IDEA

Innovations Deserving
Exploratory Analysis Programs

Transit IDEA Program

The Magnetic Rail Movement Measuring Device for Rail Safety

Final Report for
Transit IDEA Project 102

Prepared by:
Peter Bartek
PB Innovations

June 2024

NATIONAL ACADEMIES Sciences Engineering Medicine

TRB TRANSPORTATION RESEARCH BOARD

Innovations Deserving Exploratory Analysis (IDEA) Programs Managed by the Transportation Research Board

This IDEA project was funded by the Transit IDEA Program.

The TRB currently manages the following three IDEA programs:

- The NCHRP IDEA Program, which focuses on advances in the design, construction, and maintenance of highway systems, is funded by American Association of State Highway and Transportation Officials (AASHTO) as part of the National Cooperative Highway Research Program (NCHRP).
- The Rail Safety IDEA Program currently focuses on innovative approaches for improving railroad safety or performance. The program is currently funded by the Federal Railroad Administration (FRA). The program was previously jointly funded by the Federal Motor Carrier Safety Administration (FMCSA) and the FRA.
- The Transit IDEA Program, which supports development and testing of innovative concepts and methods for advancing transit practice, is funded by the Federal Transit Administration (FTA) as part of the Transit Cooperative Research Program (TCRP).

Management of the three IDEA programs is coordinated to promote the development and testing of innovative concepts, methods, and technologies.

For information on the IDEA programs, check the IDEA website (www.trb.org/idea). For questions, contact the IDEA programs office by telephone at (202) 334-3310.

IDEA Programs
Transportation Research Board
500 Fifth Street, NW
Washington, DC 20001

TRANSIT IDEA PROGRAM COMMITTEE

CHAIR
SANTOSH MISHRA
Flexlynqs, LLC

MEMBERS
MELVIN CLARK
HATCH LTK
LAUREN COCHRON SCOVILLE
Proterra Inc.
DREW DARA-ABRAMS
Interline Technologies LLC
SUZIE EDRINGTON
Texas Transportation Institute
AL MARTINEZ
Los Angeles County Metropolitan Transportation Authority
LOUIS SANDERS
Ayers Electronic Systems
MANJIT SOOCH
Alameda-Contra Costa Transit District
JASON STARR
Via Transportation
DAVID THURSTON
Canadian Pacific Railway

FTA LIAISON
RIK OPSTELTEN
Federal Transit Administration

APTA LIAISON
BRIAN ALBERTS
American Public Transportation Association

TRB LIAISON
CLAIRE RANDALL
Transportation Research Board

IDEA PROGRAMS STAFF
MONIQUE EVANS, *Director, Cooperative Research Programs*
GWEN CHISHOLM-SMITH, *Manager, TCRP*
INAM JAWED, *Senior Program Officer*

EXPERT ADVISORY PANEL
LOU SANDERS, *Ayers Electronic Systems*
DAVID THURSTON, *Canadian Pacific Railway*
DAVID STUMP, *Southeastern Pennsylvania Transit Authority*
MICHAEL SHENK, *Maryland Department of Transportation*
MICHEL DAVIS, *WSP*
BRIAN POSTON, *WSP*
MATT ALBANESE, *Metro-North*

The Magnetic Rail Movement Measuring Device for Rail Safety

Transit IDEA Program Final Report

IDEA Project T-102

Prepared for

The Transit IDEA Program
Transportation Research Board
National Academies of Sciences, Engineering, and Medicine

by

Peter M. Bartek

PB Innovations

June 30, 2024

Table of Contents

Acknowledgement

This research was supported by the Transportation Board (TRB), Federal Railroad Administration (FRA) and the Federal Transit Administration (FTA). Under the grant, the research was supported by BNSF, AMTRAK, MTA Maryland, MBTA, BART, SEPTA, Metro North, NYCT, LIRR, METRA, NJ Transit, WMATA and NS. We would also like to personally acknowledge John Paul Kupko (Amtrak), Eric Ptarcinski (LIRR), John Hasley (LIRR), Chris Schalik (LIRR), Dave Stolnis (Amtrak), Mike Davis (WSP), Brian Poston (WSP), Chad Scherwinski (BNSF), Christopher DelGallo (NS), Bradford Spencer (CSX), Joshua Marschki (CSX), Robert Fletcher (Rail Safety), David Stump (SEPTA), Douge Connect (MBTA), Matt Albanese (MBTA), William Pairman (BART), Marko Neskovic (METRA), Manny Rangel (METRA), Gary Devine (NJ Transit), Joe Fowler (WMATA), ED Berry (WMATA) for their key leadership role in supporting this project and endless work in testing, implementation, and research.

EXECUTIVE SUMMARY

Executive Summary

Over the years, major railways and transit agencies have heavily invested in programs to enhance the early detection of track movement and high rail temperatures. Extreme rail temperatures, lateral push, vertical pumping pose significant risks to railway infrastructure, leading to track misalignment, buckling, and kinking, which result in passenger and freight train delays, derailments, and costly repairs. Early detection of track shifts and temperature extremes is critical to mitigating these issues.

The economic impact of heat-induced delays in the U.S. ranges from $25 billion to $60 billion annually, according to the Transport Policy Journal. The Federal Railroad Administration (FRA) identifies extreme track movements and thermal buckling as a common cause of derailments in continuously welded rail (CWR), where extreme temperatures create compressive stresses leading to buckling. Over the past three years, the U.S. has recorded over 5,977 rail accidents, many linked to thermal buckling, necessitating extensive repairs.

To address this challenge, innovative solutions are essential. Despite extensive research, dynamic load movement or predicting rail thermal buckling remains difficult due to its nonlinear nature and numerous contributing factors. The proposed portable Magnetic Rail Movement Measuring Device (MRMMD) offers a promising solution, enabling early detection and timely alerts to prevent track damage and costly repairs.

The MRMMD system introduces a novel method to measure true rail temperature, track bed temperature, ambient temperature, lateral and vertical movements, along with superelevation, in real-time using specialized sensors, including accelerometer, laser-based and temperature sensors (rail, track bed, and ambient). It features a cloud-based data communication system that relays the sensor data to a dashboard or smart devices, enabling real-time warnings and preventive actions before track damage and derailments occur. Currently, no such real-time method exists that allows key data points to be tracked based on actual dynamic loads and temperatures.

Magnetically attached to the rail, the MRMMD operates in several modes. In automatic mode, the unit enters sleep mode between train passes, and activates (Vibration Sensor) upon the approach of a train, measuring and recording horizontal rail push and vertical track pumping under load, superelevation, and rail temperature. The device retains maximum movement data and sends alerts when preset tolerances are reached, such as when rail temperature exceeds or falls below predetermined limits. The cloud-based data is accessible from any laptop, and the MRMMD is Bluetooth-compatible.

To demonstrate the system's feasibility, 20 prototypes of the MRMMD were developed and tested successfully in collaboration with key rail and transit agencies, including BNSF, AMTRAK, MTA Maryland, MBTA, BART, SEPTA, WMATA, Metro North, NYCT, LIRR, METRA, and NS. During feasibility testing we effectively were able to combine current visual inspection and static techniques with measurable methods, such as those of a track geometry vehicle, making our results verifiable with our Bluetooth and cloud connectivity.

