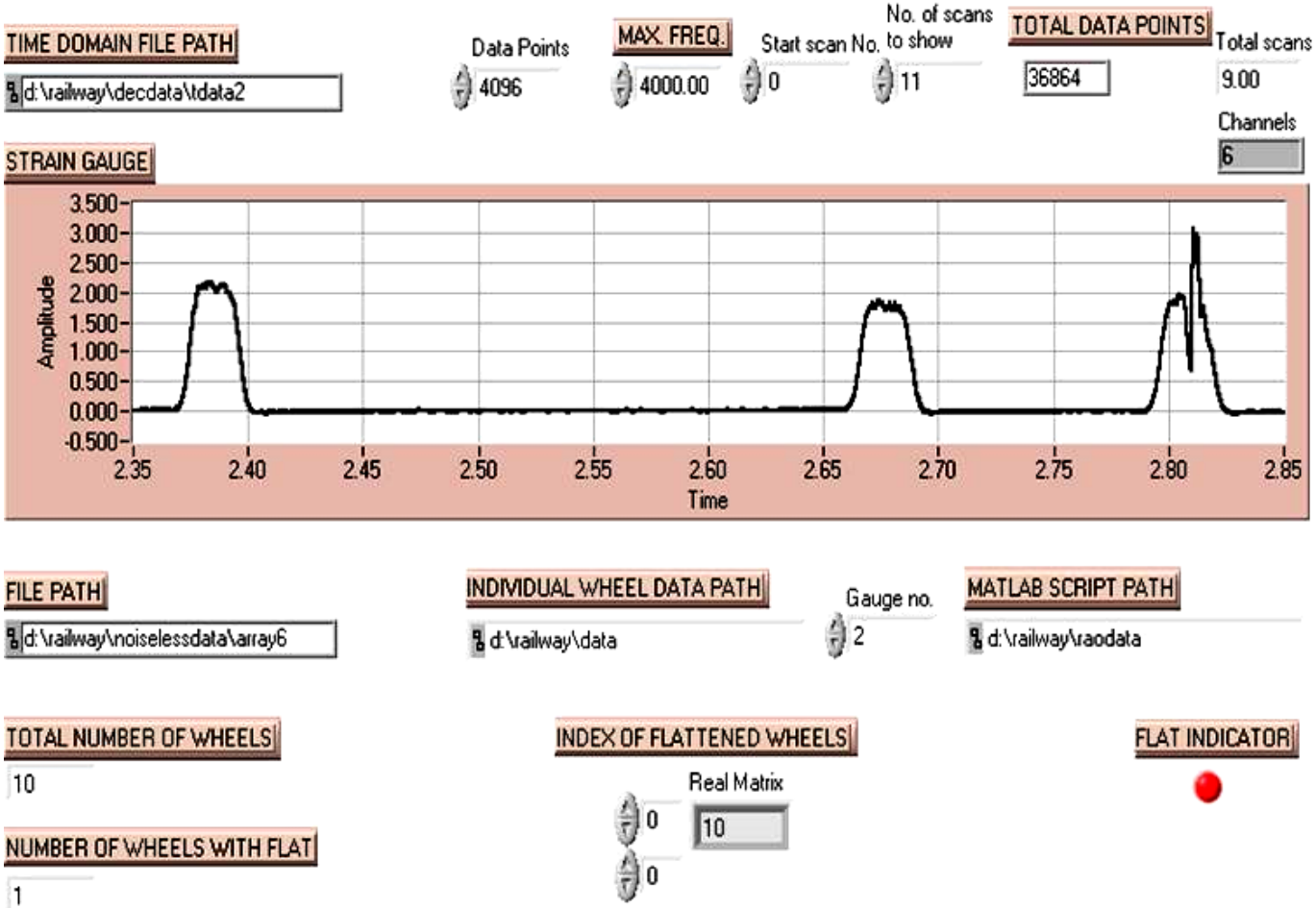


- Wheel flat is caused by the brake or some other mechanism, interfering with the normal angular velocity of the wheel
- When brakes do not function properly, the wheel ceases to rotate and a flat develops due to plastic deformation
- Wheel flats cause large dynamic forces to the track.
- According to popular practices, flats on wheels should be restricted to a length of 60 mm and a depth of 0.9-1.4 mm.

Wheel-Flat


Triggering Switch
STRAIN GAUGE SIGNAL
SIGNAL PROCESSING UNIT
Computer System With
1. DATA ACQUISITION CARD
2. DATA ANALYSIS SOFTWARE USING LABVIEW & MATLAB FOR DATA ACQUISITION, ANALYSIS AND REPORT GENERATION
3. COMMUNICATION FACILITY
Control Room

Wheel Impact Load Detector (WILD)



Analytical Formulation - *Michaël J. M. M. Steenbergen*

Vehicle System Dynamics
International Journal of Vehicle Mechanics and Mobility
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713659010

The role of the contact geometry in wheel-rail impact due to wheel flats

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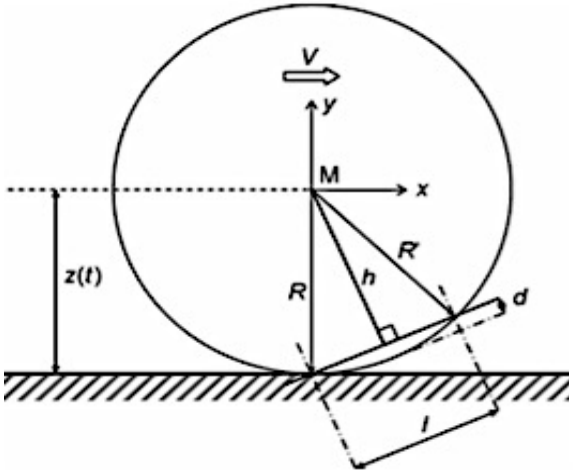
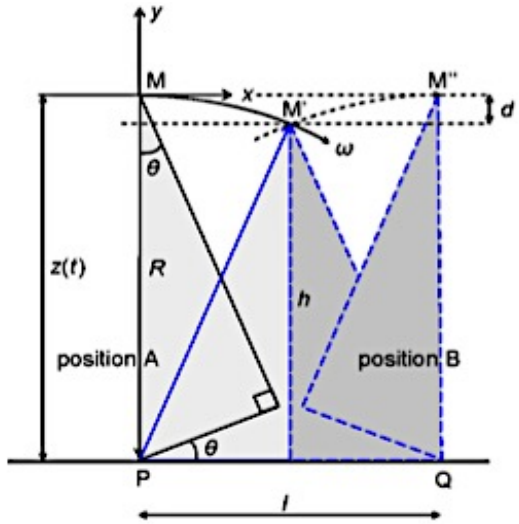
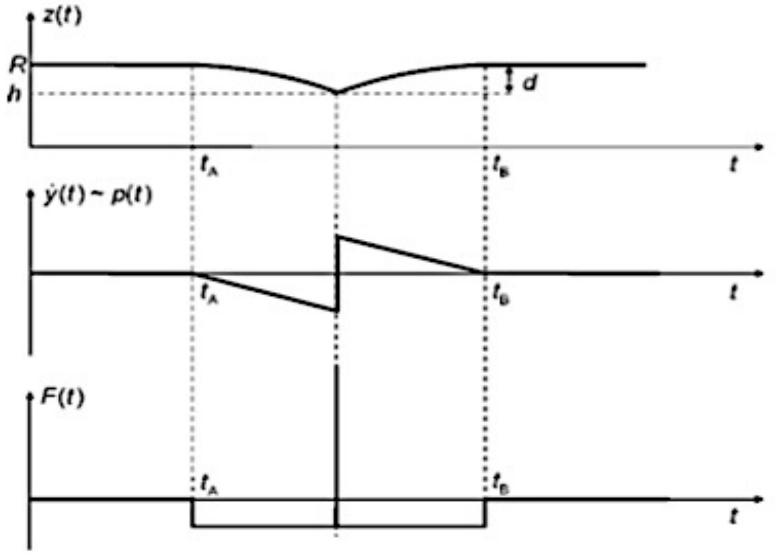




$$y(x) = (\sqrt{R^2 - x^2} - R)H\left(-x + \frac{l}{2}\right) + (\sqrt{R^2 - (x-l)^2} - R) \times \left(H\left(x - \frac{l}{2}\right) - H(x-l)\right)$$

