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The Initiatives of its Technology Divisions 4

Preface
2 Message from Managing Editor

Articles
3 Maglev Systems Technology Division
9 Center for Railway Earthquake Engineering Research
15 Vehicle Technology Division

New Master Plan of RTRI
15 RTRI Develops New Master Plan RESEARCH 2030

International Activities
21 RTRI and DZSF Sign Comprehensive Agreement to Strengthen Railway Research Cooperation

Message from Managing Editor

Hisayo DOI
Managing Editor
General Manager (International Affairs),
Research & Development Promotion Division

The special series "The Initiatives of its Technology Divisions," which has presented the research highlights of RTRI's center and twenty research divisions since Ascent No. 13, concludes with this issue.

This edition features a broad spectrum of breakthroughs in railway technology—including state-of-the-art Maglev systems, superconducting power supply, enhanced earthquake resilience, vehicle safety innovations, and digital solutions to improve maintenance efficiency. Readers will discover the latest achievements driving railway innovation.

Additionally, we introduce "RESEARCH 2030," RTRI's new five-year master plan launched in April 2025, detailing our key initiatives for strengthening resilience to natural disasters, leveraging digital technologies, advancing decarbonization, and enhancing safety toward sustainable railway systems. The master plan also focuses on the promotion and expansion of joint research with overseas institutions; notably, in July, RTRI concluded a new cooperation agreement with a German research center for railways. Through these efforts, RTRI continues to advance its research and development activities.

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Front cover photo: Front yard of RTRI

The Maglev Systems Technology Division is committed to advancing fundamental research on superconducting magnetically levitated transport systems (hereinafter referred to as “superconducting Maglev systems”). Our mission extends beyond basic research; we are leveraging the findings and insights gained from a comprehensive series of research and development (R&D) efforts to enhance conventional railway systems. Our exploration of high-temperature superconductivity spans a considerable period, during which we have effectively integrated basic and applied R&D efforts. This integration has enabled us to refine core technologies and develop practical applications across various facets of conventional railway systems. Here, we present a selection of recent research projects undertaken by the Maglev Systems Technology Division.

