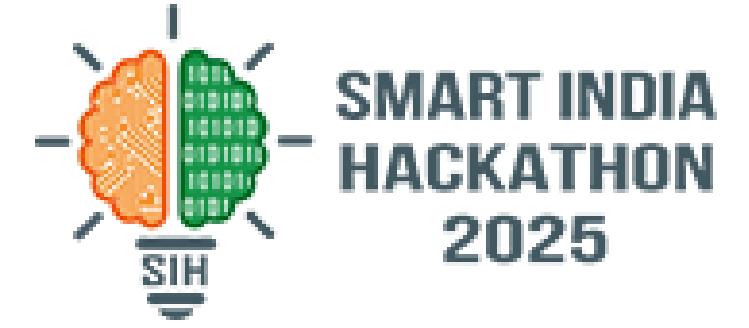
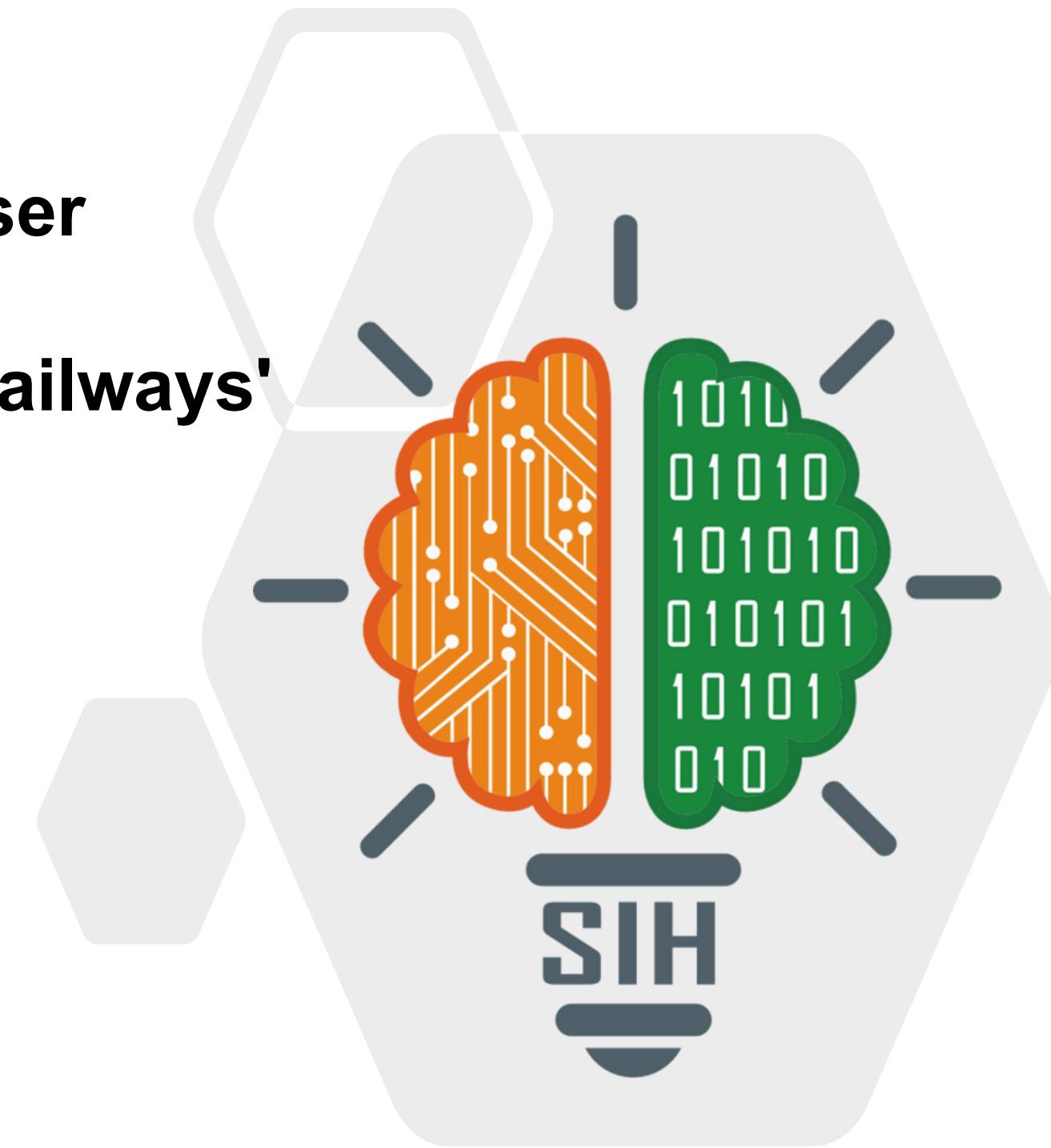
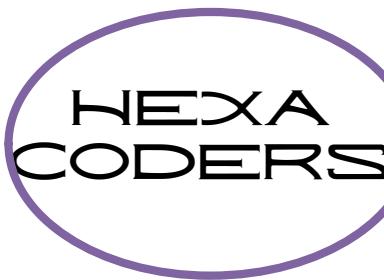


SMART INDIA HACKATHON 2025



- **Problem Statement ID – SIH25021**
- **Problem Statement Title - AI based development of Laser based QR Code marking on 'Track Fittings on Indian Railways'**
- **Theme - Transportation & Logistics**
- **PS Category - Hardware**
- **Team ID : 62334**
- **Team Name - The Hexa Coders**





IDEA / SOLUTION:

Hex-core:

- Unified industrial 4.0 technology system which automatically inspects track fittings for quality & age, designed to give **AI-assisted predictive maintenance reports** bridging P-way inspectors, supply chain and railway system ultimately creating a Digital Twin.

Imprints:

- Uses combination of imprinted **QR codes** by **dual-laser engraver** & **RFID tags** with supplementary marking (paint/engraved) to identify details of particular track fittings.

Central specialized database:

- Comprehensive database/inventory integrated with **TMS** and **UDM**, transferring data to/from **E-Enablement database** on **Cloud Server** & for area specific tracks, **solving immense rail-track data problem**.