The MRMMD (**Figure 1**) was developed through a federal grant from the Transportation Research Board (TRB), Federal Railroad Administration (FRA), and Federal Transit Administration (FTA). Development criteria included user-friendliness for track inspectors, portability, the ability to take measurements under dynamic load, cloud and Bluetooth connectivity, and obtaining FCC and EU certification. The device incorporates well-proven technologies, such as sensors and radio microprocessors, uniquely positioned to perform the required functions effectively.

Figure 1: MRMMD Device in Monitoring data from track to Smart Device to Cloud

IDEA PRODUCT

A new more effective approach for measuring and monitoring track stability and rail temperatures using the new MRMMD. Under this grant, we were able to have significant new findings by enhanced Data verification, the MRMMD allows track inspectors and track geometry car operators to verify their data with a measurable device under full dynamic loads, complementing existing practices and creating a new, improved practice of real-time data capture under dynamic loads as shown in **Figure 2.** The new technology gives real-time tracking of key data points which is a significant accomplishment, with the potential to change current practices to best practices and enhance understanding of track temperature and track data over time. Technological integration, by integrating cloud-based communication, Bluetooth compatibility, and advanced sensors, the MRMMD system sets a new standard for railway track monitoring, enabling proactive maintenance and reducing the risk of rail-related accidents.

The MRMMD represents a significant advancement in railway safety and maintenance, providing a robust tool for early detection and prevention of track issues, ultimately enhancing the reliability and safety of rail transport.

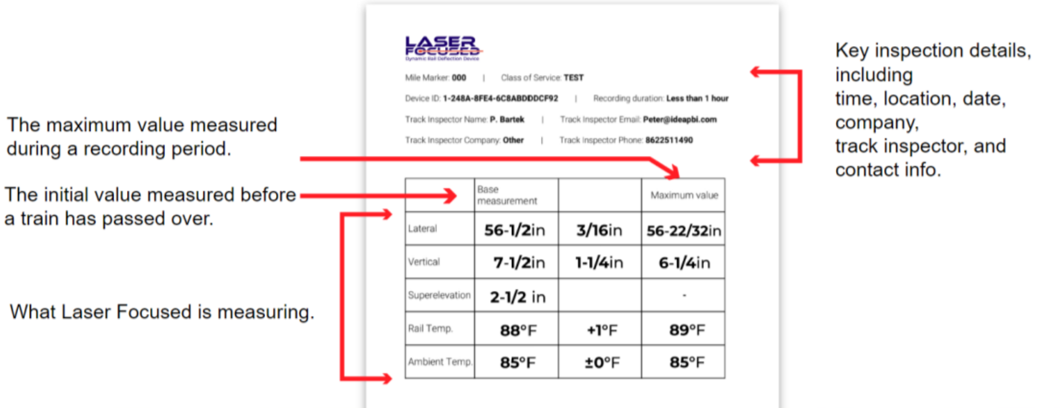


Figure 2: Real-Time Reports.

CONCEPT AND INNOVATION

What made the MRMMD so effective was how our team incorporated an array of sensors integrated into the main microprocessor and subsequently relayed to the radio chip for transmission to cloud storage or Bluetooth-enabled devices. Our approach involves employing two types of laser sensing technologies. Time-of-flight (ToF) sensors accurately measure the round-trip time of laser pulses to and from objects, ensuring precise assessment of lateral push and vertical pumping. Additionally, Triangulation-based laser sensors leverage triangle geometry to deliver precise measurements of cross-level and superelevation. The device has both a rail temperature sensor which is specifically designed to measure the temperature of a solid surface and a track bed sensor that measures moving air 6 inches from the track bed. Together with all the sensors, we can additionally bring data from the National Weather Station of actual ambient temperature. With two temperature sensors, one come into direct contact with the rail surface and the other sensor is set within 6 inches of the track bed. A significant breakthrough was our track bed temperature sensor, which is a device designed to measure the surrounding temperature of its environment near the track level surfaces. Another significant advantage that is a first is also knowing key track data such as GPS location, type of track, is the track ballasted, direct fixation or open deck, etc. Also, the type of fastening being used such as concrete, wooden, plate type, cut spike plate, fastener, rail size, class of service, tangent or curve, rail neutral temperature and date track was installed. No system offers such a detailed comprehensive approach.

MRMMD, detects and records the temperature of the rail and air in its immediate vicinity (track bed temperature). To ensure accurate angle and vibration detection we utilize a "G sensor" and “vibration sensor” that measures acceleration due to gravity, commonly known as "g-force." These sensors are also known as accelerometers and play a crucial role in enabling motion detection, orientation sensing, and acceleration measurement when a train or locomotive is passing. The system uses a miniature solar panel to generate electricity from sunlight and allow for dual power sources, leveraging lithium batteries for efficiency and lead-acid batteries for robustness in demanding environments of both hot temperatures and extreme cold temperatures. This hybrid setup ensures a reliable energy supply across diverse conditions. Our microprocessor is a central processing unit (CPU) contained on a single integrated circuit (IC) or chip. It serves as the brain of a digital device, executing instructions and performing calculations to carry out various tasks (what is measured) as shown in **Figure 3.** We utilize Bluetooth Low Energy (BLE) chip for wireless communication designed for short-range between devices and smartphones. It consumes significantly less power compared to classic Bluetooth, making it ideal for applications where power efficiency is crucial. The BLE allows devices to exchange data over short distances, typically within a range of up to 100 feet. Within our Cloud radio chip, we focused on 6 different areas, Data Collection, Data Transmission to the Cloud, Data Storage and Processing, Dashboard Creation, Data Visualization and User Access.

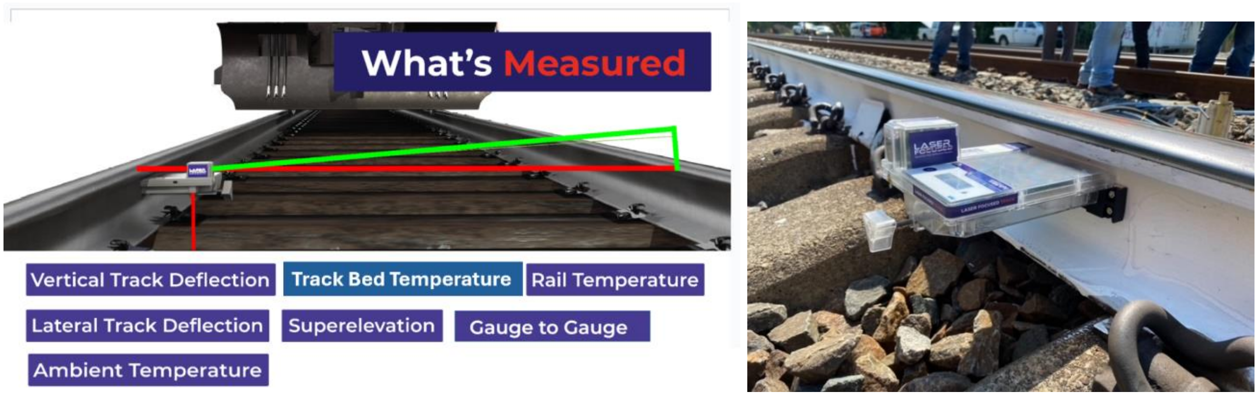


Figure 3: Showing the Laser Measure Device Sensors that measure lateral, vertical, cross-level, super elevation, track bed and rail temperature.