Maglev Systems Technology Division

Dr. Masaru TOMITA
Director,
Head of Maglev Systems Technology Division

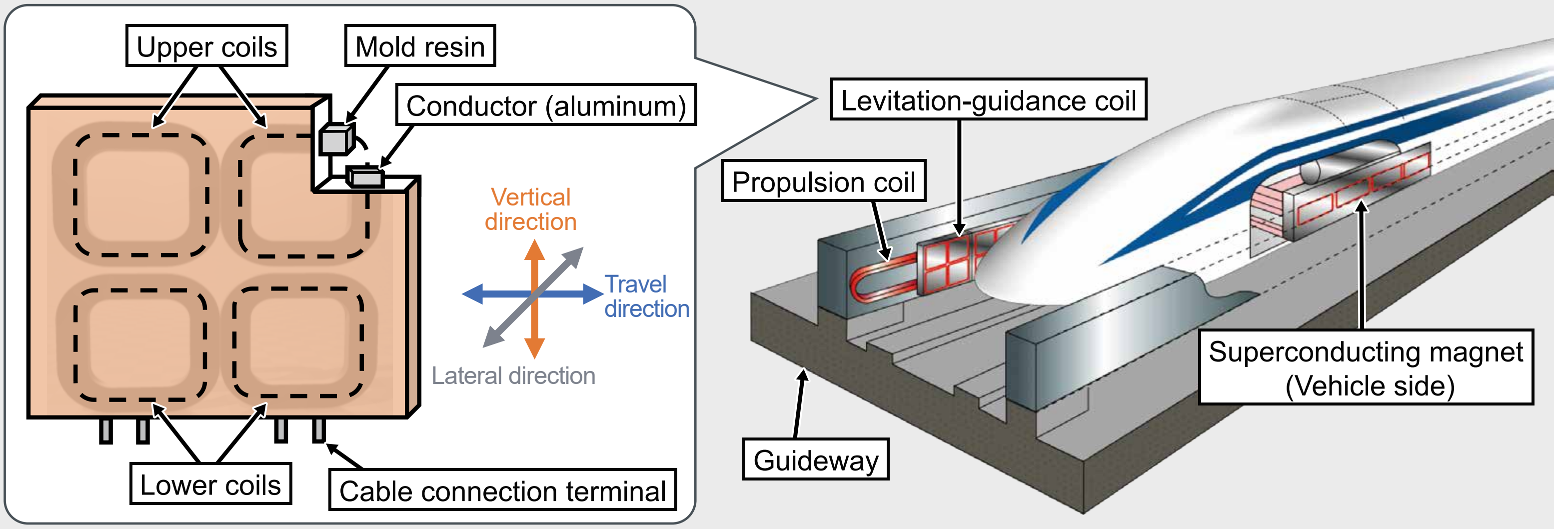
Introduction

The Maglev Systems Technology Division evaluates both the ground coils for superconducting Maglev systems and the magnetic fields associated with conventional railway systems. Our division has also dedicated significant resources to a diverse array of R&D projects focused on superconducting technology. Our foundational research focuses on the fabrication of high-temperature superconducting materials and assessing their performance. In applied research, we focus on enhancing winding and coiling technologies for superconducting materials. Additionally, we are advancing the development of integrated approaches combining superconducting technology with essential railway technologies such as power transmission, energy storage, and power converters. The Maglev Systems Technology Division has consistently devoted substantial resources to R&D aimed at the practical implementation of superconducting Maglev technology in real-world railway operations.

Maglev Railway System and Technology

Evaluation of Remaining Life of Ground Coils

Basic Configuration of Superconducting Maglev System and Structure of its Ground Coils shows the basic configuration of the superconducting Maglev system and



Basic Configuration of Superconducting Maglev System and Structure of its Ground Coils