Inspection System:

- Track scheduled and scanned by **Track Recording Cars** and **mobiles** of P-way inspectors for immediate detection of implemented track fitting. **Cameras/Sensors** used on manufacturing site for methodology checkups.

Smart Network Hub:

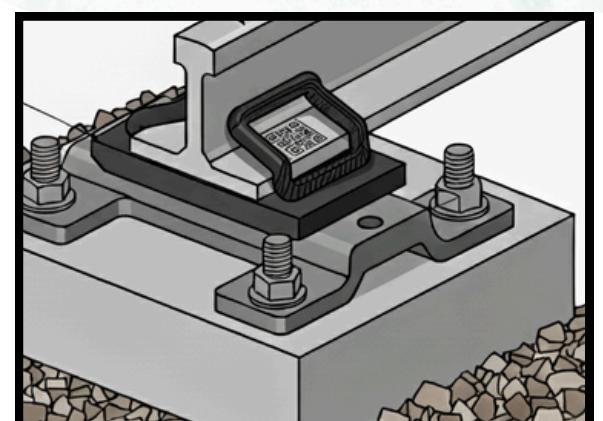
- Utilizes **Cloud & CRIS servers** and implements an **auto-sync client** on **TRC** and **ITMS trains** which stores record of scanned track fittings (**offline**) and transfers data to cloud whenever it is detected (**online**), updating Digital Twin & **solving network problems**.

VisionRail:

- A fully synced **Virtual Vails/Digital twin** divided in 5 sectors (pertaining to each Central Station) of tracks & its fittings on a client of **TRC** on journey, calculating **TRC's current location** precisely by **GPS** (**online**) & by calculating **displacement** (**offline**) due to track being **static path**, creating a **fitting identifier** when QR- codes becomes **unreadable**, **providing ultimate surveillance**.

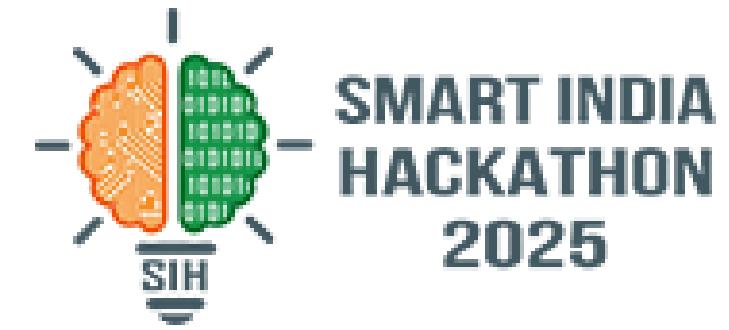
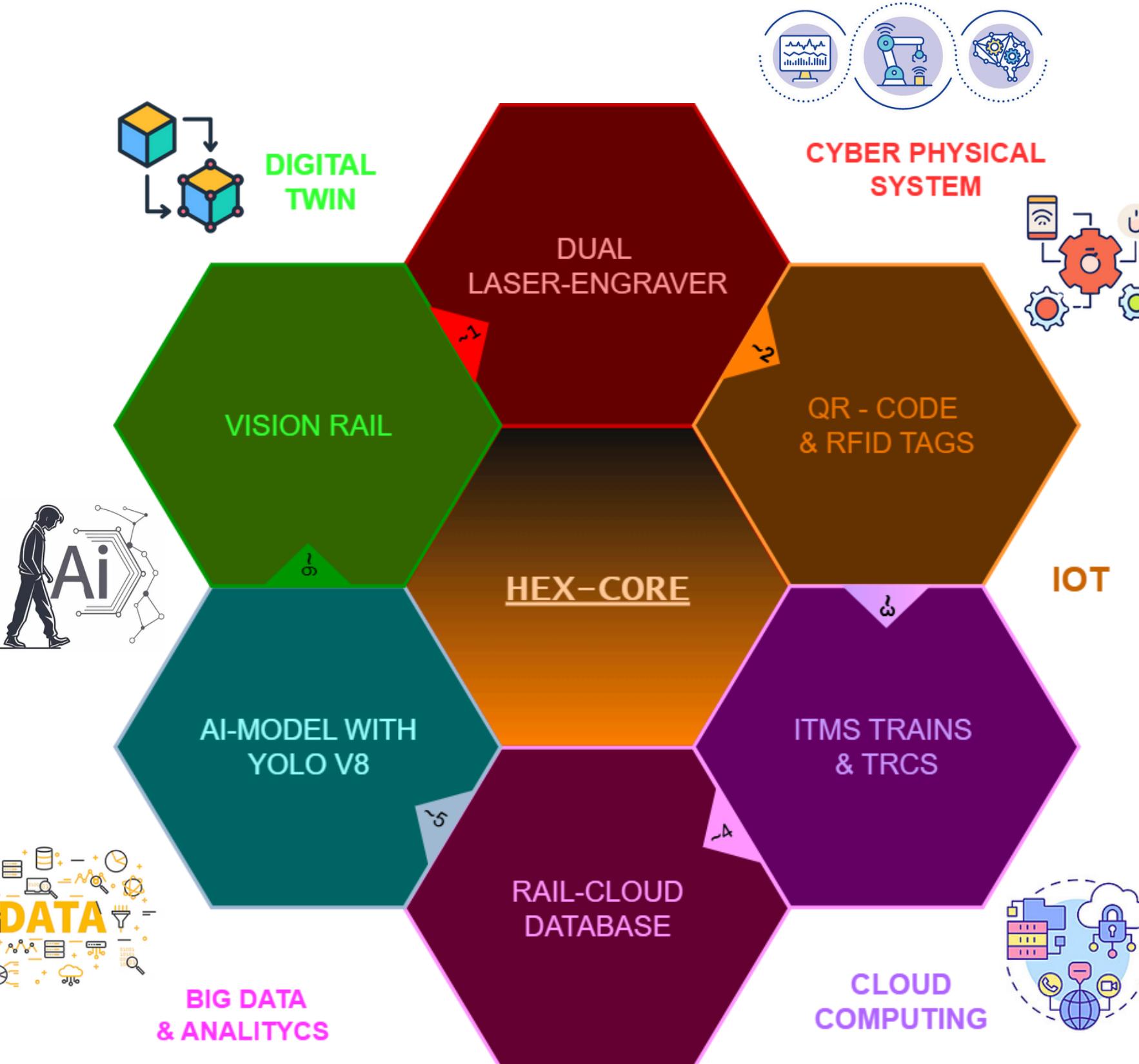
AI-Model:

- Procures and aggregates **essential details** of each fitting item from Digital Twin, inspection stages, material data by UDM & TMS portal, uneven SOD-MMD, wear-tear & RCF of Rail track and to generate an AI-based Performance Report of these Track Fittings while pinpointing improvement on methodologies.