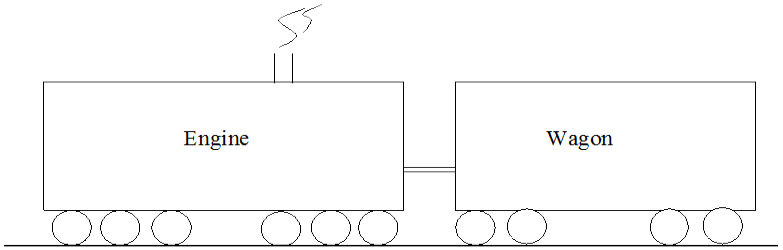
$$p(t) = m\dot{y}(t) = \frac{-mV^2 t}{\sqrt{R^2 - V^2 t^2}} H\left(-t + \frac{0.5l}{V}\right) - \frac{mV(Vt-l)}{\sqrt{R^2 - (Vt-l)^2}} \times \left(H\left(t - \frac{0.5l}{V}\right) - H\left(t - \frac{l}{V}\right)\right)$$

$$F(t) = \frac{-mV^2R^2}{\sqrt{(R^2 - V^2t^2)^3}} H\left(-t + \frac{0.5l}{V}\right) + \delta\left(t - \frac{0.5l}{V}\right) - \frac{mV^2R^2}{\sqrt{(R^2 - (Vt-l)^2)^3}} \left(H\left(t - \frac{0.5l}{V}\right) - H\left(t - \frac{l}{V}\right)\right)$$

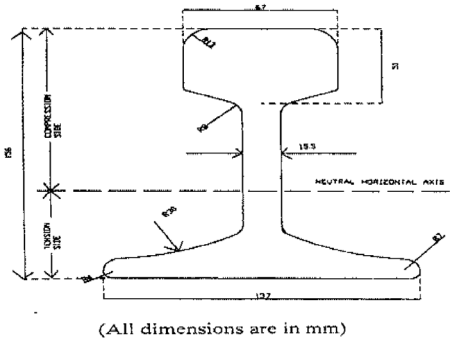


Trajectory of the gravity centre of the wheel, vertical velocity of the wheel mass and contact force