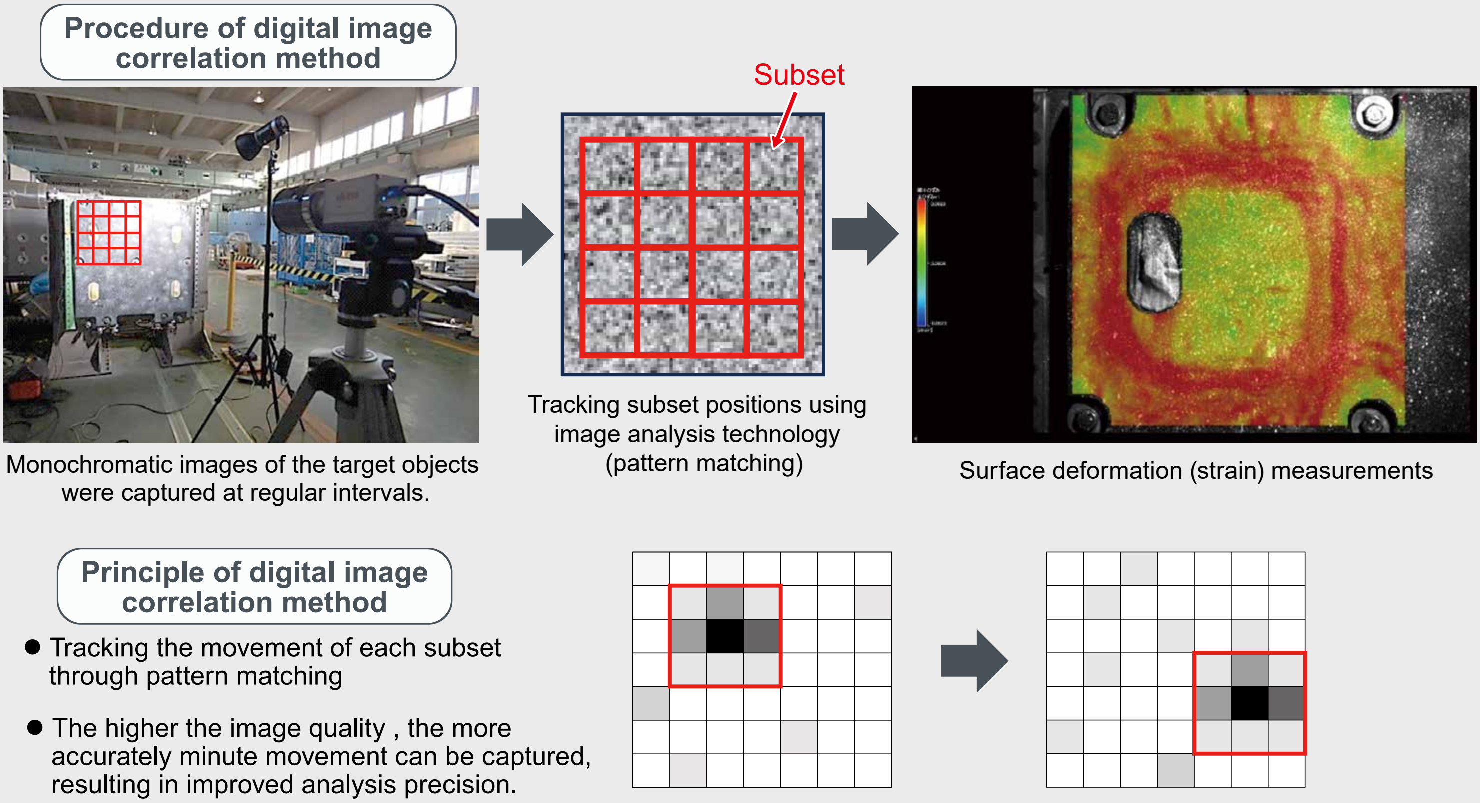
the basic structure of its ground coils. In superconducting Maglev systems, a large number of ground coils installed along the sidewalls of the guideway makes durability a critical factor. Consequently, we engaged in R&D aimed at evaluating the service life of ground coils. Ground coils are electromagnets responsible for generating propulsion, levitation, and guidance forces for vehicles and can be categorized into two types: propulsion coils and levitation-guidance coils. The levitation-guidance coils generate levitation and guidance forces through their interactions with superconducting magnets. During the operation of Maglev vehicles, these ground coils vibrate due to the reaction between the levitation and guidance forces. Therefore, the ground coils must have mechanical strength and dynamic durability against vibrations. To address this, we conducted electromagnetic excitation tests in a stationary setup using superconducting magnets and levitation-guidance coils. The results from our numerical analysis and the obtained vibration data confirmed that an electromagnetic force equivalent to that experienced at 500 km/h could be applied to the levitation-guidance coil. Looking ahead, we plan to conduct long-term electromagnetic excitation tests to assess the remaining service life against vibrations.

Image Processing Technology

To evaluate the mechanical strength of ground coils, it is essential to understand the strain induced by electromagnetic forces during vehicle passage and deformation from temperature rise in windings. Conventionally, strain gauges have been employed to measure strain; however, assessing strain distribution across the entire ground coil necessitates numerous sensors, complicating actual measurements. To overcome this problem, we examined the application of the digital image correlation (DIC) method, which analyzes deformation in images captured by cameras to measure strain. By pre-applying a random pattern to the ground coil surface and energizing the windings, we were able to by a observe the deformation caused temperature increase through image processing. This approach enabled us to measure the strain near the coil windings (*Strain Evaluation of Ground Coils Using Digital Image Correlation Method*). We plan to use this technique to further strength evaluations.

Evaluation of Low-Frequency Magnetic Fields in the Railway Environment

The evaluation of magnetic fields generated by superconducting magnets installed on the Maglev railway system began during running tests at the Miyazaki Test Center, a facility of the Railway Technical Research Institute (RTRI). Leveraging the expertise from these early experiments, the