A Rough Sketch
Optional:- QR At Rail

HEX-CORE



Unique Value Proposition :

Digital Twin:

- Virtual Tracks stored on Trains & CRIS servers
- Backup for unreadable/untraceable track fittings
- Ultimate surveillance model for P-way Engineer
- Sync with MVIS & other OMRS

Dual-laser Engraver:

- Fiber- laser for metal-track fittings
- Diode-laser for polymer-track fittings
- XTOOL F1 ULTRA / ACCELaser HD1, etc.

Multi-Source Identification:

- Laser-engraved QR codes (Level H-Q)
- RFID tags on concrete sleepers
- Supplementary Markings- Painted/Engraved
- Vision Rail - Digital Twin

Inspection coverage:

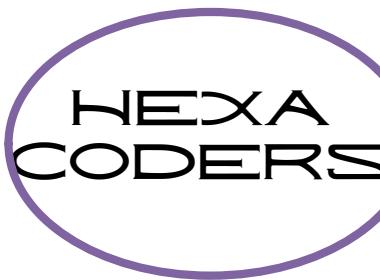
- In-yard by mobile devices
- Out-yard by ITMS-trains & TRCs
- Scheduled Re-Routing (no 24/7)

Three-Way Synced System:

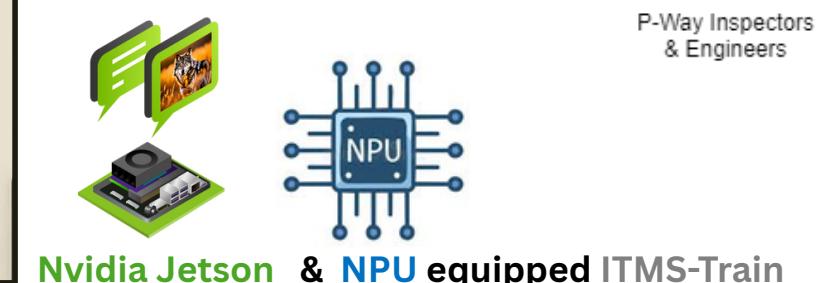
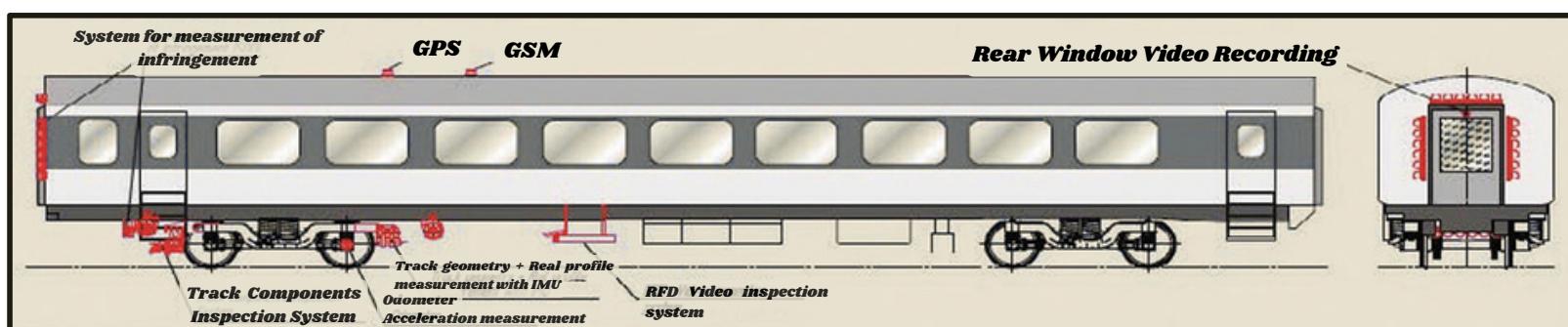
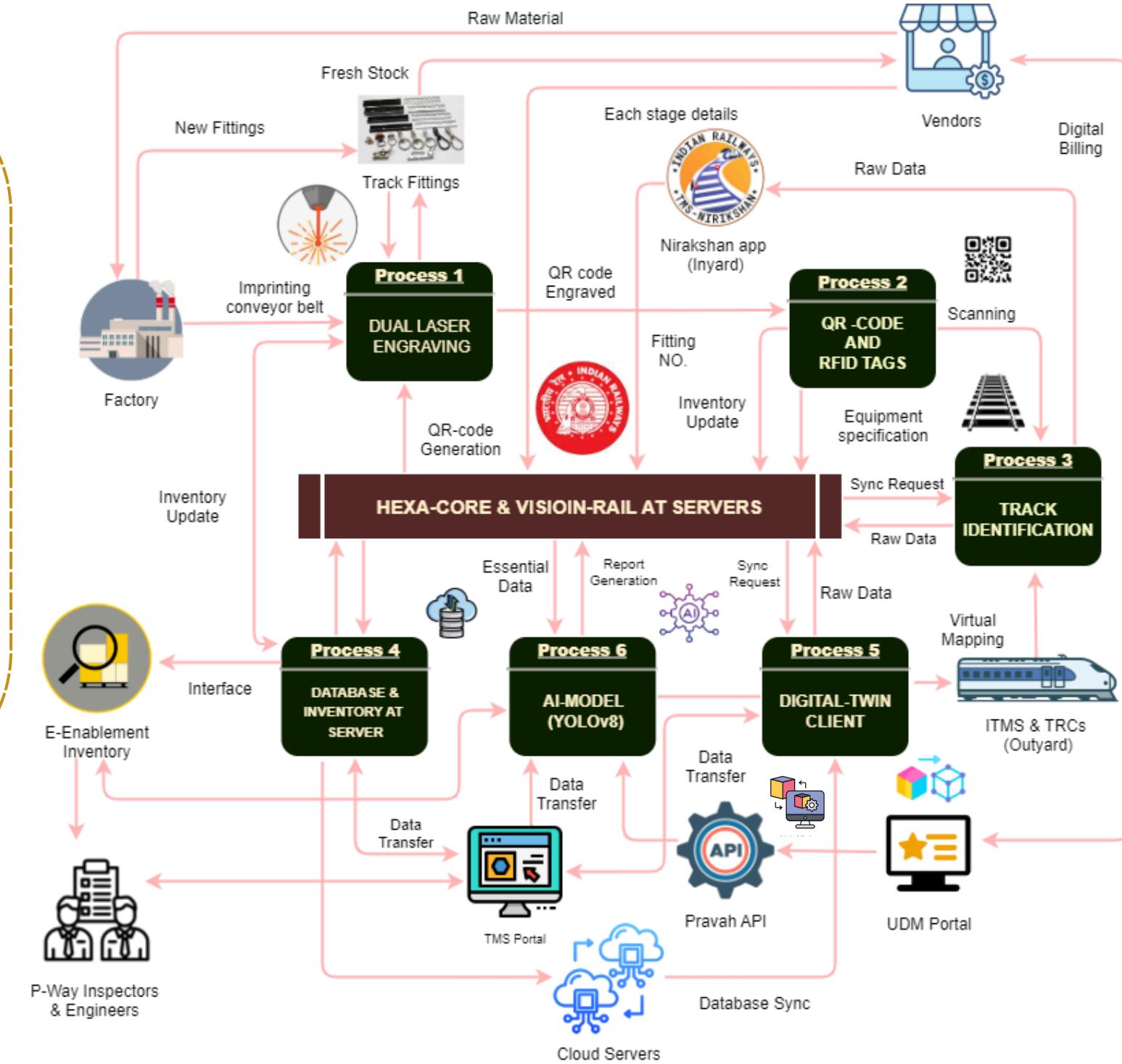
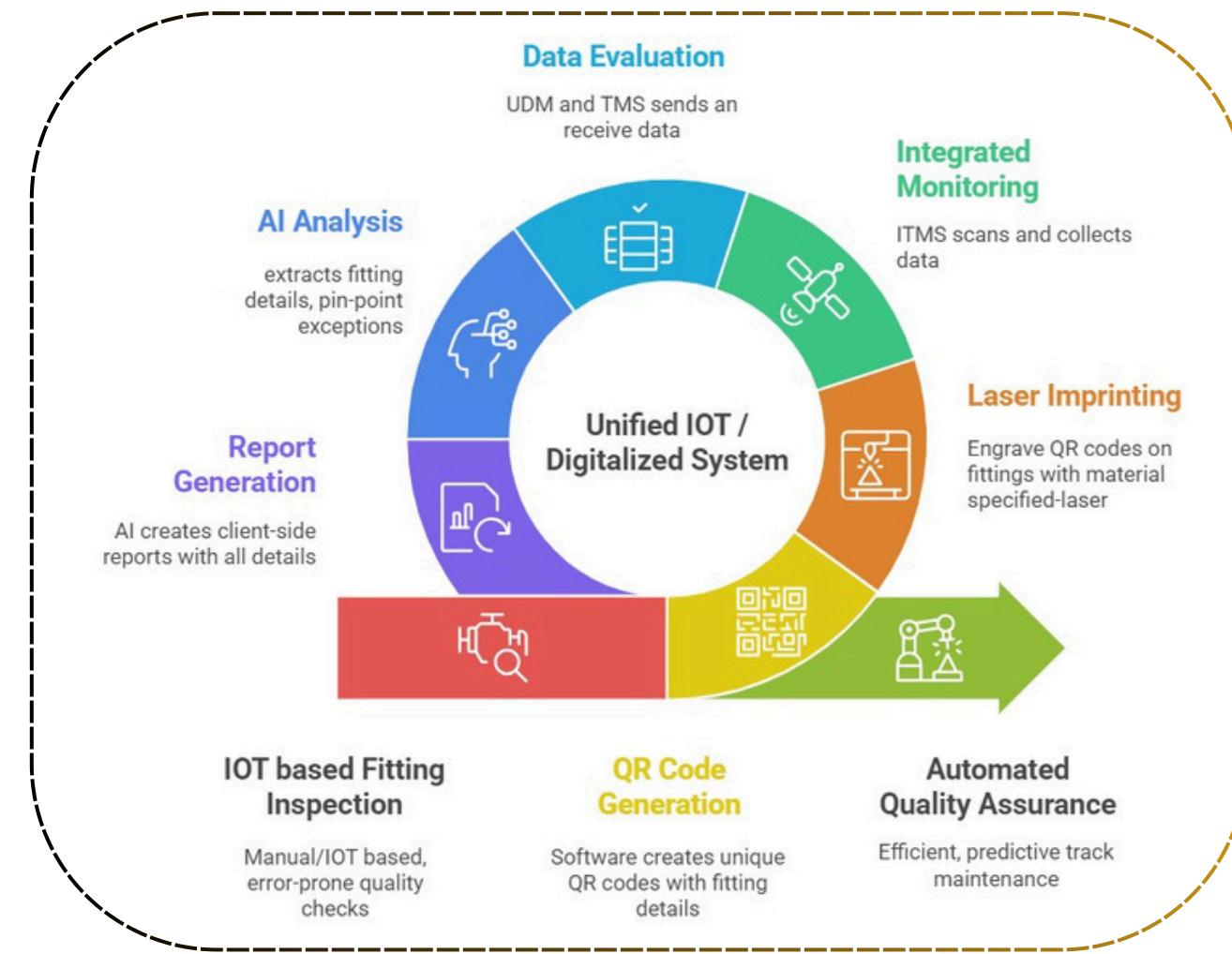
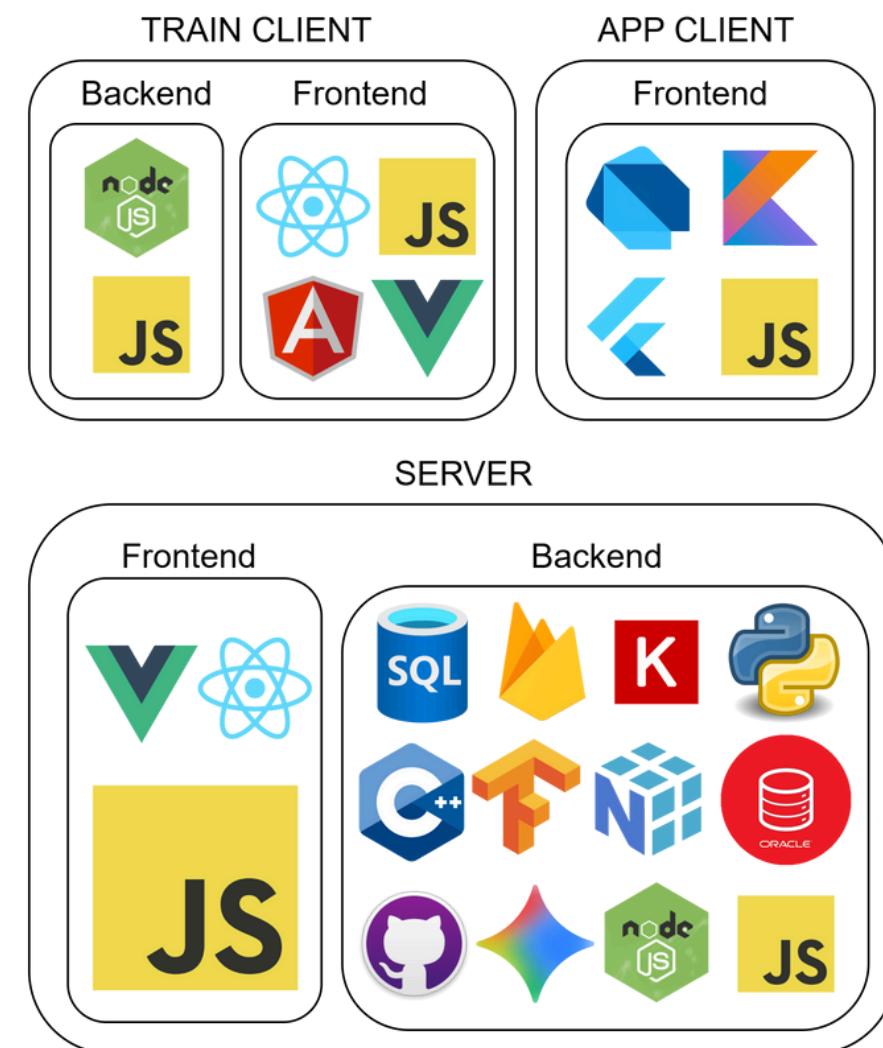
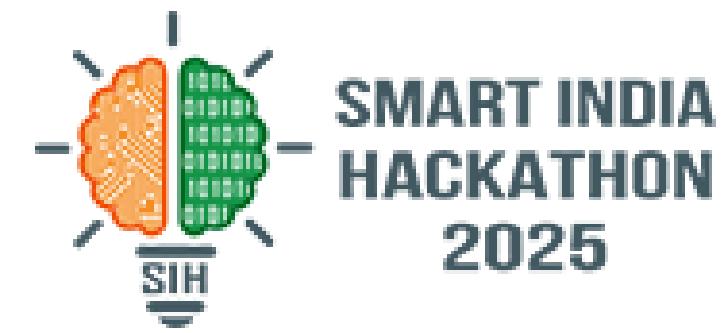
- Digital Twin & AI model - CRIS/CLOUD
- AI reports client (TMS Nirakshan App)
- TMS & TRCs client (Auto-sync)
- Integration--TMS & UDM (Pravah API)
- RSA-secured authentic ID Logins