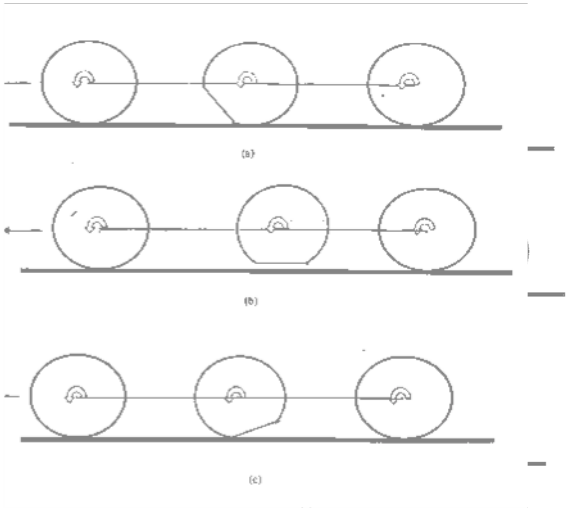
FE Simulation – *Gupta & Vyas*



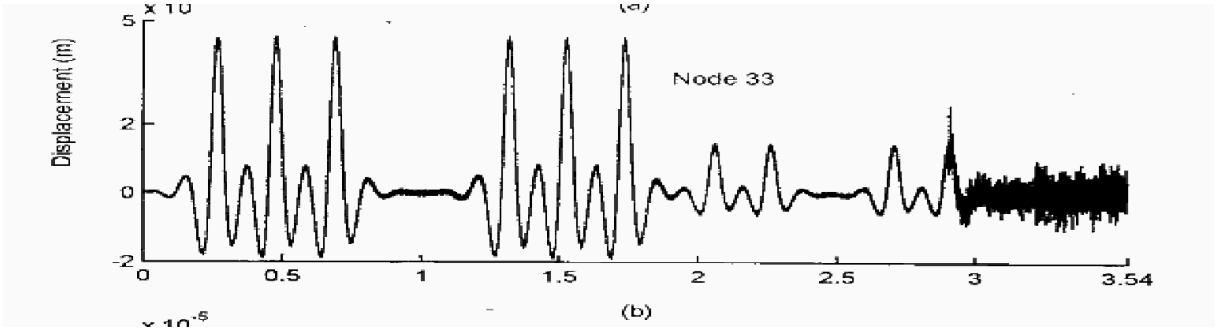
Schematic of test train



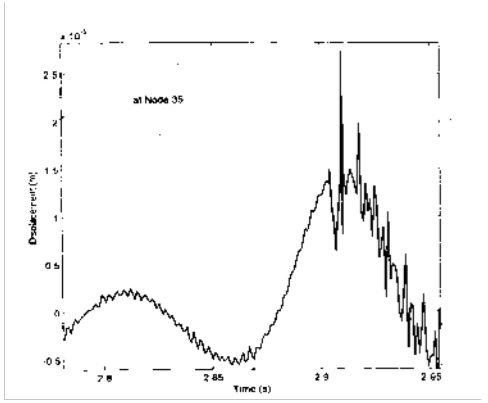
Rail section

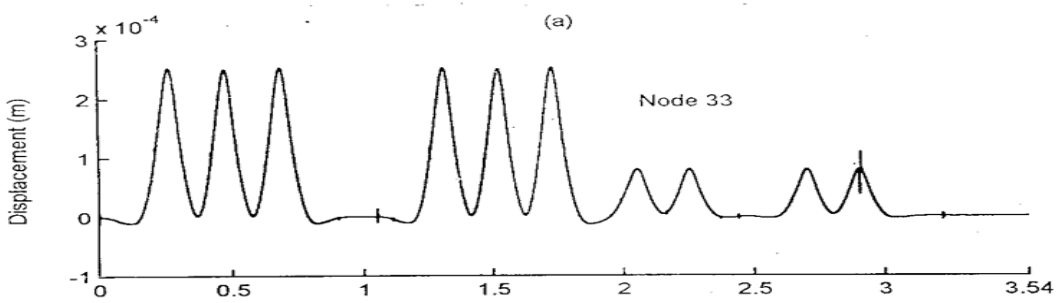


Lift and hit phenomenon of wheels

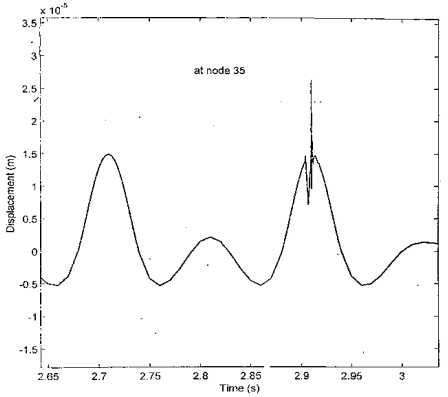


Response at a point on the rail for Rigid supports

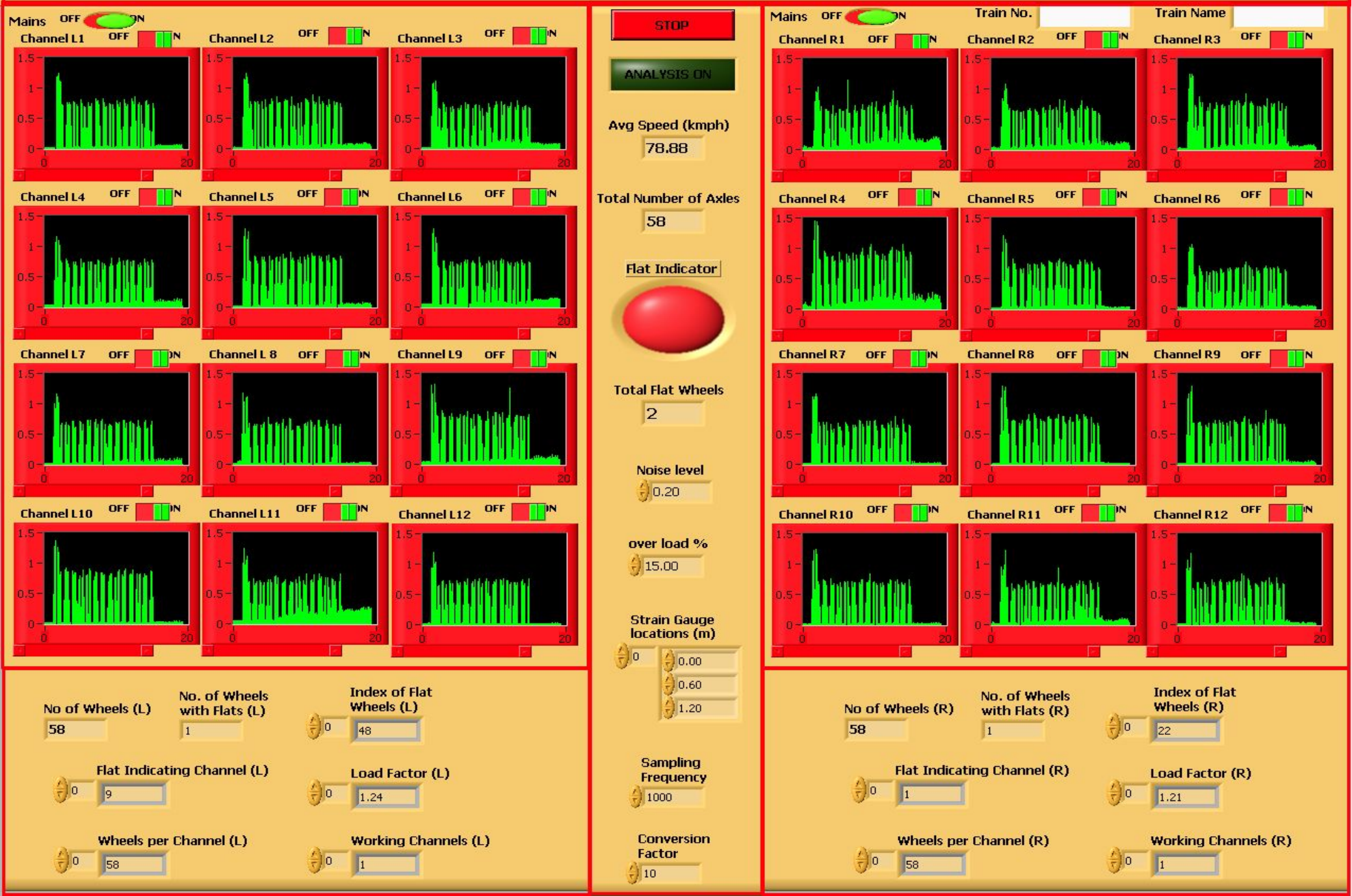




Response at a point on the rail for Flexible supports

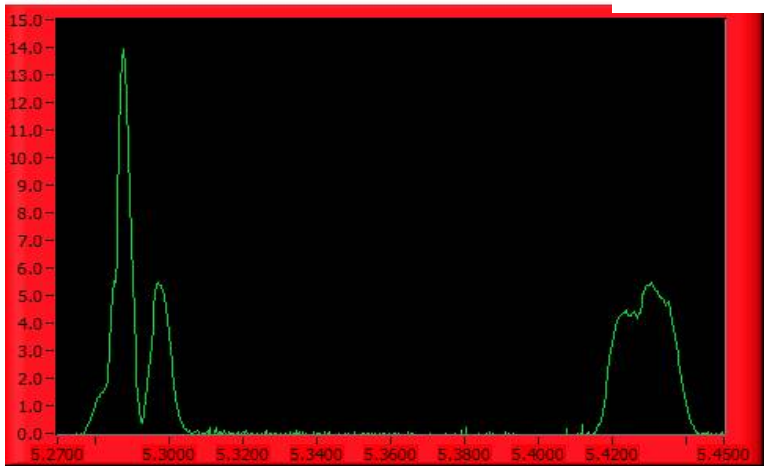


Rail Wheel Impact Load Detection System IIT Kanpur / RDSO Lucknow

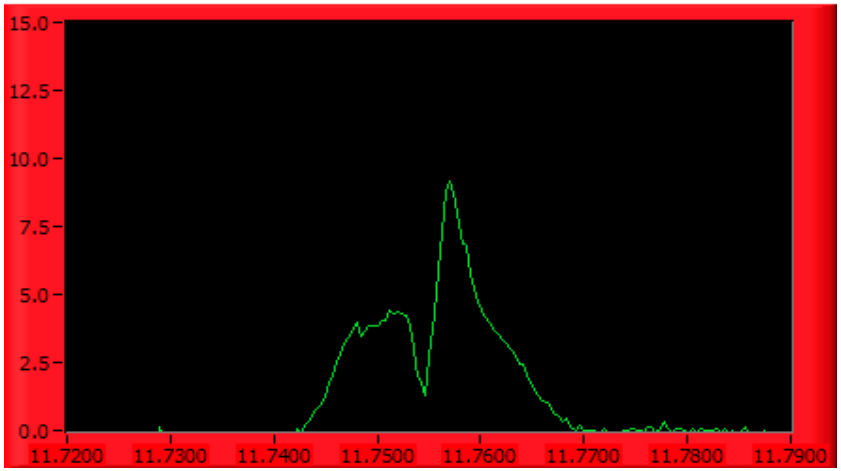


Flat Patterns