Strain Evaluation of Ground Coils Using Digital Image Correlation Method

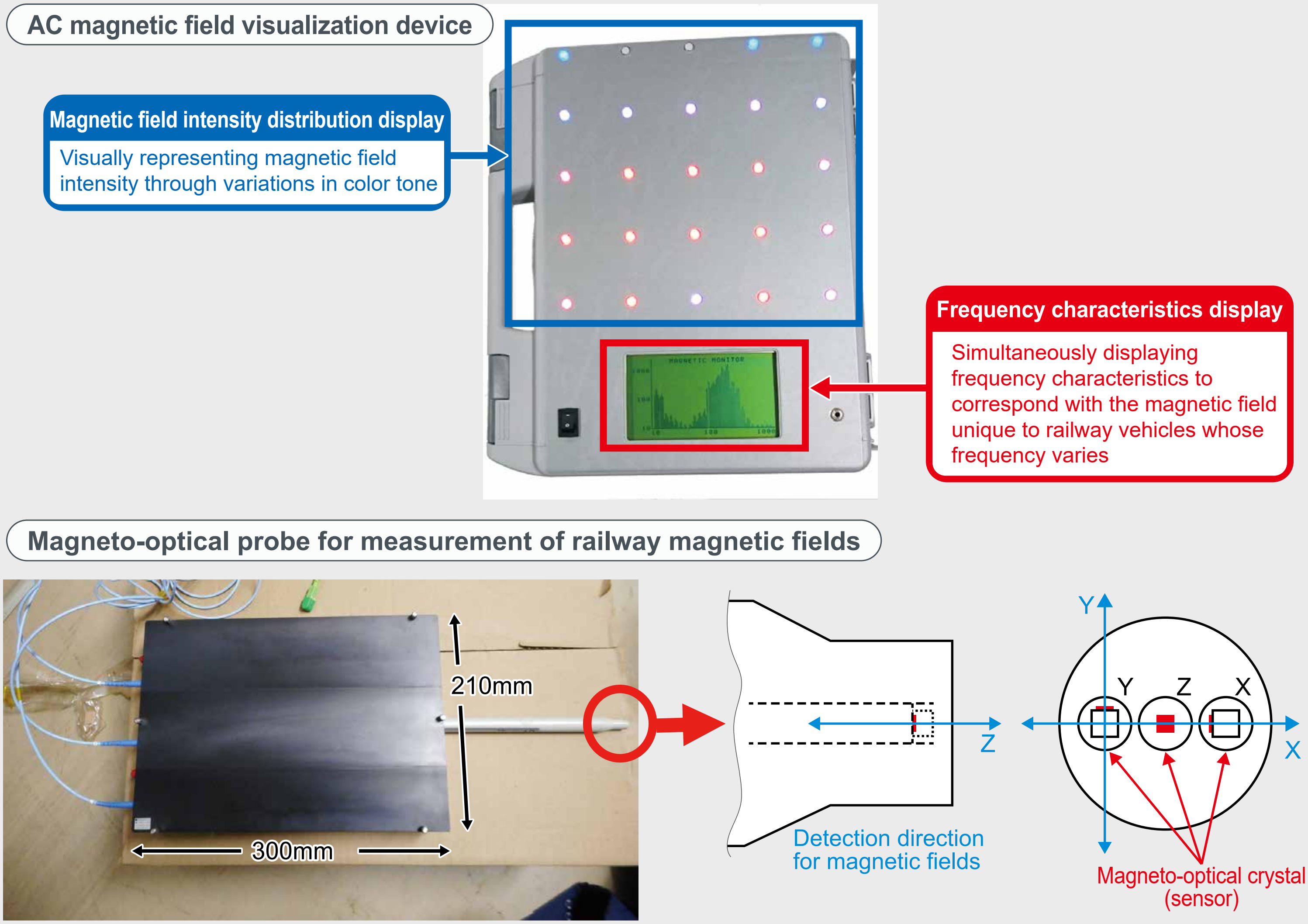
Maglev Systems Technology Division currently conducts measurements and evaluations of magnetic fields in conventional railway vehicles, including the Shinkansen. During this process, we developed a Magnetic field visualization device to simplify the understanding of magnetic field distribution. Additionally, for detailed evaluations at specific locations, we developed a new tri-axial magneto-optical probe that utilizes light as a magnetic field sensor (*AC Magnetic Field Visualization Device (Top) and Magneto-Optical Probe for Railway Magnetic Field Measurement (Bottom)*). This measurement probe detects magnetic fields using a phenomenon known as the Faraday effect. It can be applied for measurements over a wide frequency range.