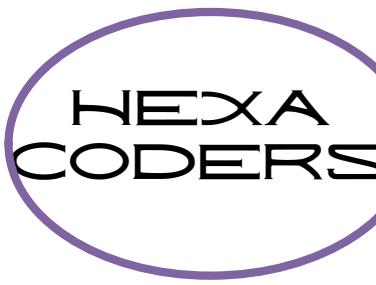
AI- Model

- YOLO-v8 with Multi-Modal capabilities
- Detection--wear-tear-age
- Comparative capabilities
- Predictive Reports

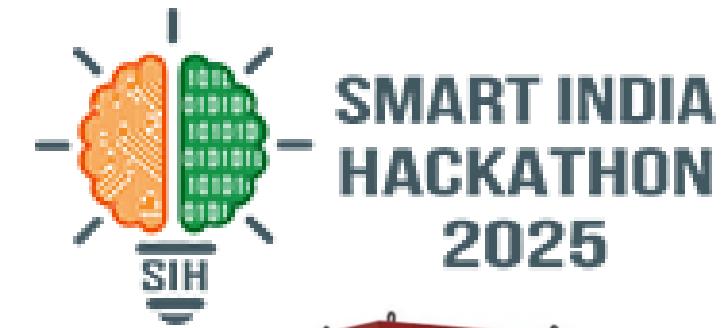


TECHNICAL APPROACH





FEASIBILITY AND VIABILITY



FEASIBILITY:

- **Diode & Fiber Laser:** Material-efficiency.
- **Dynamic-system:** Long term usability.
- **Cloud-synced:** Architecture with offline fallback
- **Full synced:** System ensures data continuity.
- **Durability:** QR codes engravement.
- **High Recovery:** QR-Codes (Level-H).