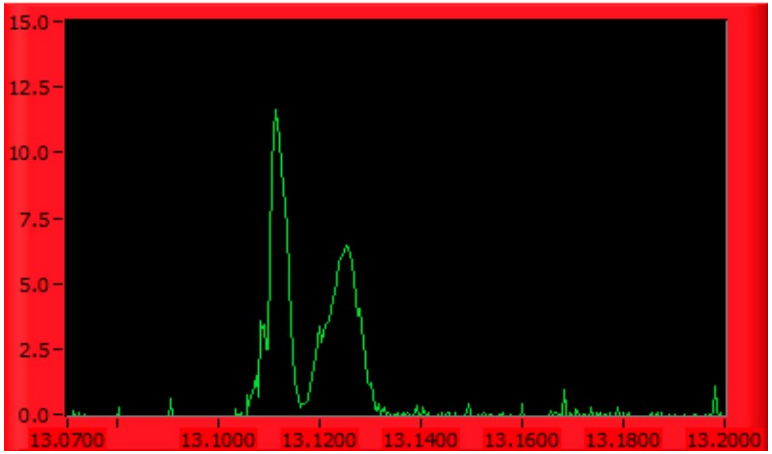
Channel 5



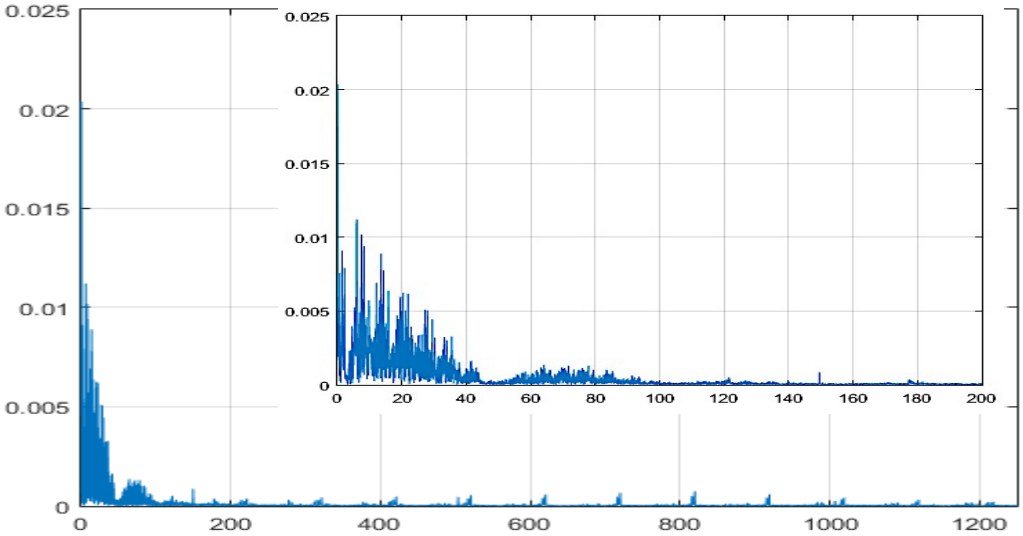
Channel 9



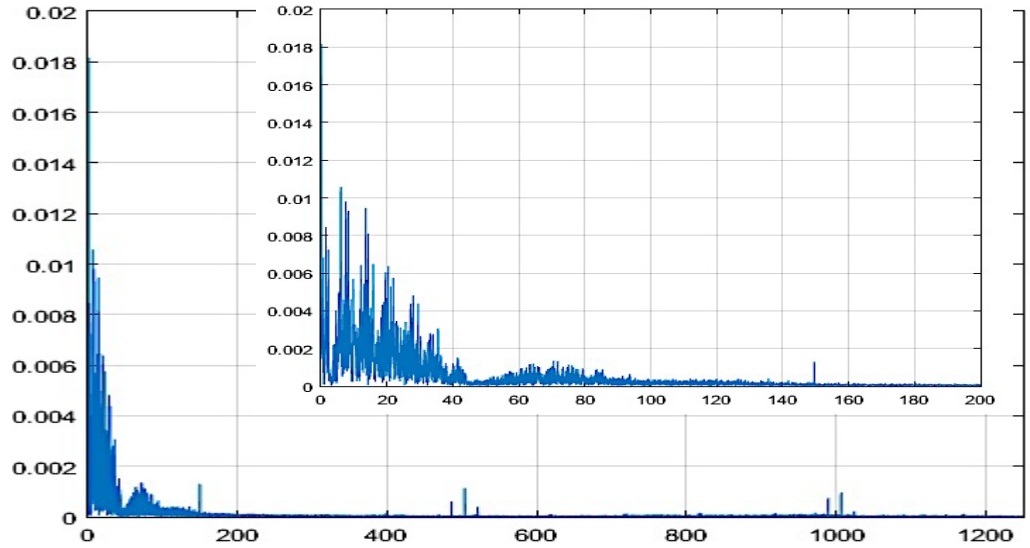
Channel 8



Fourier Transform

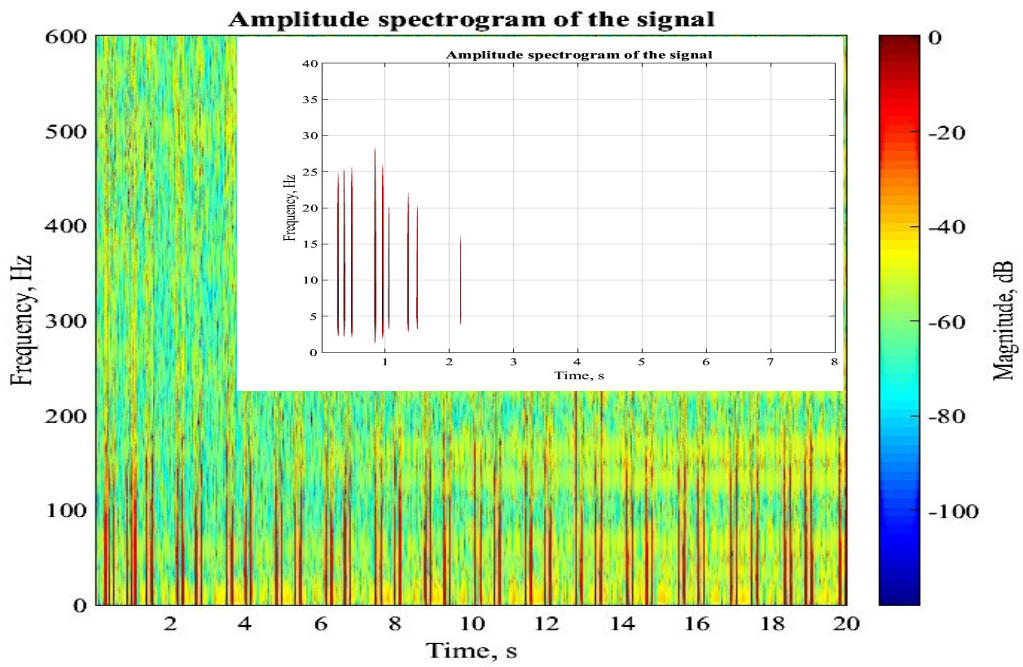


Channel – not showing Flat

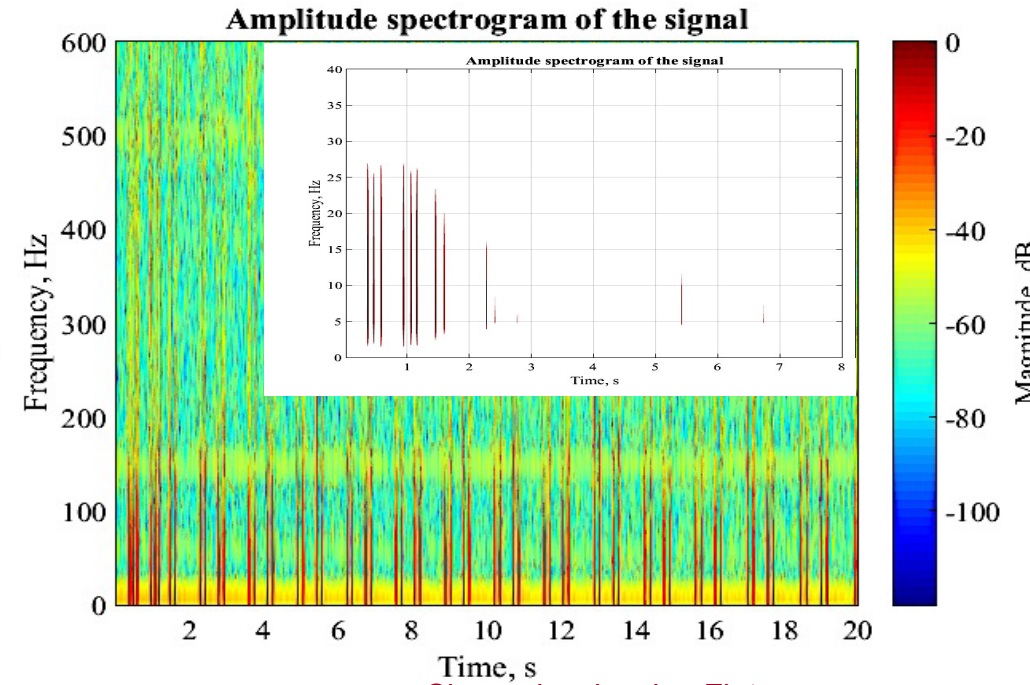


Channel – showing Flat

Short-Time Fourier Transform

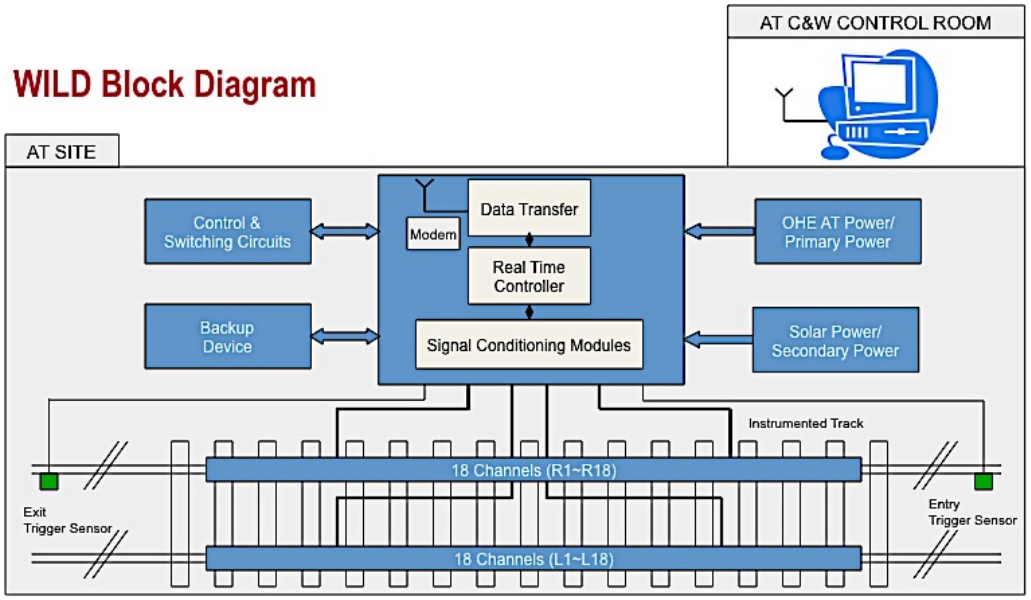


Channel – not showing Flat



Channel – showing Flat

WILD Block Diagram



WILD Implementation

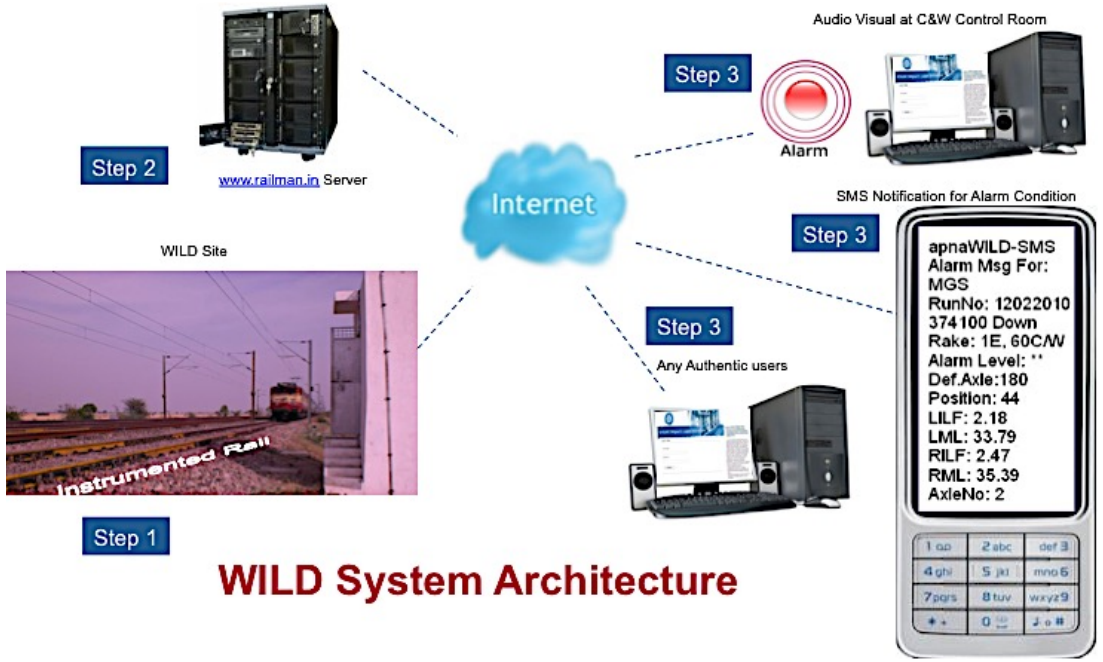
- Industry Partner: Apna Technologies & Solutions, India

apna group — apna technologies & solutions — www.apnatech.com | info@apnatech.com