INVESTIGATION

The main objective of this grant is to develop an innovative portable dynamic load measurement device that integrates multiple advanced sensors to enhance track inspection capabilities. Under this grant, our goal was to develop a device that will verify track geometry reports and continuously monitor critical data points between geometry car runs. To facilitate real-time identification of hot spots and anomalies under full dynamic loads, streamline inspection processes, and provide real-time monitoring of rail and track bed temperature with alarms based on predefined thresholds. Our goal was to leverage predictive analytics and integrate NOAA weather data, to effectively track rail temperature fluctuations across extensive rail networks, contributing to improved maintenance and safety measures. Our key objective was to develop a technology that allows verification of current dynamic methods such as a track geometry car. Also to allow current visual and static methods to be replaced with the more accurate method of using the MRMMD dynamic method, as shown in **Figure 4**, to allow my dynamic to dynamic measurements and significantly improve current inspection and temperature monitoring methods.

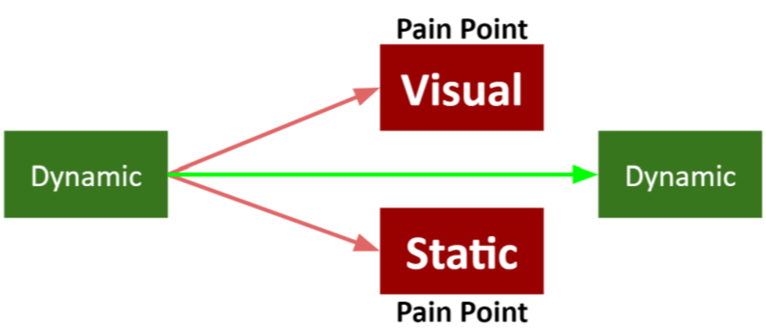


Figure 4: Key Objective is Dynamic to Dynamic

To understand the significance of the new MRMMD, and the critical role of dynamic load data in rail inspection and rail temperature monitoring, our investigation examined the three main methods currently used for track inspection—visual, static, and dynamic—and how track movement and rail temperatures are currently collected.

In visual track inspections, it is heavily based on a prescribed playbook dictating based on frequentcy. However, this system is fraught with unreliability. External factors like severe weather conditions or seismic events constantly disrupt the planned inspections, necessitating adjustments on the fly. Moreover, inspectors must rely on their visual acuity to detect anomalies such as mud spots, fastener changes, or tie movement, gauging the extent of track displacement. This visual inspection method, while essential, is inherently subjective, dependent on the individual inspector's judgment, making it prone to errors and oversights.

The track inspector will also watch when trains pass by. During these moments, they observe how the ties react, noting any signs of pumping or pushing. However, determining these extremes relies heavily on the inspector's judgment as shown in **Figure 5.** Despite this critical aspect of their job being primarily visual, this adds a high degree of unreliability. The inspector must interpret subtle visual cues to gauge the severity of issues, making the assessment subjective and prone to error.

Figure 5: Track Inspector inspecting key problem areas such as Mud Spots and signs of pumping

When it comes to static devices, there are a few static devices inspectors use for determining pumping, gauge, and cross level measurements, but these devices are static measuring devices and can't measure under a train's dynamic load. For pumping as an example, track inspectors may use a static stick ruler to assess pumping issues along the track. When evaluating gauge and cross level, inspectors utilize static track gauges or static roller-based system. The drawback of static tools lies in their cumbersome setup, time-consuming assembly, fouling time required on track and demand for frequent calibration for accurate readings. Consequently, inspectors may be reluctant to utilize these devices due to their inconvenience and safety concerns, especially as they place inspectors in the midst of the right-of-way. Moreover, their metallic construction necessitates caution in electrified areas, mainly third rail territories. Most critically, static tools only furnish static measurements, lacking dynamic or load-based assessments. Although they can be useful, they fail to assess accurate rail pumping or pushing data, rendering them insufficient and lacking comprehensive track inspection as shown in **Figure 6**.

In the realm of track maintenance, a good example of the pivotal goal for track inspectors is to limit track pumping within the confines of one and a half inches "1 ½" across different properties. Surpassing this threshold serves as an early indicator of potential rail fatigue, where the undue movement resulting from shifting ties and rails accelerates fatigue propagation along the rail itself. This acceleration precipitates the emergence of head defects and exacerbates tie crushing. So track pumping becomes a catalyst for future fatigue progression over time, thereby amplifying rail defects and elevating the risk of derailments. Furthermore, track inspectors confront additional risks associated with track 'hotspots'—localized zones of track instability arising from diverse factors including mud spots, tie displacement, fastener misalignment, temperature changes, and seasonal ground thawing/freezing cycles. The nature of these hotspots means that they can undergo significant movement upon the passage of trains. Consequently, it becomes imperative for inspectors not only to swiftly detect and quantify these changes but also to implement timely interventions to mitigate potential risks with the right technology.

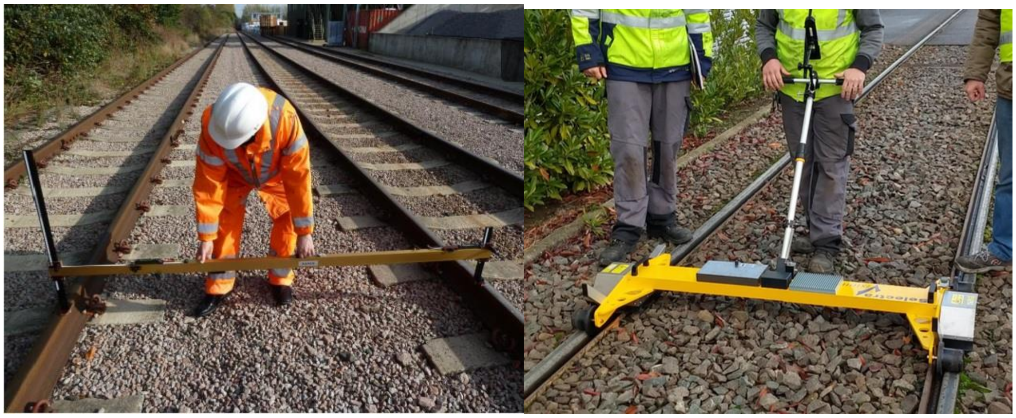


Figure 6: Useful Static tools track that inspectors but don't do dynamic loading

Dynamic load technology, in the realm of railway engineering, the evaluation of track geometry vehicles and other dynamic methods as shown in **Figure 7**. under dynamic conditions holds paramount importance for maintaining the integrity of rail corridors. Geometry cars, engineered to operate at speeds ranging from 30 to 150 mph in and out of revenue service, for passenger, transit and freight corridors, and play instrumental roles in quantifying the dynamic loads experienced by track infrastructure. Equipped with advanced sensor technology, these rolling stock units survey and report on track conditions over extensive territories, providing invaluable data to track inspectors in the form of a report.

However, as accurate as these geometry car reports produce hits (anomalies), these hits need to be verified. The challenge is that the traditional visual or static tools used by inspectors to validate these reports often yield less reliable and unofficial results, failing to accurately capture dynamic track behavior. While Railway properties, adhere to FRA and FTA regulations by conducting monthly to yearly geometry runs, this creates issues with data accuracy depending on visual inspection scheduling that can range from 1 month to 12 months depending on frequency of geometry car runs with the latest reports. This can make insights into track conditions inaccurate.

Despite the utility of track geometry cars in providing comprehensive reports, their high cost and operational limitations pose challenges. Procuring a track geometry car costs millions and scheduling or renting geometry vehicles for transit properties can be time-consuming and costly, with contracts for a one-time yearly geometry car inspection ranging from $500,000 to $1 million or more for a 3-to-5-year period. This leads to the reliance solely on track geometry vehicles for dynamic load testing and possibly outdated data reports, underscoring the need for complementary dynamic inspection device such as the laser measurement device.