Superconductivity

Fundamentals of Superconductivity

High-temperature superconducting materials are generally classified into two primary forms: cylindrical bulk materials used for magnetic field applications and longitudinal tape-like materials for power transmission. Despite differences in shape, both types utilize similar materials and fabrication processes, including the mixing, forming, and sintering of raw material powder. Our laboratory focuses on the fabrication and evaluation of these high-temperature superconducting materials, with all basic research activities conducted entirely within the institute.

Bulk materials are produced by packing mixed powder into a mold, pressing it into a disk shape, and sintering it in an electric furnace. To achieve uniform crystal orientation during sintering, crystals are grown via the melt-solidification method using a single-crystal seed. This technique promotes crystal growth from the center outward. Precise control of temperature and

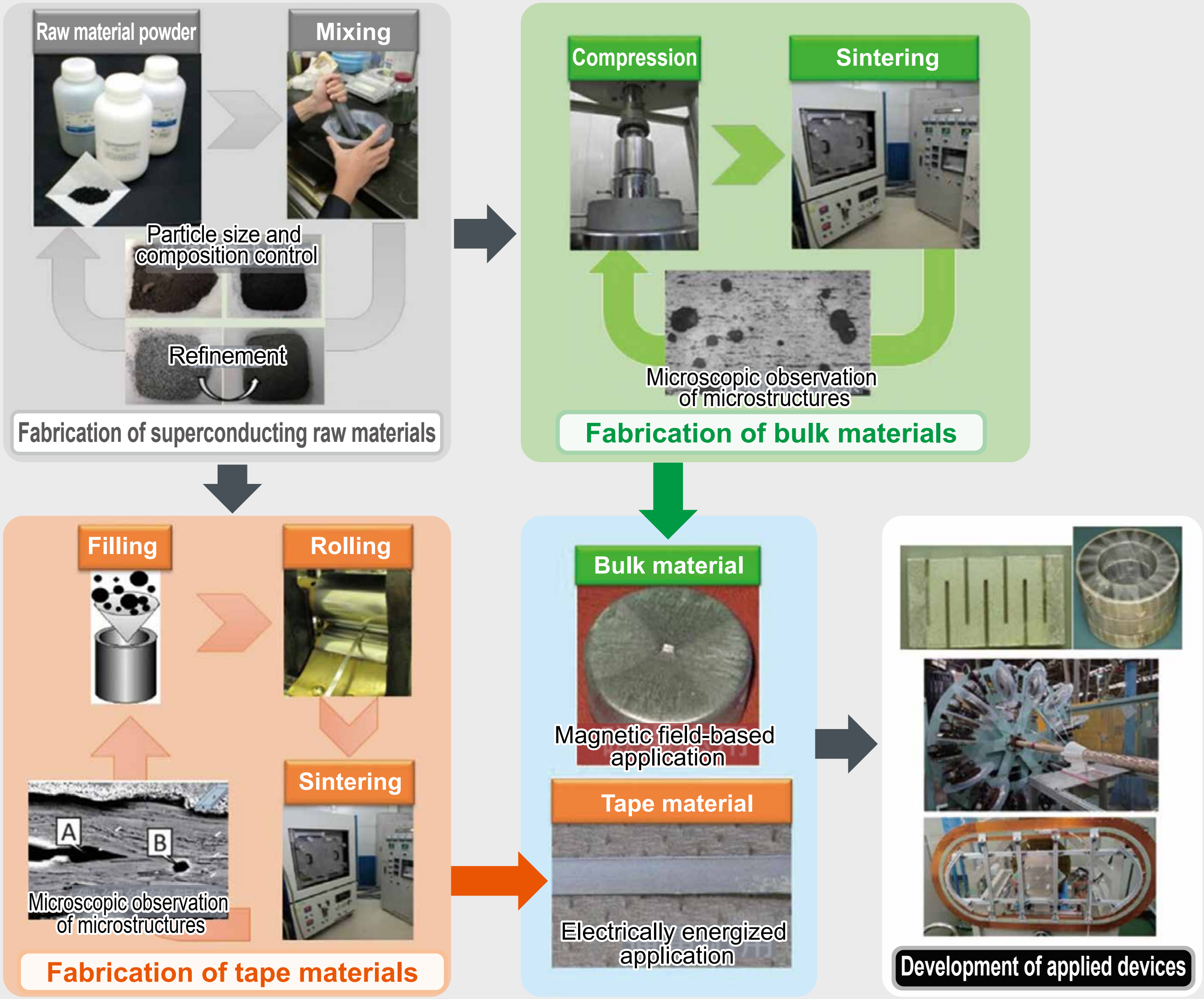


AC Magnetic Field Visualization Device (Top) and Magneto-Optical Probe for Railway Magnetic Field Measurement (Bottom)