- Current Installation: 15 systems across India
- Technical Evaluation: Indian Railways evaluated and compared this system against World's Best WILD Systems from US & European Companies
- Future: More than 250 installations in Indian Railways network

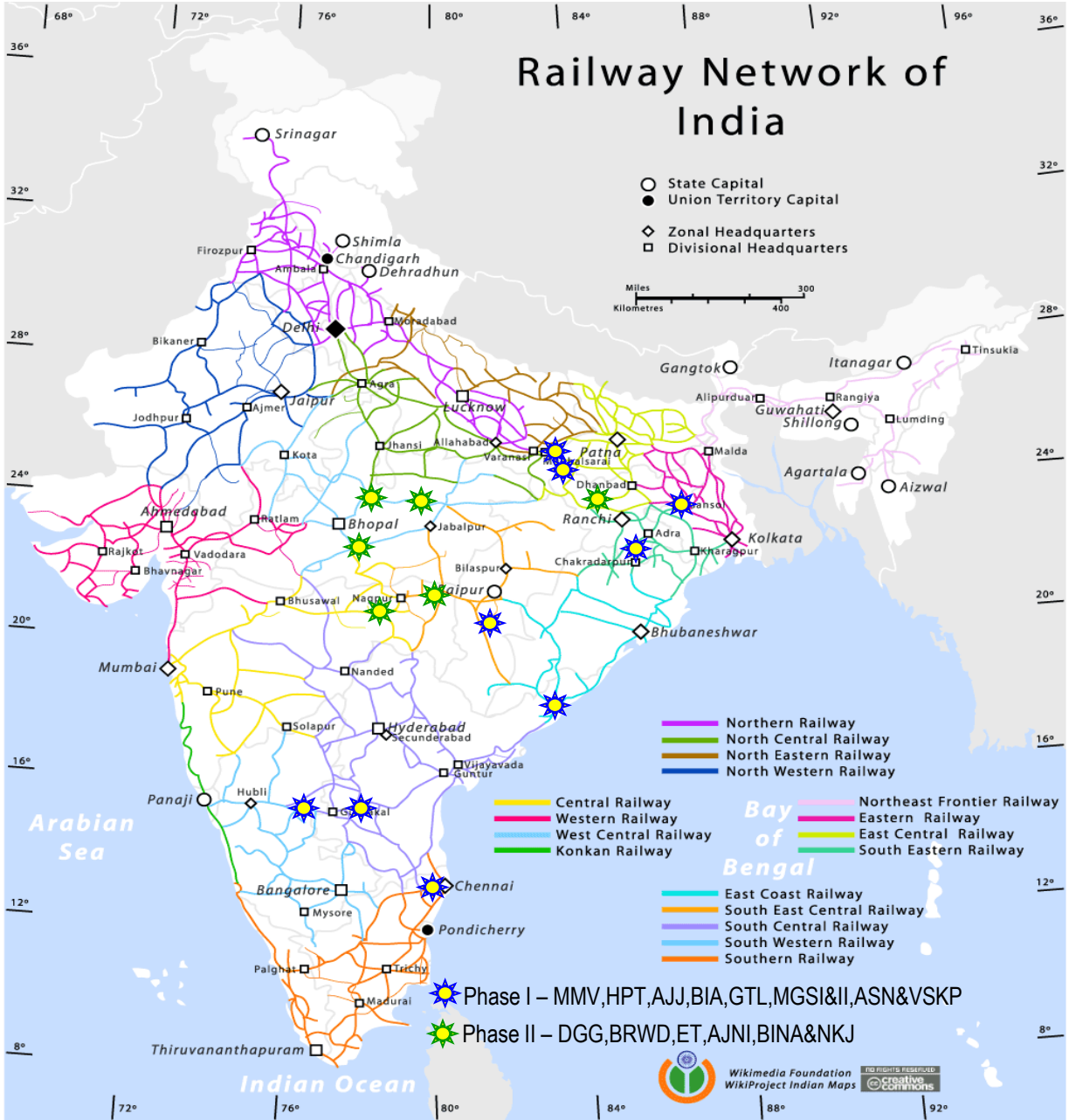
Salient Features

- Wayside System with 24x7 reliable operation
- Automatic Identification and Measurements
- Dynamic Load and Impact Force Measurement
- Automatic Transfer of Report and Alarm to Central Examining Station by GSM/GPRS
- Bidirectional Traffic
- Provides Engine, Wagon, Coach, Wheel and Axle information
- Speed Measurement
- Self Calibration & Self Diagnostics

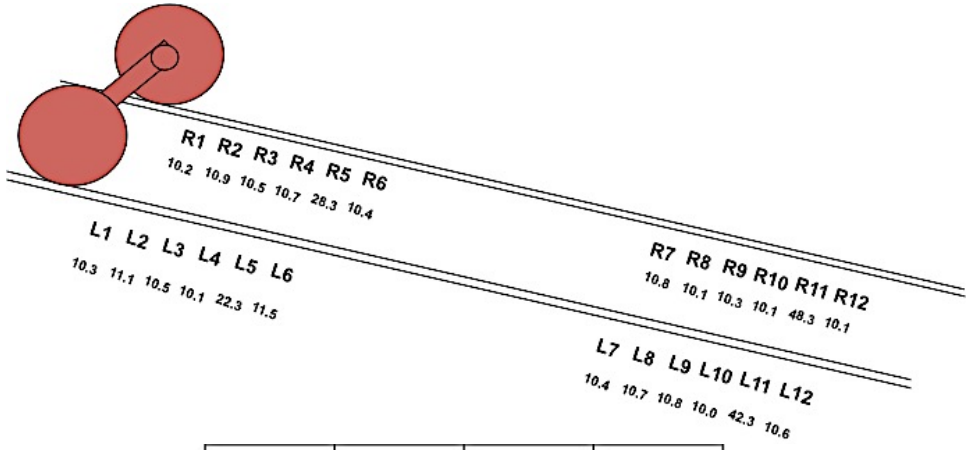


WILD System Architecture

WILD – Wheel Impact Load Detector in India



Impact Load Factor Calculation



L Rail	Load T	R Rail	Load T
L1	10.3	R1	10.2
L2	11.1	R2	10.9
L3	10.5	R3	10.5
L4	10.1	R4	10.7
L5	22.3	R5	28.3
L6	11.5	R6	10.4
L7	10.4	R7	10.8
L8	10.7	R8	10.1
L9	10.8	R9	10.3
L10	10	R10	10.1
L11	42.3	R11	48.3
L12	10.6	R12	10.1

Second Left Max Dy Wheel Load

Second Right Max Dy Wheel Load

First Left Max Dy Wheel Load

First Right Max Dy Wheel Load

Left Maximum Dy Wheel Load = 42.3

Left Average Dy Wheel Load = 10.6

$$\text{Left Impact Load Factor} = \frac{\text{Left Maximum Dy Wheel Load (42.3)}}{\text{Left Average Dy Wheel Load (10.6) (Avg. Of Lowest ten readings)}}$$

Left Impact Load Factor (L ILF) = 3.99

Right Maximum Dy Wheel Load = 48.3

Right Average Dy Wheel Load = 10.41

$$\text{Right Impact Load Factor} = \frac{\text{Left Maximum Dy Wheel Load (48.3)}}{\text{Left Average Dy Wheel Load (10.41) (Avg. Of Lowest ten readings)}}$$

Right Impact Load Factor (RILF) = 4.64

WILD records 12 values of wheel impacts for every wheel that passes over each rail.

Thus a total 24 impact values are acquired 12 for left and 12 for
the right wheel of one wheel set.

Given the length of the instrumented rail, the wheels in the diameter range of 770 – 1100mm have approximately 2 revolutions over the sensing zones.

Out of the 12 samples the two max samples are removed and the remaining ten are averaged to get the average load of wheel.

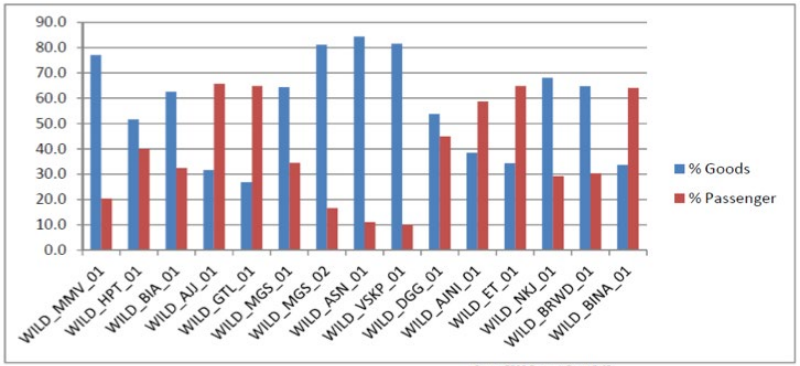
The ratio between the max load value to the average load value is called the ILF.