With geometry report in hand, track inspectors focus on areas that show the highest changes in data. As an example, A two-class of service drop from the report, would be an indication of a potential problem. So, if the geometry report shows that your Class 4 track service is now a Class 2 service, based on the FRA requirements, this would become a priority for the track inspector to visit and identify the defect and its severity.

The second way geometry reports are used for defects is by visual inspection. Tack inspectors will prioritize the report and walk a section of track twice a week, eight times a month. Track inspectors are your eyes and ears on the right of way, so it's essential that the track inspectors have the right tools to identify these defects shown in the report and the severity that's being identified from the geometry vehicle reports.

In addition to track geometry reports, visual inspections serve as vital means of identifying defects and anomalies along railway tracks. Track inspectors, serving as the eyes and ears on the right-of-way, conduct regular inspections to ensure the safety and integrity of the railway network. If they are equipped with the right tools and training, inspectors can effectively identify and assess defects identified in track geometry reports, further enhancing the reliability of track inspection practices. Unfortunately, today's static tools don't allow this reliability.

Another device used to measure dynamic loads is a technology called Portable Track Loading Fixture (PTLF) where you hook this device up to both web rails of both rails and you pump it up to 3000/4000 pounds to put lateral forces on the rail. This device is very heavy, weighing between 40 and 50 lbs., and you're required to be in the right of way when used. Portability from location to location is difficult, track time from the dispatcher is required and revenue trains do not pass over the device.

A final method used to measure dynamic loads; specifically lateral push is the Gauge Restraint Measurement System (GRMS) integrated within a track structure assessment vehicle. This system, featuring a hydraulically actuated split axle design, applies dynamic forces onto the track to assess the lateral resistance of wooden ties. Operational constraints limit the GRMS vehicle to speeds of approximately 30 mph, and its use is confined to non-revenue service hours, predominantly at night. Consequently, the practical application of this valuable diagnostic tool is hindered by scheduling challenges. Moreover, the GRMS deployment is limited to wood ties only. The GRMS importance is due to the inability of standard track geometry with lighter mass cars to replicate the substantial forces exerted by fully laden passenger trains like the AMTRAK Acela and another area were the laser measurement device fills a major role.

Figure 7: Dynamic tools used today, PTLF, GRMS and Geometry Car

During hotter summer months, temperatures soaring above 95 degrees Fahrenheit pose significant challenges for railways, leading to issues like rail buckling and kinking. When the mercury climbs to this level, major players like Class 1 railroads, Passenger Transit, and Transit Agencies mobilize substantial teams to meticulously inspect rails for heat-induced deformities, ensuring the safety of train operations remains paramount. The primary objective is to mitigate the risk of heat-related derailments as shown in **Figure 8**. Although handheld infrared thermometers have been a common tool for these inspections in the past, many agencies have discovered their unreliability. To prevent buckling-induced derailments, numerous railroads have implemented precautionary measures such as imposing speed restrictions when daily trail temperatures surpass a specific threshold. However, this approach doesn't comprehensively address all potential buckling hazards. Conversely, excessive speed restrictions incur significant financial losses for the railroad industry annually.

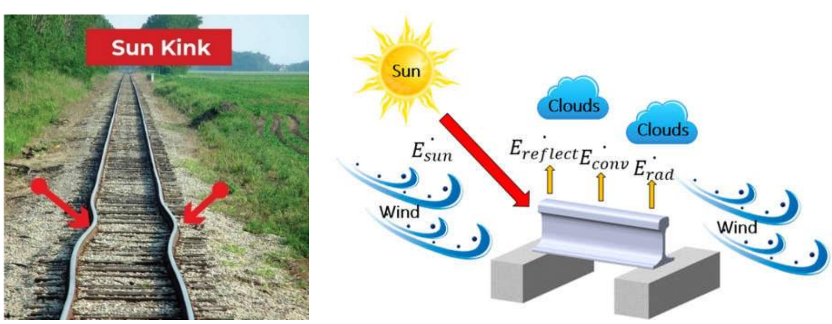


Figure 8: Typical Sun Kink in rails created by excessive hear and track stability.

PAYOFF

With the MRMMD, track inspectors can now take visual and static inspection methods and make them dynamically measurable. The MRMMD can take dynamic measurable devices such as track geometry vehicles and make them dynamically verifiable. With MRMMD, the track inspector will be able to accurately measure vertical pumping, lateral pushing, cross-level, and superelevation under dynamic loads from any revenue service train. By simply installing and turning on the device within seconds and wait for the train, the device does the rest. As the device is recording, you can see lateral, vertical, superelevation, temperature, track bed temperature in real-time as the train is passing. Once the train has passed the device, generates a live report showing location, data max, and min data within seconds. The MRMMD automatically compares the data against the current FRA or FTA standards. You can now send the report in real time to your supervisor. An additional feature is if you have cloud connection, the data can now be viewed on the dashboard from any location. The device can be removed within seconds and placed with seconds at the next reported hot spot identified that needs to be checked or verified, it's that simple. **Figure 9** shows the data you can verify dynamically which was only possible statically.

Agency Name	Green	Yellow	Y Mitigation	Red	R Mitigation	Black	B Mitigation
1. Cross-Level Pumping	Less or Equal 1"	Greater 1 Inch – 1 ½ Inch	Med	Greater 1 ½ Inch – 2 Inch	SLOW	Greater 2 Inch	OOS
2. Cross-Level Pumping	Less or Equal 2"	Greater or equal 3 "	24 insp./10-25 MPH	Greater or equal 3 ½"	24 insp./10-25 MP		
3. Cross-Level Pumping	1 ¼"	1 ¾"	31 to 60 MPH	2"	16 to 30 MPH	3"	15 to 0
4. Cross-Level Pumping	1 ¼"	1 ¾"	31 to 60 MPH	2"	16 to 30 MPH	3"	15 to 0

Class of Track	Guard Check Gauge	Guard Face Gauge
1	1375 mm (4'-6" 1/8")	1352 mm (4'-5" 1/4")
2	1378 mm (4'-6" 1/4")	1349 mm (4'-5" 1/8")
3/4	1381 mm (4'-6" 3/8")	1349 mm (4'-5" 1/8")
5/6	1384mm (4'-6" 1/2")	1346 mm (4'-5")

Exception Report
Exception List Section
Chain 0 to Chain 128

Page 2 of 14
2022-11-30
Run ID: 2022113001

CH 489.0 Cromwell Station to CH 124.4 Water View RD

CH	FT	Parameter	Value	Length	Speed	TSC	LC	PC	Level	Track	Peak Lat /	Long
475	80	Crosslevel	1.51	27	19	T	0	3	LEVEL2	2	39.174767	-76.635188
475	39	Crosslevel	1.15	5	19	T	0	3	LEVEL3	2	39.174861	-76.635267
474	92	Crosslevel	1.26	31	19	T	0	3	LEVEL3	2	39.174969	-76.635358