Viability:

- **High Annual Costs:** Massive ₹745 to ₹1,550 crores annually.
- **Targeted Savings:** Significant saving annually == ₹40~150cr
- **One-Time Investment:** Hex-Core system cost == ₹325cr ~ ₹670cr



Challenges:

- **Existing Inventory:** Not much info from Railway Dept.
- **Impractical:** QR being on Sleepers made of concrete
- **Digital Illiteracy:** Trackmen and most P-way Inspectors
- **Existing Methodology:** Overlapping technologies



Rail Fittings Cost Annually:

Rail Pads	=	10 ~ 20 x 8.5cr	=	₹ 85cr ~ ₹170cr
Elastic Rail Clip	=	50 ~ 90 x 10cr	=	₹ 500cr ~ ₹900cr
Rail Liners	=	20 ~ 60 x 8cr	=	₹ 160cr ~ ₹480cr
Total			=	₹ 745cr ~ ₹1550cr

One Time Costs:

Inventory Implementation	~	₹4.4 Cr - ₹15 Cr
Laser Implementation	~	₹15 Cr - ₹60 Cr
Hexa-Core System	~	₹20 Cr - ₹75 Cr >> Total Cost = ₹40~150cr

Savings

QR-Code-Warranty savings	=	745~1550 x 0.05	=	₹38cr ~ 78cr
Automated Inventory	=	745~1550 x 0.08	=	₹60cr ~ 124cr
Digital Twin Technology	=	745~1550 x 0.30	=	₹225cr ~ 465cr
Total Savings			=	325cr ~ ₹670cr = 20%~80% !!



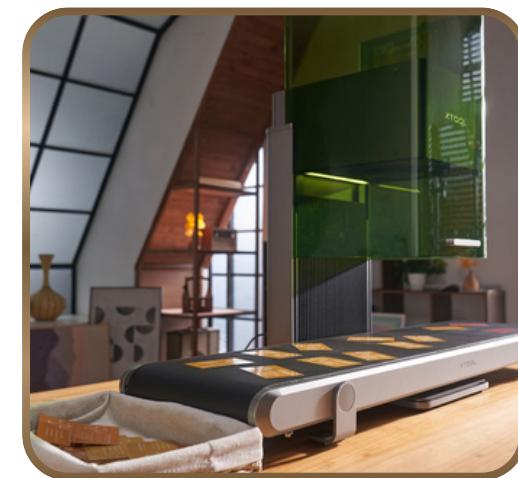
Solutions:

- **All-Rounder System:** Dynamic-Base for every case/issue
- **Alternate Methods:** like RFID tags and markings on Sleepers
- **User-Friendly UI:** Interactable Interface of clients & server
- **Sample Data:** During prototype showcase.



Use Cases:

- **Real - Time Track Inspection:** For every type of track fitting.
- **Automation:** It can automatically report to server & generate report.
- **Enhanced Inspection:** Inspection process with Digital Twin.
- **Digitalization:** Uses industry 4.0 technology for future ensurety.



**XTool F1 ULTRA with
Conveyor Belt**

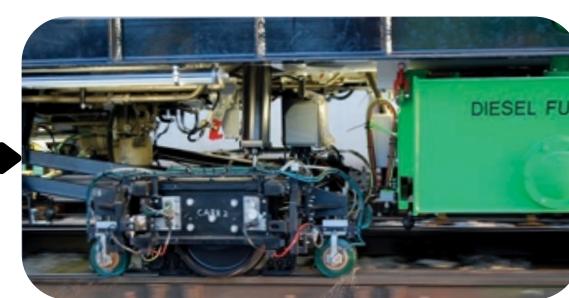
Defected Tracking Fittings



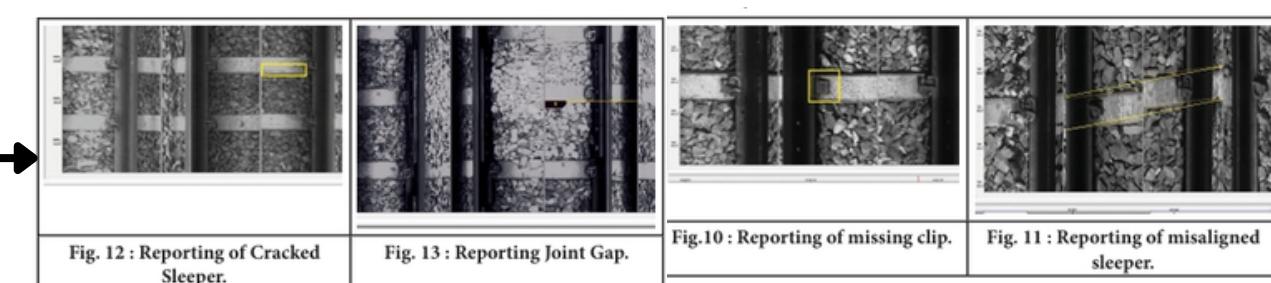
Track Recording Car (TRC)