composition is critical for uniform crystal orientation. Our research focused on the following aspects: minimizing factors such as particle size, controlling the composition of the powders to be synthesized, and temperature conditions during sintering in an electric furnace (*Development of Superconducting Technologies*).

For tape materials, powder is filled into metal tubes and drawn into tapes using rolling machines, which helps align the crystal orientation. Microscopic examination revealed impurity phases within the tape, which disrupted the continuity of the crystal plane of the superconductor. We reduced these impurity phases and controlled crystal orientation by adjusting the sintering temperature and applied pressure. Additionally, a method for aligning crystals on a metal substrate exists.

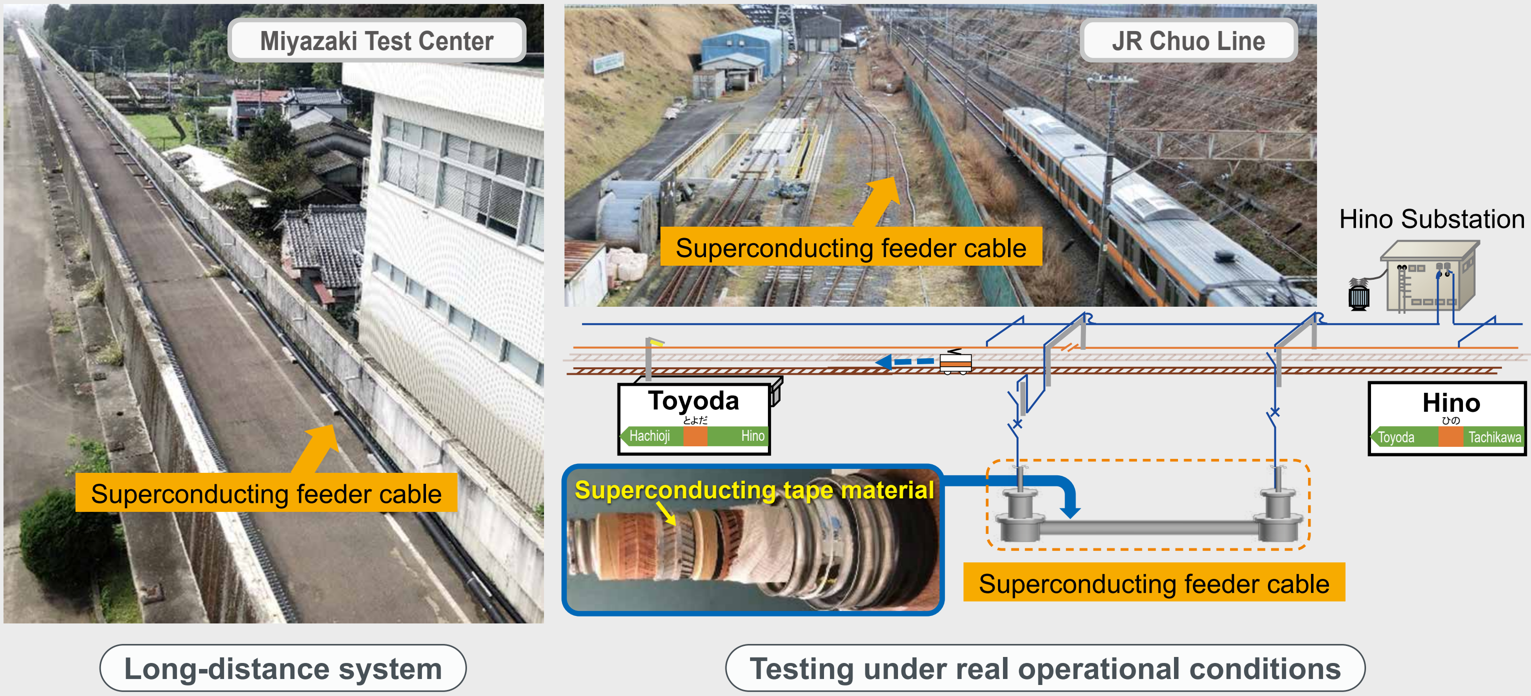
Based on these research outcomes, we are advancing evaluation techniques and technologies for winding and coiling. Through prototype testing of cables and coils, we aim to develop superconducting devices for railway applications, including power transmission and energy storage.