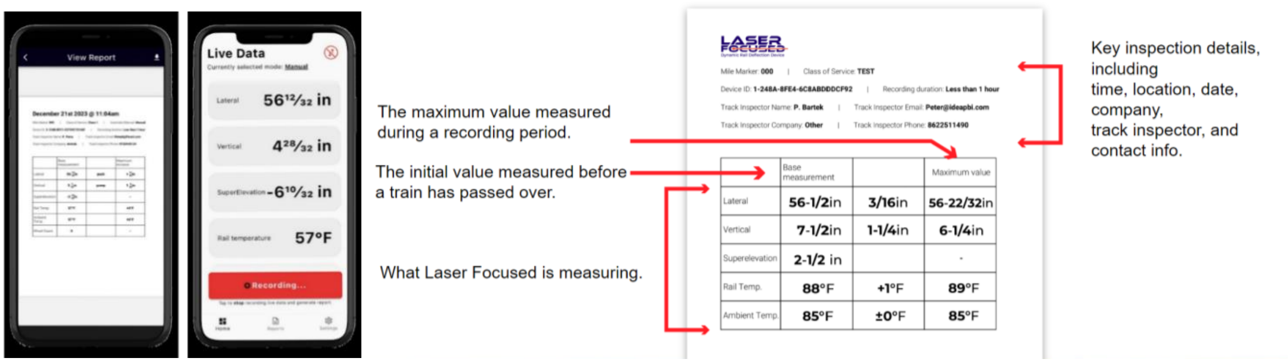


Figure 9: Generated reports from device and other methods.

Significant Payoff 1: Go from static devices and now measure under full dynamic loads. With the laser measurement device, a track inspector now has better choices in using the right tool for the right job or a toll to be used for verification. When needing to do measurements in the static mode throughout the railway network, the track inspector can use any static track gauges or static roller-based system and use our device for verification, but more importantly, the track inspector can simply install the device within seconds, adjust the sensors, simply wait for the train, record and watch the vertical pumping and lateral pushing in real-time data as the train is passing. The system generates a detailed report that can ensure the data at the location meets FRA or FTA standards.

Significant Payoff 1: Dynamic to Dynamic - Allows Track Geometry Measurable Data to be Verifiable and Current. A great advantage of using the laser measurement device is with the geometry car operation. When testing on the car is taking place, the geometry car runs into false positives. The geometry car stops, a geometry engineer gets out to try to find the anomaly with static devices in static not dynamic operation. With the laser measurement device, the geometry car can now use the device to verify false positives under dynamic loads shown in **Figure 10**.

An even bigger advantage to using the laser measurement device now allows inspectors can now stay current with geometry reports by prioritizing dynamic load testing in revenue service based on the actual reports and scheduling the highest priority to the lowest priority until the next geometry car run. By simply installing the laser measurement device which takes seconds, adjust the sensors, simply wait for the train, record the real-time data as the train is passing, which generates a detailed report that can ensure the data at the location meets FRA or FTA standards.

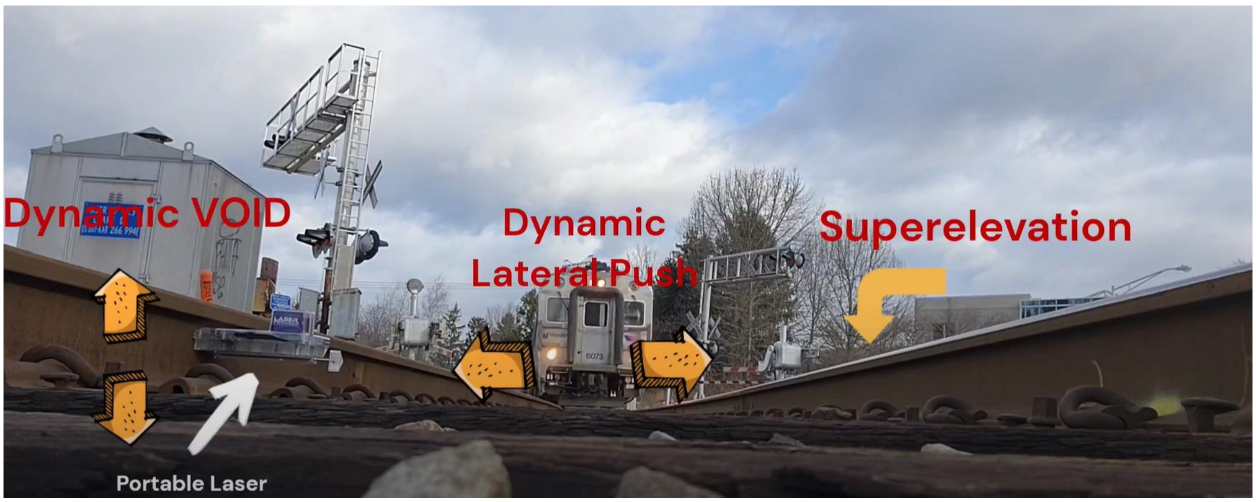


Figure 10: train passes over the device at full revenue speed as the device gathers data under full dynamic load.

Significant Payoff 3: Rail and Track bed Temperature Detection / Real-Time Monitoring and Cloud Connection. The device encompasses key features that can be used independently from the laser measurement device. During the grant process, AMTRAK, BART, MBTA and MTA Maryland requested that we add sensors for rail temperature, track bed temperature, real-time data to the cloud and predefined thresholds to trigger alarms. **Figure 11** shows the new dashboard that allows the data from each track device to transfer via cellular to any dashboard using program JSON and MQTT.