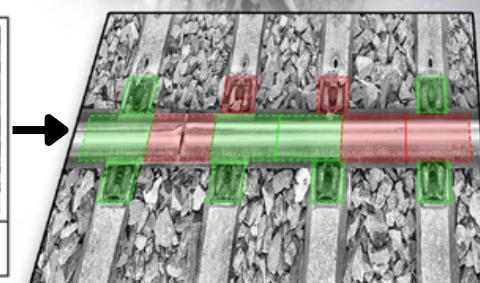
Ultrasonic probe wheel

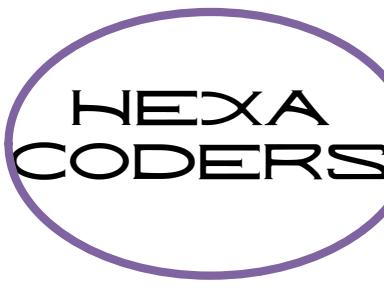


Monochrome-Camera Footage of Rail-Track

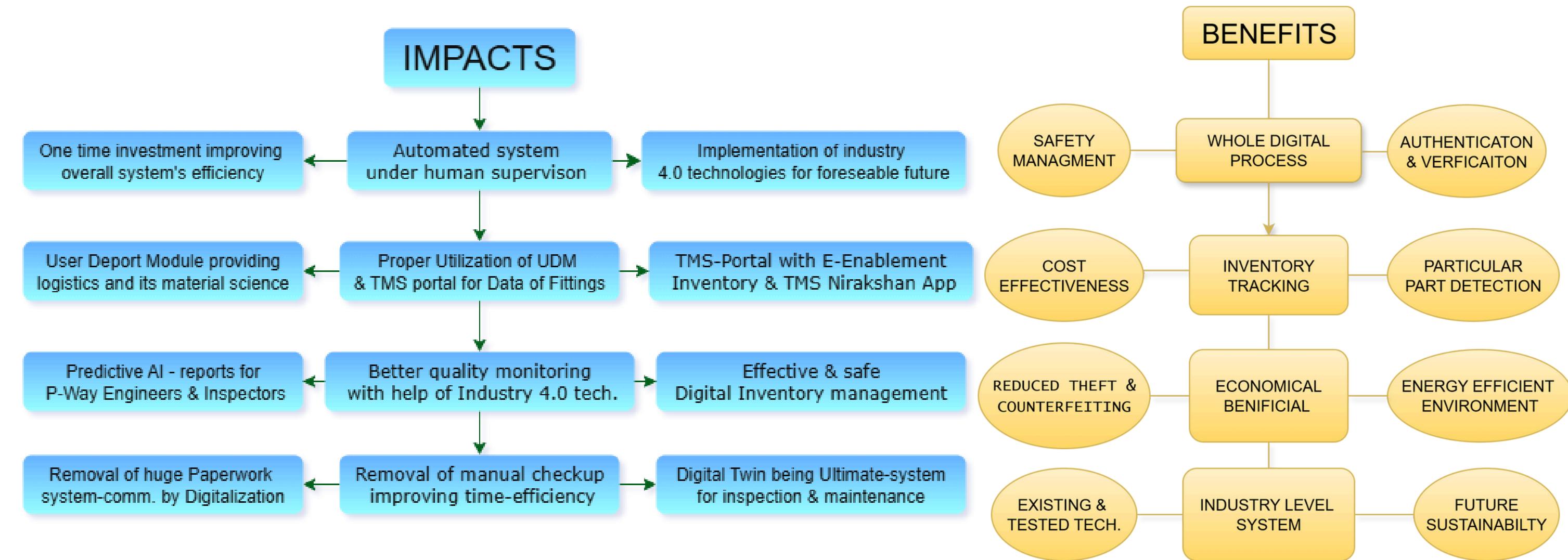
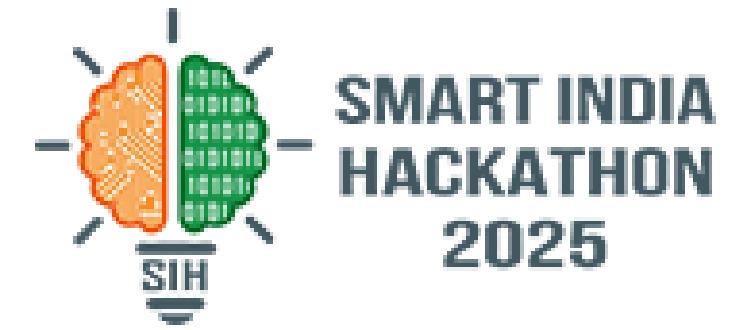


Digital Twin





IMPACT AND BENEFITS



Track Parameter Recording System



Acceleration Measurement Unit



LED Lights and Cameras



TMS Input Unit



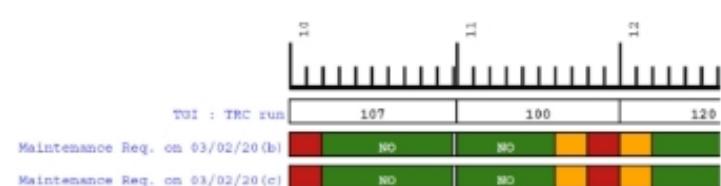
TMS Display unit



Track Diagram

Track Diagram is a pictorial depiction of track structure data such as Rails, Sleepers, Ballast, Fastenings, Bridges, Tunnels, Curves etc. Apart from track structure details, Track diagram also shows the following details which are critical for making any decision:

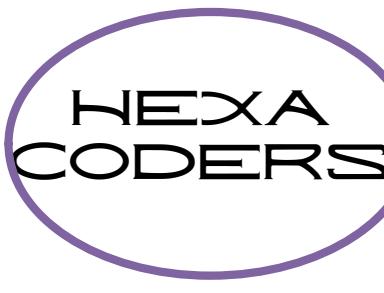
- PSR (Permanent Speed Restriction)
- Track Machine Deployment
- Fracture Details
- USFD (Ultrasonic Flaw Detection) defects
- Traffic Density (Yearly GMT)
- Track Geometry Index (TGI) as recorded by TRC Machines



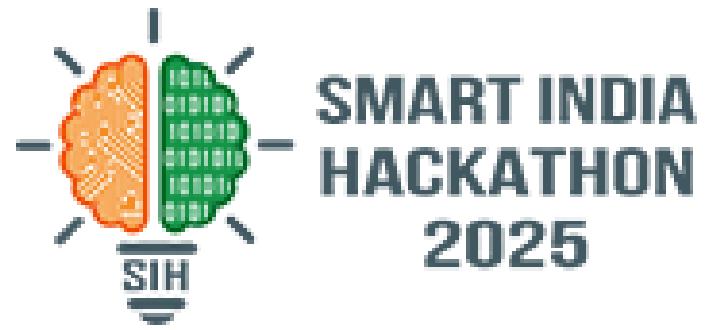
Fracture Analysis

Fracture analysis module is decision support related as it shows number of fractures based on various parameters. This gives immense flexibility to take decisions. Apart from this, facility has been provided to compare fracture results with previous dates so that historical analysis can also be done.