Development of Superconducting Technologies

Superconducting Feeding Systems

In electric railways, power transmission losses and voltage drops occur due to electrical resistance of the transmission lines delivering electricity from substations to vehicles. Substations are strategically located to ensure a reliable power supply for railway operation, particularly on urban lines. To mitigate issues related to increased electrical resistance from multiple substations, we are developing superconducting feeding systems. By utilizing superconductors with zero electrical resistance, we expect energy-saving benefits, including reduced transmission losses, improved regenerative efficiency, and consolidation of substations[1]. Our R&D began with studies on high-temperature superconducting materials, followed by optimization of cable structures and system experiments. This process culminated in demonstration testing on a test track within our facilities. Subsequently, we connected a 408-m superconducting feeder cable to a section between the Hino and Toyoda stations on the JR Chuo Line. By running a 10-car E233 series train, we confirmed that the voltage



Superconducting Feeding Systems

drop was suppressed on an actual railway line[2]. At the Miyazaki Test Center, we are currently advancing the construction of a long-distance (km-scale) superconducting feeding systems designed for intersubstation connections. These R&D efforts aim to realize practical superconducting feeding systems that will revolutionize the energy efficiency and reliability of railway operations (*Superconducting Feeding Systems*). These advancements will lead to a more sustainable future for electric railways.

Conclusions

Over a century has elapsed since the development of superconducting, magnetically levitated transport systems. During this time, numerous innovations emerged alongside the Maglev railway system. For instance, superconducting feeding systems transmitting power using high-temperature superconductors officially approved by the Ministry of Land, Infrastructure, Transport, and Tourism as railway equipment. The world's first demonstration of superconducting power transmission in commercial operation is being conducted[3]. This technology offers a fundamental solution to issues caused by electrical resistance in conventional railway systems. We will continue to refine superconductivity and other innovative technologies to address the challenges faced by the Maglev, Shinkansen, and conventional railway systems. Our aim is for these technologies to significantly contribute to the future of railway systems.

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Center for Railway Earthquake Engineering Research

Dr. Kenichi KOJIMA
Principle Researcher,
Former Head of Center for Railway Earthquake Engineering Research

Among natural disasters, earthquakes are particularly destructive, capable of causing exceptionally severe damage when they occur. The Center for Railway Earthquake Engineering Research focuses specifically on earthquake-related disasters, aiming to ensure the safety and security of railway systems against seismic hazards. Our comprehensive research and development (R&D) efforts span from preventive measures to post-disaster restoration, addressing both software and hardware aspects. Moreover, as the only organization at the Railway Technical Research Institute (RTRI) officially designated as a research center, we are committed not only to R&D but also to actively disseminating information about our R&D outcomes externally. Here, we introduce some of the representative R&D projects undertaken by the Center for Railway Earthquake Engineering Research.

Introduction

Japan is a country highly prone to earthquakes, and various structures—not only railways—have suffered significant damage over the years. In January 2024, a 7.6-magnitude earthquake with its epicenter in the Noto Peninsula of Ishikawa Prefecture occurred, extensively damaging infrastructure such as railways, roads, and water supply systems. The figure titled *Damages to railway structures caused by earthquakes* shows examples of damages caused by some earthquakes. The upper row illustrates the conditions immediately after the disaster, while the lower row depicts the situation following restoration.