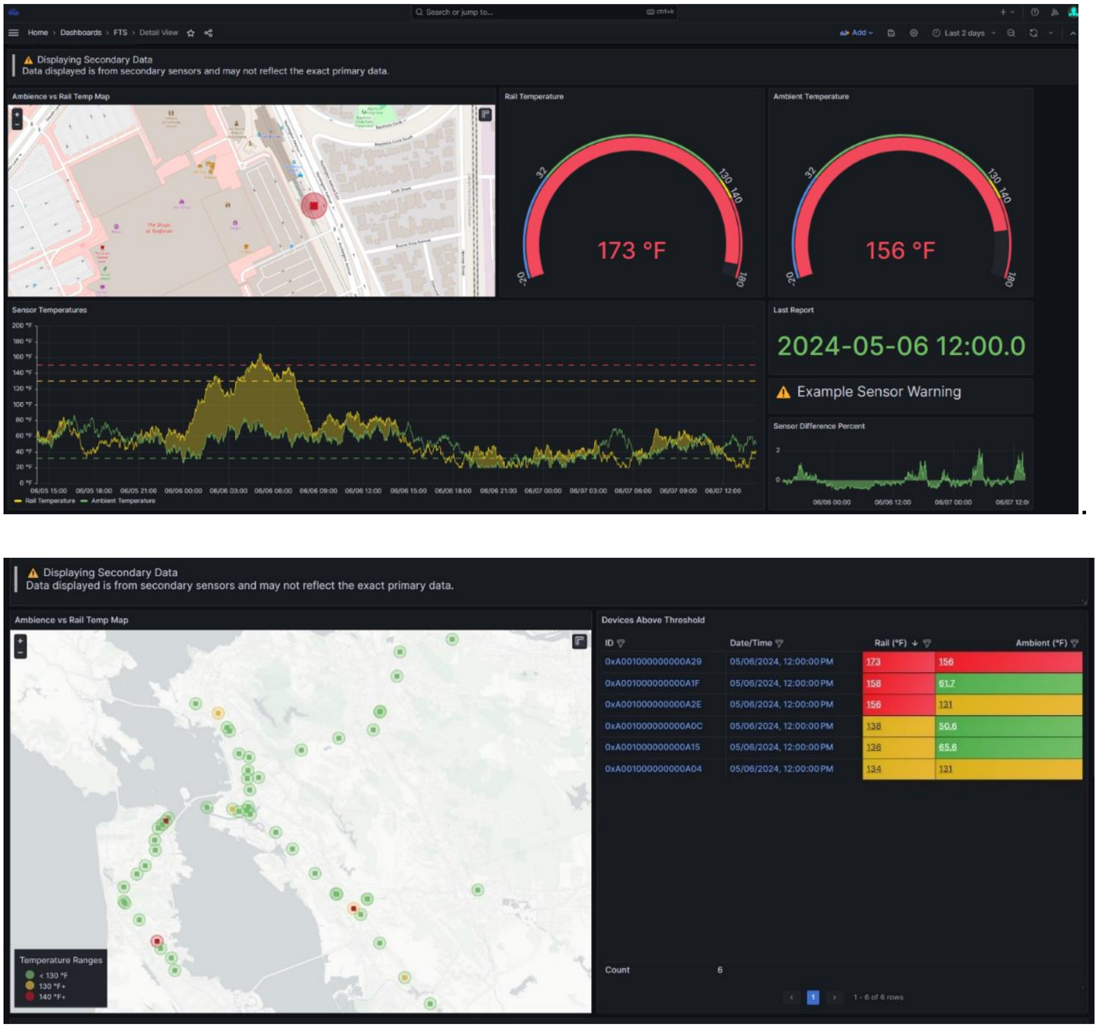


Figure 11: shows the new dashboard that allows the data from each track device to transfer via cellular

Our innovative temperature monitoring solutions, known as tempTrac. Simply affix the device to the rail's web, turn the unit on which goes automatically to our cloud connection, enabling continuous monitoring of both rail and track bed temperatures. With predefined thresholds to trigger alarms when temperatures reach critical levels, tempTrac contributes to predictive maintenance strategies by offering real-time analytics accessible from remote office dashboards as shown in **Figure 12**. This capability is essential for anticipating and mitigating temperature-induced track deformations, ensuring sustained operational safety and efficiency.

Figure 12: System being used for monitoring temperature and sending to a cloud-based system in real time.

PLANS FOR IMPLEMENTATION

This grant was instrumental in finalizing the development of 20 prototypes of the MRMMD. The device is now in full production with two different versions being offered. One being the full Magnetic Rail Movement Measurement Device which we now have renamed (Laser Focused Device for marketing purposes) and our Rail Temperature Monitoring System (which we call TEMP TRAC, for marketing purposes) as shown in **Figure 13**. We have received orders for some 200 units that we are now implementing at major Transit Agencies and Class Railroads. For heat watch purposes, we have started the installation of our TempTrac System for both BART in California and MBTA in Massachusetts. Further, we have received contracts with Metro North Railroad, Long Island Railroad, Alaska Railroad.

Figure 13: Laser Focused and Temp Trac Devices developed under this grant.

CONCLUSIONS

In the realm of rail inspection, the advent of the MRMMD marks a significant leap forward in addressing critical challenges inherent in traditional methods. The device's ability to provide real-time, accurate data under dynamic loads will be a paradigm shift for track inspection and temperature monitoring, offering a host of advantages over visual, static, and dynamic load measurement tools.

Visual inspections, while fundamental, suffer from subjectivity and lack of precision. Static tools, although useful, are cumbersome, time-consuming, and offer only static measurements. Some dynamic load measurement methods, such as those using technology like the Portable Track Loading Fixture face limitations in portability, scheduling, and operational constraints. Moreover, they fail to provide real-time data under full revenue service conditions. One benefit is how the Laser Measurement Device complements geometry car reports and the GRMS.

In contrast, the MRMMD, offers portability, real-time data collection, and seamless integration with smart devices or cloud platforms. Its ability to measure vertical rail pumping, lateral rail pushing, cross level, and rail temperature under full revenue service conditions empowers track inspectors with actionable insights, enabling them to identify anomalies swiftly and proactively address potential risks. By filling the gap in current inspection methods, the device enhances the efficiency, accuracy, and safety of rail inspection processes.

Furthermore, with the adoption of some 200 units of the MRMMD by industry leaders and its recognition through prestigious awards underscore its transformative impact on rail safety practices. By mitigating derailments, preventing rail kinks and buckling, and facilitating proactive maintenance, the Magnetic Rail Movement Measuring Device promises to substantially improve the safety and reliability of rail transportation networks, ushering in a new era of rail inspection technology.

INVESTIGATORS' PROFILES

Peter M. Bartek Sr., PB Innovations, LLC, President

- Holds over 44 patents in Rail & Transit and several in the subject matter
- Awarded three previous successful IDEA grants implemented in Transit practice today.
- Wharton Business School Executive Graduate

Mike S. Davis, WSP, Sr. Engineer

- Over 40 years' experience, expert in Maintenance of Way operational practice [MOW]
- Holds 4 patents in Rail and Transit

Brian Poston, WSP, Sr. Engineer

- Over 25 years of experience in track geometry and Maintenance of Way operational practice (MOW)
- Inspections and Track Production.

Peter J. Bartek Jr., FTS Tools LLC, Director of Business Development

- Over 7 years in Product Development
- FCC and EU Product Certifications
- Testing and Product Evaluations

<u>Industry key sponsors:</u>

Under the grant, the research was supported by BNSF, AMTRAK, MTA Maryland, MBTA, BART, SEPTA, Metro North, NYCT, LIRR, METRA, NJ Transit, WMATA and NS. We would also like to personally acknowledge John Paul Kupko (Amtrak), Eric Ptarcinski (LIRR), John Hasley (LIRR), Chris Schalik (LIRR), Dave Stolnis (Amtrak), Mike Davis (WSP), Brian Poston (WSP), Chad Scherwinski (BNSF), Christopher DelGallo (NS), Bradford Spencer (CSX), Joshua Marschki (CSX), Robert Fletcher (Rail Safety), David Stump (SEPTA), Douge Connect (MBTA), Matt Albanese (MBTA), William Pairman (BART), Marko Neskovic (METRA), Manny Rangel (METRA), Gary Devine (NJ Transit), Joe Fowler (WMATA), ED Berry (WMATA) for their key leadership role in supporting this project and endless work in testing, implementation, and research.

Expert Review Panel:

1. SEPTA – David Stump – Chief Engineer
2. M-DOT – Michael Shenk – Deputy Chief MOW
3. Michel S. Davis – WSP – Sr. Principle Technical Specialist
4. Brian Poston – WSP - Sr. Technical Specialist – Track Inspection, CWR, Geometry
5. Matt Albanese – Metro-North – Track Geometry and Track Inspection Expert

.