RESEARCH AND REFERENCES



Track Management System :

- TMS.irfa.com
- Track Management System.com
- Machine-based Vision Inspection System.com

Track Recording Cars :

- Track Recording Cars
- Multi-Functional Track Recording Cars.pdf

Integrated Track Monitoring System :

- Integrated Track Monitoring System.pdf
- Goldschmidt.com/en/portfolio/inspection.com

Material Science & equipment preference :

- Material Science of Laser Engraving Process.com
- Top.product.expert.in

User Depot Module :

- [User Depot Module\(UDM\)](http://User Depot Module(UDM))

AI (Multi-modal & YOLOv8):

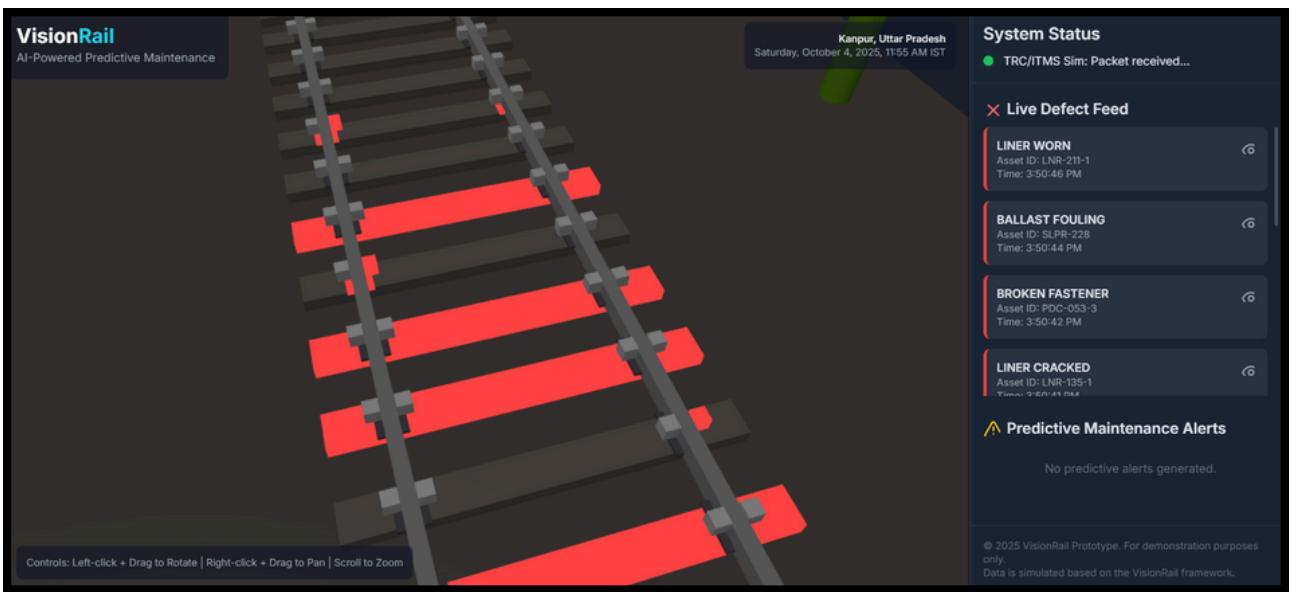
- Multimodal Machine Learning: A Survey and Taxonomy

Rolling Contact Fatigue:

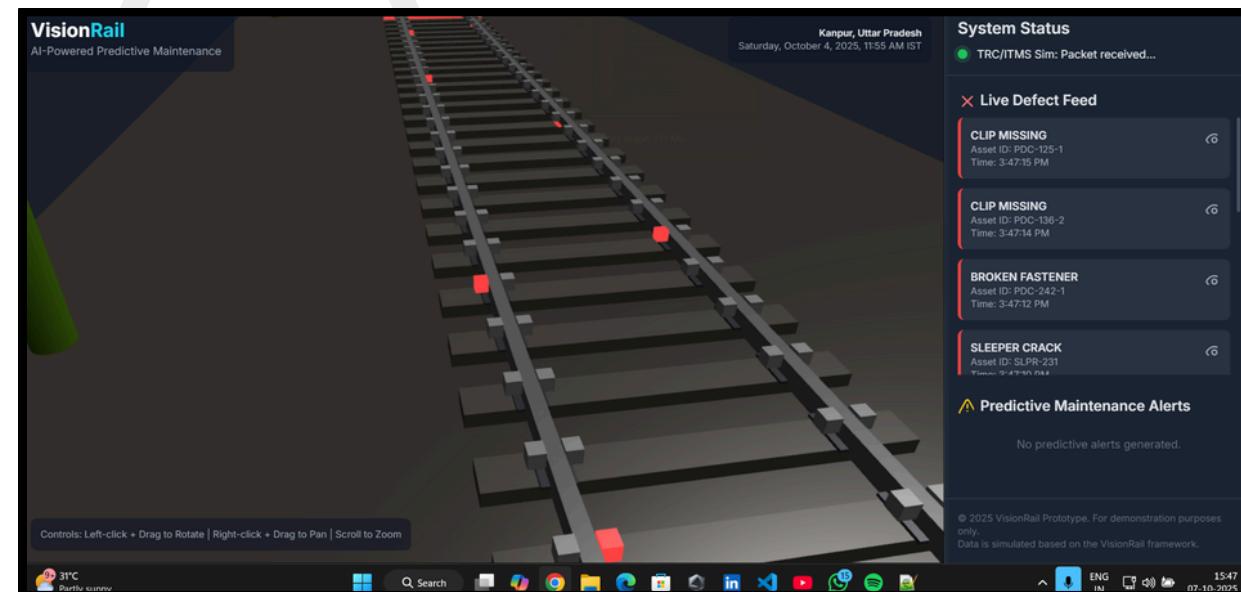
- RCF.gov.in



[Click Here To See Prototype \(GitHub\):](#)



Digital Twin - Rough Sketch



QR Code Generation