WILD system flags the defects purely based on the measured impact load and limits set by the railway board

- Current limits (i) >/=20T maintenance alarm or ILF >/=2.0 ~ <4.5 (ii) >/=35T critical alarm or ILF >/=4.5
- The system however features a facility for the end user to set the limits as well

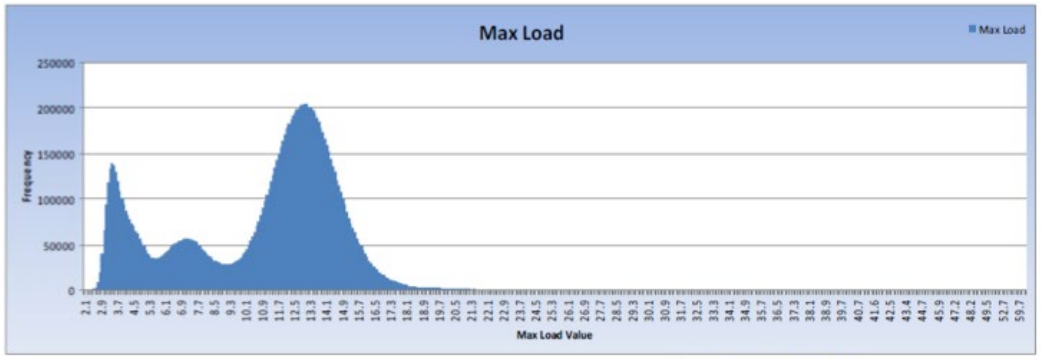
Indian Railways Statistics

Goods & Passenger Trains in WILD Network



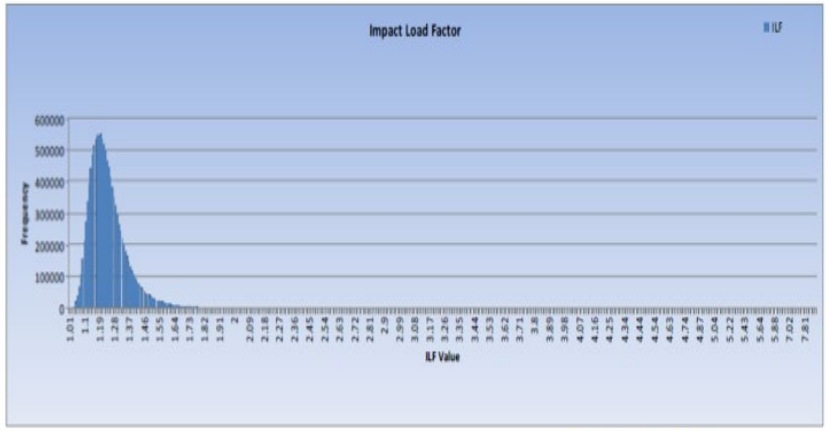
Source: RDSO Research Report R107

Wheel Max Load Distribution



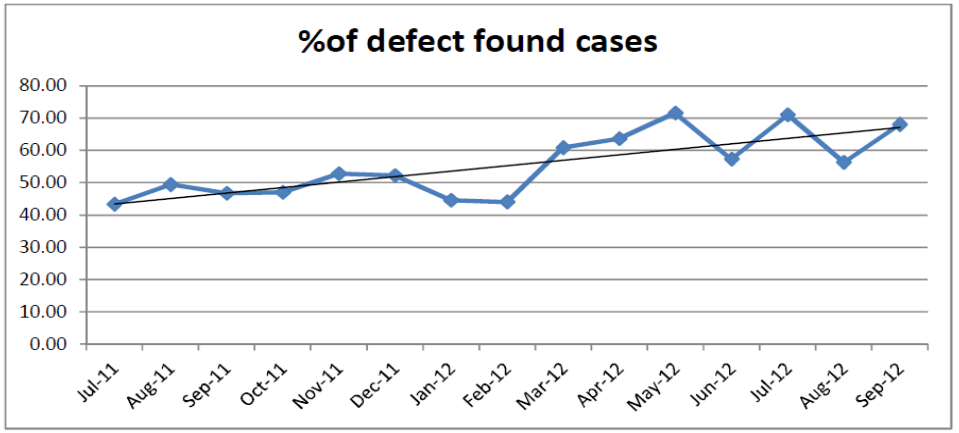
Source: RDSO Research Report R102

Impact Load Factor Distribution



Source: RDSO Research Report R102

Critical Alarm – Visual Examination



Source : RDSO Research Report R109

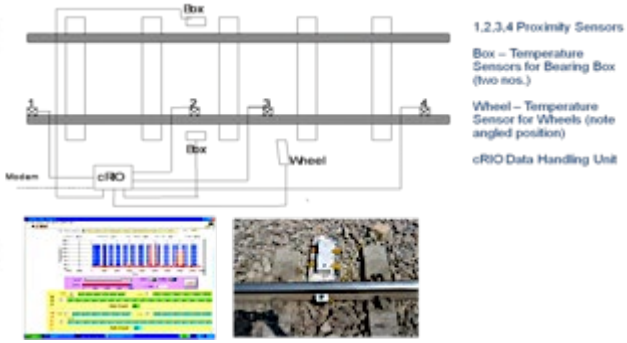
Defects that can cause High Impact Load

- Uneven loading
- Coil spring weak
- Shell Tread
- Friction liner broken
- Snubber spring broken
- Axle box canting
- PU/CC/EM Pad Shifted/Pressed/Perished
- CC housing broken
- S/Bearer roof/Friction Liner welding open
- Bolster tilted one side
- Defect in suspension
- Broken spring
- Skid mark, etc.

Previous Mission 2003 - 09

Derailment Detection Devices

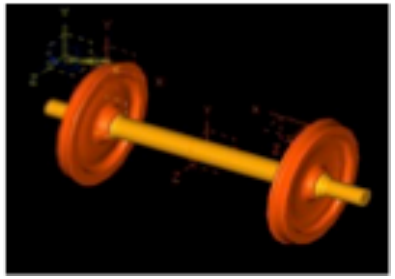
Sensors for Hot Boxes & Hot Wheels



Corrosion Prevention of Rails

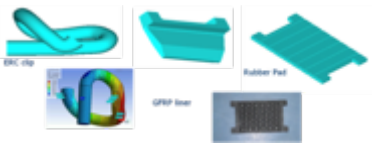
On-Board Diagnostics of Locomotives

Wheels & Axles of Improved Metallurgy

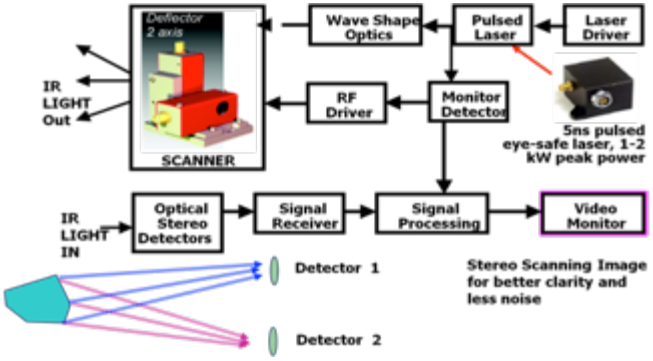


Measuring Wheel Technology

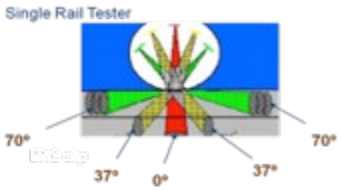
Improved Rail Fastenings



Fog Vision Instrumentation

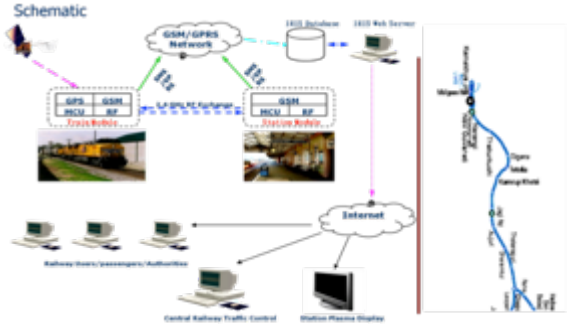


Rail Flaw Detection Instrumentation



- Used for testing one rail at a time.
- Used for hand probing of welds.
- Used on fish plated track.