REFERENCES

Di H, Zhou S, Luo Z, He C, Xiao J, Li X (2018) A vehicle–track–tunnel–soil model for evaluating the dynamic response of a double-line metro tunnel in a poroelastic half-space. Comput Geotech 101:245–263

"Valuating the Effect of Rail Fastener Failure on Dynamic Responses of Train-Ballasted Track-Subgrade Coupling System for Smart Track Condition Assessment", Yuanjie Xiao, April 2022

"NTSB: 'Poor Track Conditions' Led to 2021 Empire Builder Derailment", Written by Marybeth Luczak, Executive Editor Railway Age

"Track Buckling Prevention: Theory, Safety Concepts, and Applications", Federal Railroad Administration, 2013

"NTSB Safety Alert Warns of Wheel Movement on Rail Transit Trains and Commuter Railroads", Safety Alert 083, December 2021

"RAILROAD SUPPLIERS PROVIDE WAYS TO PREVENT TRACK FROM BENDING AND TWISTING", *BY WALTER WEART, MARCH 2023, PROGRESSIVE RAILROADING*

"Analysis of lateral movement of railway track due to the passage of trains" Robert Konowrocki, Institute of Fundamental Technological Research, January 2009

"Railroads could see more sun kinks if climate change-related heat waves become more severe and more frequent", By: Bobby Magill, Scientific America, June 2014

"Railroads say they're making safety changes to reduce derailments after fiery Ohio crash", By Associated Press, Josh Funk, February 3, 2024

"Monitoring of the Static and Dynamic Displacements of Railway Bridges with the Use of Inertial Sensors", By: Piotr Olaszek, [1]Road and Bridge Research Institute, 03-302 Warsaw, Poland, May 2020

APPENDIX: RESEARCH RESULTS

Sidebar Info

Program Steering Committee: TRANSIT IDEA

July 1st, 2024:

The Magnetic Rail Movement Measuring Device for Rail Safety

Project Number: T-102
Start Date: May 09, 2023
Completion Date: July 1st, 2024

Product Category:

Principal Investigator: Peter Bartek, President PB Innovations (dba-JPPJ, LLC), peter@ideapbi.com, 862-251-1490

TITLE: Innovative Device Detect Monitor Rail Movement Early

SUBHEAD: Railways invested in early detection of track movement and high temperatures, introducing MRMMD for real-time monitoring to prevent issues.

1. WHAT WAS THE NEED?

Railway infrastructure, essential for efficient passenger and freight transportation, faces significant risks due to extreme rail temperatures and track movements. Historical data reveals that these conditions can lead to track misalignment, buckling, and breaking, resulting in train delays, derailments, and costly repairs. According to the Transport Policy Journal, heat-induced delays alone cost the U.S. economy between $25 billion and $60 billion annually. The Federal Railroad Administration (FRA) has identified thermal buckling as a prevalent cause of derailments, particularly in continuously welded rail (CWR), where extreme temperatures induce compressive stresses that lead to buckling. Over the past three years, the U.S. has recorded 5,977 rail accidents, many of which are linked to thermal buckling, necessitating extensive repairs.

Traditional methods of track inspection, such as visual inspections and static measuring devices, are fraught with limitations. Visual inspections are highly subjective and dependent on the inspector's judgment, leading to inconsistencies and potential oversights. Static devices, while useful for certain measurements, cannot capture the dynamic behavior of tracks under the load of passing trains. Additionally, the current methods fail to provide real-time data, which is crucial for timely intervention to prevent track failures.

The challenge of predicting rail thermal buckling is compounded by its nonlinear nature and numerous contributing factors. Despite extensive research, accurately forecasting when and where buckling will occur remains difficult. Existing technologies and methods do not adequately address the dynamic conditions under which track anomalies develop, and there is a clear need for a more effective solution.

The proposed Magnetic Rail Movement Measuring Device (MRMMD) was developed to address these gaps. This innovative device aims to enhance the early detection of track movements and high rail temperatures, providing real-time data and alerts to prevent track damage and costly repairs. By integrating advanced sensors and cloud-based communication, the MRMMD offers a comprehensive approach to track monitoring that current methods lack.

Federal mandates and safety regulations also underscore the necessity for improved track monitoring technologies. The FRA and the Federal Transit Administration (FTA) emphasize the importance of proactive maintenance and early detection of track issues to ensure the safety and reliability of rail transportation. The development of the MRMMD aligns with these regulatory requirements, aiming to provide a robust tool for track inspectors and railway maintenance teams.

In summary, the research was conducted to address the critical need for a reliable, real-time track monitoring system that can detect track movements and temperature extremes under dynamic conditions. The historical challenges associated with traditional inspection methods, the significant economic impact of rail accidents, and the regulatory mandates for enhanced safety measures justified the development of the MRMMD.

2. WHAT WAS OUR GOAL?

The primary goal of the research was to develop an innovative, portable device capable of real-time monitoring and measurement of rail movements and temperatures under dynamic conditions, enhancing the early detection and prevention of track issues to improve railway safety and maintenance.

3. WHAT DID WE DO?

The research and development process for the Magnetic Rail Movement Measuring Device (MRMMD) involved several key steps and collaborations with various organizations. The following activities were undertaken:

- **Prototype Development:** Twenty prototypes of the MRMMD were designed and built. These prototypes incorporated advanced sensors, including acceleration, laser-based, and temperature sensors, to measure rail temperature, track bed temperature, ambient temperature, lateral and vertical movements, and superelevation in real-time.
- **Collaboration:** The project involved collaboration with major rail and transit agencies such as BNSF, AMTRAK, MTA Maryland, MBTA, BART, SEPTA, WMATA, Metro North, NYCT, LIRR, METRA, and NS. These agencies played a crucial role in testing and validating the prototypes in real-world conditions.
- **Testing and Validation:** The prototypes were tested under various operational scenarios to evaluate their performance and reliability. The testing process included combining current visual inspection and static techniques with the MRMMD's dynamic measurement capabilities, ensuring the results were verifiable with Bluetooth and cloud connectivity.
- **Data Communication System:** A cloud-based data communication system was developed to relay sensor data to a dashboard or smart devices. This system allowed real-time warnings and preventive actions before track damage and derailments occurred. The data could be accessed from any laptop, and the MRMMD was made Bluetooth-compatible for ease of use.
- **Certification and Compliance:** The device was designed to be user-friendly for track inspectors and portable for easy deployment. It was also engineered to operate under dynamic loads, with cloud and Bluetooth connectivity. The device obtained FCC and EU certification to ensure compliance with regulatory standards.
- **Advanced Technologies:** The MRMMD employed well-proven technologies such as sensors and radio microprocessors. The device used laser sensing technologies (Time-of-Flight and Triangulation-based sensors) for precise measurements, as well as temperature sensors for accurate rail and track bed temperature readings.

- **Energy Solutions:** To ensure reliable operation in various environmental conditions, the MRMMD utilized a hybrid power setup with miniature solar panels, lithium batteries for efficiency, and lead-acid batteries for robustness and colder weather environments.

4. WHAT WAS THE OUTCOME?

The development and testing of the MRMMD led to several significant outcomes, demonstrating the feasibility and effectiveness of the device. The following points summarize the key outcomes:

- **Real-Time Data Collection:** The MRMMD provided real-time data on rail temperature, track bed temperature, lateral push, vertical pumping, cross-level, and superelevation under dynamic conditions. This capability addressed the need for timely and accurate detection of track anomalies.
- **Enhanced Track Inspection:** The device enabled track inspectors to verify geometry car reports dynamically, bridging the gap between static inspection methods and dynamic conditions. This improved the accuracy and reliability of track inspections, leading to more effective maintenance and safety measures.
- **Portable and User-Friendly:** The MRMMD's design emphasized portability and ease of use, allowing track inspectors to deploy the device quickly and efficiently. The Bluetooth compatibility and cloud-based data system facilitated seamless data access and sharing.
- **Proactive Maintenance:** By providing real-time warnings and alerts, the MRMMD allowed for proactive maintenance actions before track damage and derailments occurred. This preventive approach enhanced the safety and reliability of railway operations.
- **Technological Integration:** The integration of advanced sensors, cloud communication, and Bluetooth connectivity set a new standard for railway track monitoring. The device's ability to operate under dynamic loads and provide comprehensive data points marked a significant advancement in rail inspection technology.
- **Industry Adoption:** The successful testing and validation of the MRMMD prototypes led to its adoption by major rail and transit agencies. This adoption underscored the device's transformative potential in improving rail safety and maintenance practices.
- **Future Research and Development:** The project highlighted areas for future research, including the potential for further enhancing the device's capabilities and expanding its applications in different railway environments. The ongoing development aims to refine the MRMMD and explore additional features and functionalities.

5. WHAT IS THE BENEFIT?

The Magnetic Rail Movement Measuring Device (MRMMD) offers numerous benefits to the public, and other entities involved in railway operations. The following points outline the key benefits:

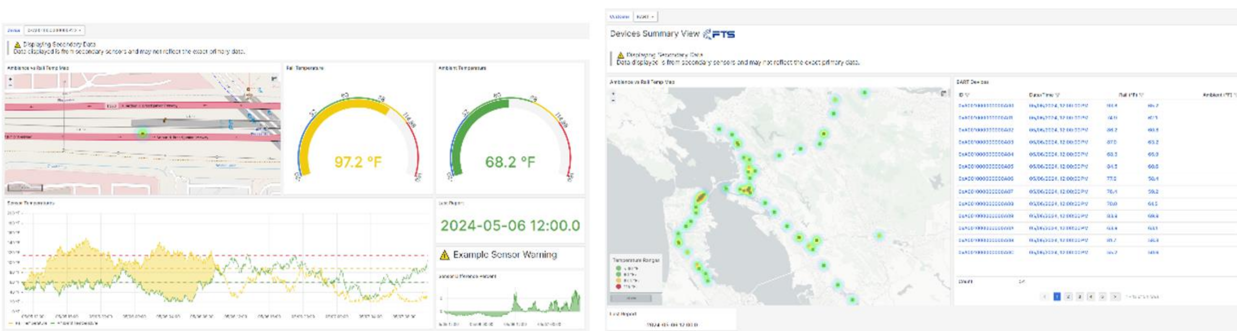
- **Improved Safety:** By providing real-time data and early detection of track anomalies, the MRMMD enhances the safety of railway operations. This reduces the risk of derailments and accidents, protecting passengers, freight, and infrastructure.
- **Cost Savings:** The device's proactive maintenance capabilities help prevent costly repairs and delays caused by track damage. The economic impact of heat-induced delays, estimated to cost the U.S. economy between $25 billion and $60 billion annually, can be significantly mitigated through early intervention and preventive measures enabled by the MRMMD.
- **Enhanced Efficiency:** The portability and ease of use of the MRMMD allow track inspectors to conduct more efficient and accurate inspections. This leads to better resource allocation and streamlined maintenance processes, ultimately improving the overall efficiency of railway operations.
- **Data-Driven Decision Making:** The real-time data provided by the MRMMD empowers railway operators to make informed decisions based on accurate and up-to-date information. This data-driven approach enhances the effectiveness of maintenance strategies and operational planning.

- **Technological Advancement:** The integration of advanced sensors, cloud communication, and Bluetooth connectivity represents a significant technological advancement in railway track monitoring. The MRMMD sets a new standard for the industry, promoting the adoption of innovative technologies for improved rail safety and maintenance.
- **Regulatory Compliance:** The MRMMD supports compliance with federal mandates and safety regulations established by the FRA and FTA. By providing accurate and reliable data, the device helps railway operators meet regulatory requirements and maintain high safety standards.
- **Broader Impact:** The benefits of the MRMMD extend beyond Caltrans and the public to include other entities such as state departments of transportation (DOTs), private and public sector rail operators, and transit agencies. The widespread adoption of the device can lead to a safer and more reliable railway network nationwide.

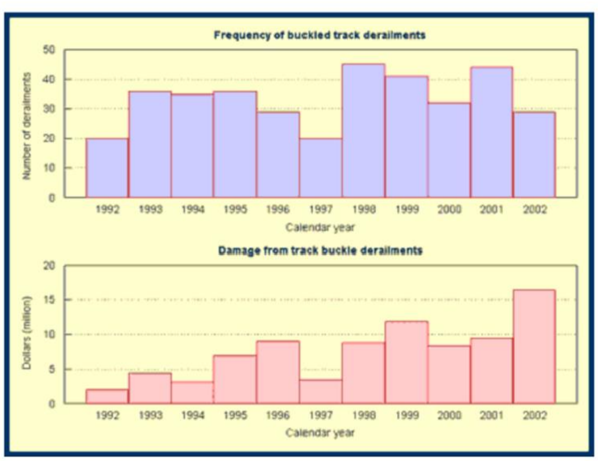
In conclusion, the Magnetic Rail Movement Measuring Device (MRMMD) represents a significant advancement in railway safety and maintenance. By addressing the critical need for real-time, accurate track monitoring under dynamic conditions, the device offers substantial benefits in terms of safety, cost savings, efficiency, and technological progress. The successful development and implementation of the MRMMD underscores its transformative potential in enhancing the reliability and safety of rail transport, ultimately benefiting the public and the broader railway industry.

LEARN MORE
Grant-Results@ftsrail.com

IMAGES



Dashboard data



Frequency and Damage from Track Buckling


Current Method of Temperature Thermostat

1.3 Installing CWR

The following procedures shall be used to establish the proper [DRNT or PRLT] while laying rail out-of-face, laying curve patch, or installing a long maintenance rail. These procedures do not apply to the installation of plug rails or short track panels. The amount of rail laid at any one time is not limited to any specific length; these procedures can be performed on rails as short as a few hundred feet or as long as 1600'. The maximum installation length is essentially limited by what could be reasonably expected to expand uniformly. Excessively long rails can have considerable resistance to longitudinal movement during installation which can inhibit proper rail expansion and result in not achieving a uniform [DRNT or PRLT].

Follow these procedures when installing CWR:

(a) Refer to the [DRNT or PRLT] for the geographical area of the installation.

(b) Ensure the rail is in a stress-free state as it is laid in the track.

(c) Measure the rail temperature (RT) at the center of the web on the shady side of the rail and determine if the current RT is within the [DRNT or PRLT] safe range.

(d) If installed correctly, the RNT is established, and is equal to the RT.

Key place to measurement temperature

Testing Device in White Rail Program

Device being tested in different Track Types

Testing at LIRR, NYCT, AMTRAK and BNSF

June 8th 2024 @ 11:46am

Latitude, Longitude: **37.97516, -122.02888**

Mile Marker: **Concord** | Class of Service: **Class 5** | Automatic/Manual: **Manual**

Device ID: **E-C1D1-2128-F500CEB83211** | Recording duration: **Less than 1 hour**

Track Inspector Name: **T. Account** | Track Inspector Email: **Apps+1@ideapbi.Com**

Track Inspector Company: **Amtrak** | Track Inspector Phone: **9738620129**

Was sun block used: **No**

	Base measurement		Maximum increase
Lateral	**48 $\frac{3}{4}$in**	**push**	**+0in**
Vertical	**2 $\frac{1}{8}$in**	**pump**	**$\frac{1}{8}$in**
Superelevation	**3 $\frac{1}{16}$in**		**-**
Rail Temp.	**120°F**		**+0°F**
Ambient Temp.	**104°F**		**+0°F**

Report from devcie in real-time

Awarded top Rail Award 2024

Going from 3D Printing

Meeting with FRA and FTA at ENSCO EVENT