Satellite Imaging for Rail Navigation (SIMRAN)

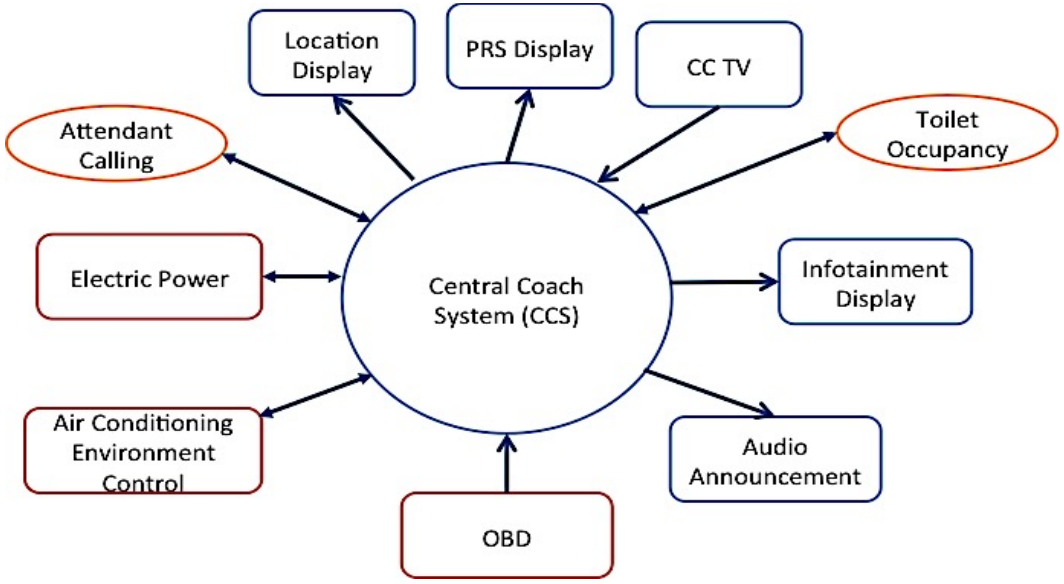


Typical current TMIR Projects

- New Apparatus for Year Around Navigation (NAYAN)- A feasibility study, **IIT Kanpur, IIT Kharagpur, IIT Madras, SAMEER, Kolkata**
- Design Methodology & software development for Railway Formation Design, **IIT Roorkee**
- *Initiation Phase* - Design of Advanced Performance Next Generation .....Freight bogie designs, **IIT Kanpur, KTH Sweden**
- *Initiation Phase* - Development of capability for testing of high speed rolling stock, **IIT Kanpur, RWTH, Aachen, Germany**
- On-board Diagnostics & Condition Monitoring, **IIT Kanpur, IIT Delhi, IIT Guwahati, IIT Mumbai**
- Digital Train Communication Network, **IIT Kharagpur**
- MEMS based Energy Harvesters for Fire Alarm Sensors & Emergency LED Lamps, **IISc Bangalore**
- Way Side Monitoring System, **IIT Bombay, University of Illinois, USA**
- Design and Development of In Motion Weigh-Bridge, **IIT Kanpur**

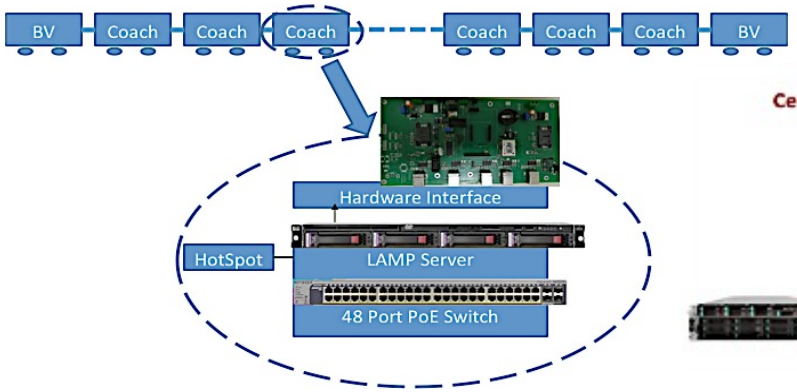
SMART Passenger Information & Coach Computing Unit (PICCU)

Multiple modules related to Passenger Information, CCTV, Infotainment, Coach Diagnostics, Condition Monitoring are proposed to be built.



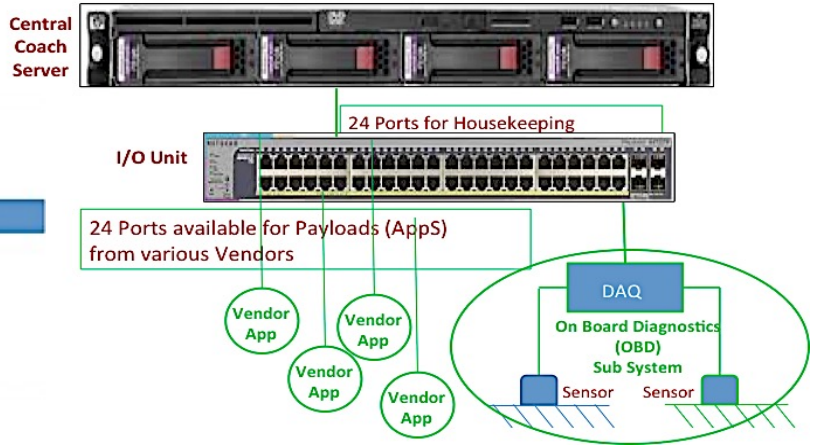
- Location Information Display (2)
- PRS Coach Related Data Display (2)
- Audio Announcement
- Coach On-Board Diagnostics, OBD
- Infotainment
- IP Based Cameras (8)
- Toilet Occupancy System
- Coach Attendant Calling System
- AC & Environment related Parameters / Control
- Power related Parameters (Voltage / Current etc)

Normal Coach Modular Design

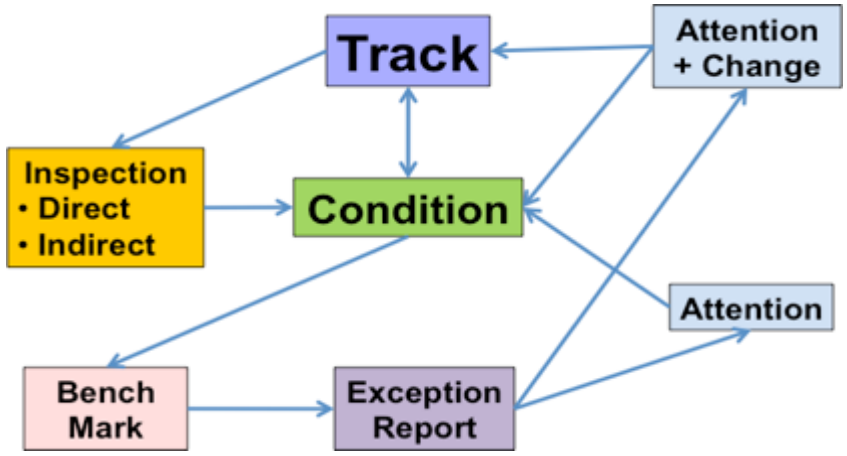


Central Server to Coach Communication

Access to Vendors for Applications (AppS)



Railway Track Management System



Inputs

- **Initial – One time**
  - Jurisdiction and domain data
  - Master Assets (All – Rail, sleeper, welds, joints… everything) with correct chainage
  - One last inspection from all inspection registers
- **Periodic**
  - Sanctioned works (once a year)
  - GMT (once a year)
- **Regular Working**
  - All Inspections (Individual assets, trolleys, etc.)
  - TRC/OMS/Oscillograph results
  - USFD testing
  - All Works (Maintenance, Renewal, Machines, gang input, etc..)
  - Track machine work
  - Contractual works/inputs

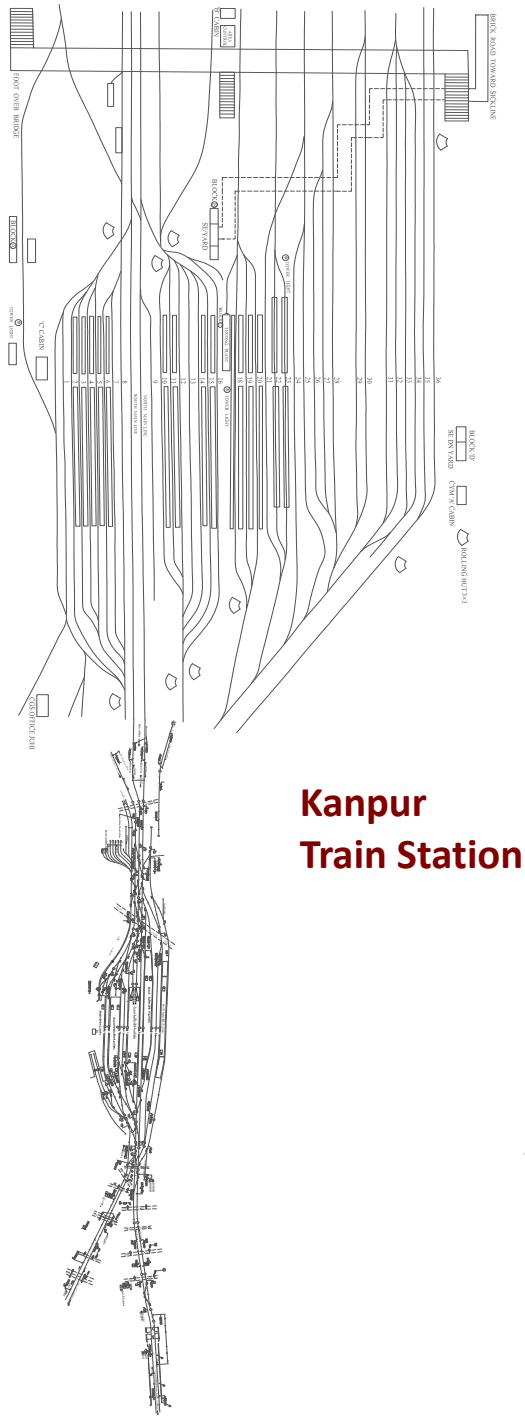
Outputs

- **Master Asset related :**
  - Jurisdiction and domain data
  - Assets classification & exception
  - Track statistics
- **Inspection related :**
  - Inspection Planning, Inspection charts
  - Due/Overdue, Shortfall
  - Quality, Pending compliance
- **Asset Condition related :**
  - Various Reports (Xing worn beyond limit, curve needing local/re-alignment, rail corroded/worn, etc)
  - USFD classification, progress & condition related
  - Due D/s, renewal, tamping, etc
- **Work Related :**
  - Machine progress/quality,
  - Machine planning
  - Gang progress/utilisation

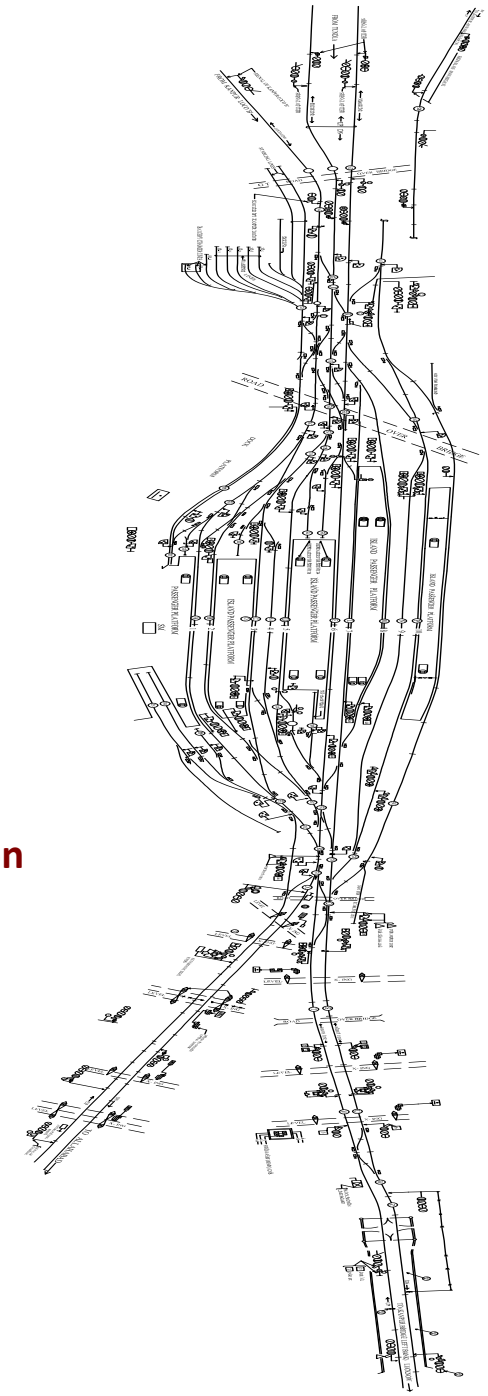
Scheduling

Some major scheduling processes are as follows.

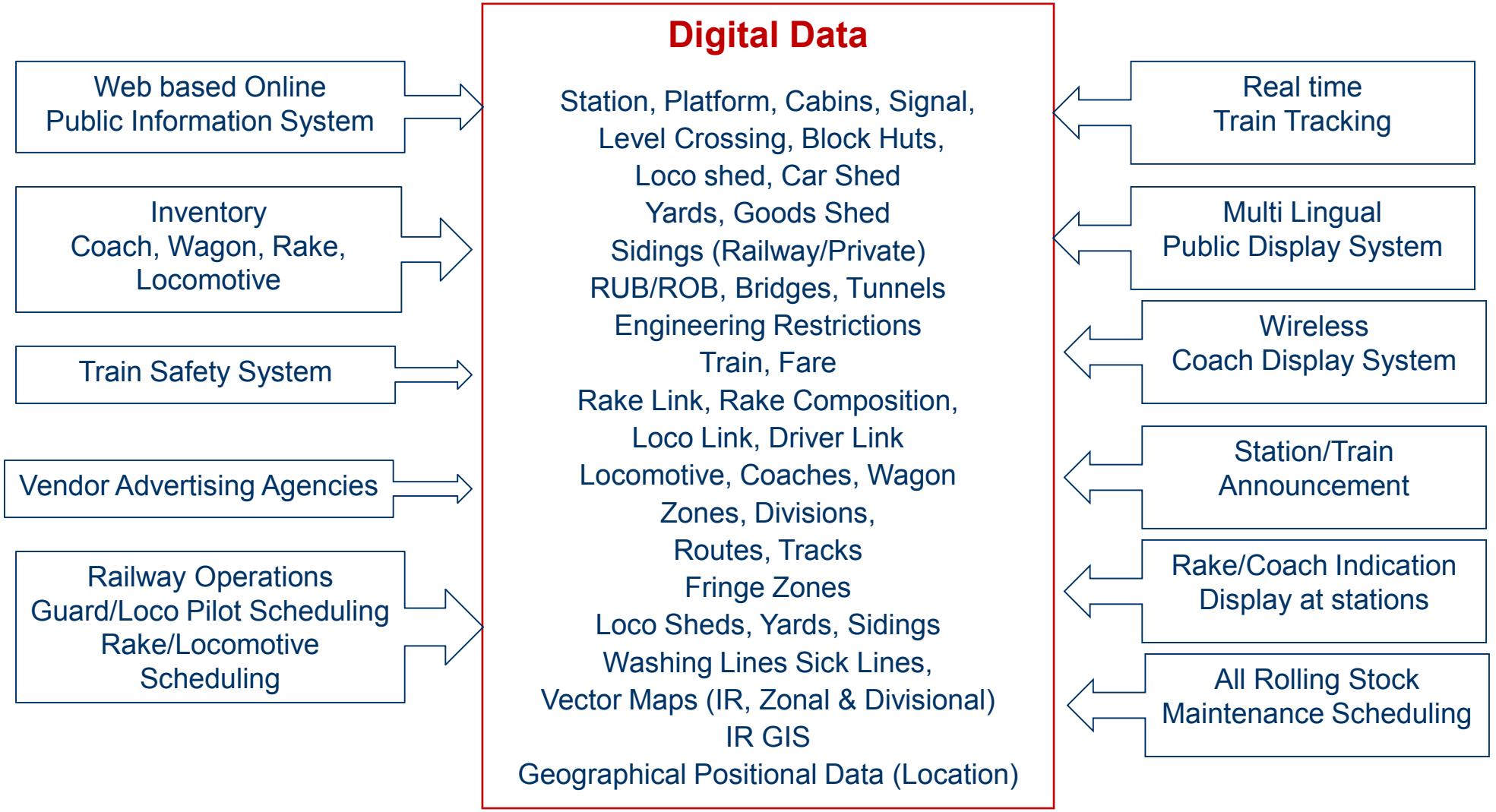
- Locomotive Scheduling (Utilization)
- Locomotive Scheduling (Maintenance)
- Coach Scheduling Utilization
- Coach Scheduling Maintenance
- Rake Maintenance Scheduling
- Rake Scheduling (Operational Utilization)
- Driver Scheduling
- Signal Scheduling
- Guard Scheduling
- Other Running and Stationed Staff Scheduling
- Platform Scheduling
- Passenger Scheduling
- Track Usage Scheduling
- Water Filling Scheduling
- Track Maintenance Scheduling
- OH Power Calculation for their yearly usage
- OH Power Line Maintenance Scheduling
- Scheduled Railway Reservation for a train
- Train Scheduling



Kanpur Train Station



Ongoing Work



Technology Mission for Indian Railways

Opportunities

1. Suburban corridor projects through PPP
2. High speed train projects
3. Dedicated freight lines
4. Rolling stock including train sets, locomotives/coaches manufacturing & maintenance facilities
5. Railway Electrification
6. Signaling systems
7. Freight terminals
8. Passenger terminals
9. Infrastructure in industrial park pertaining to railway lines or sidings including electrified railway lines and connectivity to main railway lines
10. Mass Rapid Transport Systems.

Thank You