The year 2023 marked the 100th anniversary of the Great Kanto Earthquake, a pivotal event that led to the introduction of seismic design in railways and had a profound impact on earthquake disaster prevention in railway systems. This centennial milestone provided a valuable opportunity to reflect on past disasters and the responses to them, underscoring the importance of continuously strengthening railway disaster prevention over the next century.

Based on the belief that continuous efforts to address earthquake risks are indispensable for ensuring the safety and security of railways, the Center for Railway Earthquake Engineering Research conducts comprehensive R&D across three laboratories: Seismic Data Analysis, Soil Dynamics and Earthquake Engineering, and Structural Dynamics and Response Control. Our work covers a broad range of topics, from earthquake occurrence to post-disaster response, addressing seismic challenges in an integrated manner. The figure titled *Example of seismic reinforcement for railway structures* illustrates the improvements achieved (top: before reinforcement, bottom: after reinforcement), while the figure on *Seismometers used in railways* shows a device employed for earthquake detection. This report presents representative R&D projects that we have been advancing to date.

Toward Realization of Earthquake-Resilient Railways[1)]

The term “resilience” has become increasingly familiar in recent years. It refers to the capacity to recover or the robustness of a system, and its application has expanded across various fields. In the context of railways and earthquakes, resilience encompasses two key aspects: reducing the loss of railway functionality caused by earthquakes (robustness) and restoring lost functions as quickly as possible (restorability). By advancing measures to strengthen both aspects, it is possible to build earthquake-resilient railway systems. The figure titled *Resilience and countermeasures against earthquakes* presents a schematic diagram illustrating the concept of earthquake resilience and a timeline of corresponding response measures.

The Center for Railway Earthquake Engineering Research categorizes responses to earthquake-induced damage to railways into four stages: prior measures, emergency response, initial action, and long-term restoration. By streamlining processes and enhancing expertise in each stage, we are advancing R&D to ensure immediate and effective responses to earthquakes under any circumstances. Among various efforts to realize earthquake-resilient railways, we focus here on two key priorities: “stopping trains quickly to ensure safety at the time of an earthquake” and “resuming train operation as swiftly as possible after an earthquake.” In the following sections, we present related R&D activities of the Center for Railway Earthquake Engineering Research in these areas.

Detecting Earthquakes Earlier and Stopping Trains Quickly

To ensure the safety of trains traveling at high speeds during an earthquake, it is crucial to stop them as quickly as possible. For this purpose, the Center for Railway Earthquake Engineering Research has developed an early earthquake warning system.

Since shortly after the opening of the Tokaido Shinkansen in 1965, systems for detecting earthquakes and stopping trains have been developed and implemented. The current operating system detects P waves (primary waves)—the faint initial tremors preceding destructive S waves (secondary waves)—to stop trains before the arrival of the subsequent strong shaking. This system can determine whether to stop a train within as little as 1 s after detecting the P waves. The figure titled *Early earthquake warning system* illustrates the workflow from earthquake detection to warning output.

Since the P waves used for detection in the current system are extremely weak, it is crucial to quickly and accurately distinguish seismic motion from various other vibrations (noise), such as those generated by passing trains or nearby vehicles, and to determine whether the identified vibration is indeed an earthquake. The

Damages to railway structures caused by earthquakes

Damages to railway structures caused by earthquakes (by courtesy of JRTT, Japan Railway Construction, Transport and Technology Agency)

Damages to railway structures caused by earthquakes

Restoration status (by courtesy of JRTT, Japan Railway Construction, Transport and Technology Agency)

Restoration status

Center for Railway Earthquake Engineering Research has newly developed a method incorporating machine learning, which has recently begun to be applied across various fields, for this identification task[3]. The figure titled *Noise identification using machine learning* illustrates the conceptual diagram of this approach. The method involves training on a large dataset of seismic motion and train-induced vibrations in advance, enabling the system to determine whether the detected vibration is caused by an earthquake. Specifically, the method employs a convolutional neural network (CNN)*, a representative technique actively used in recent years to solve problems in image recognition. The figure titled *Examples of noise identification based on machine learning* presents an example of how this method is applied. Here, the Center investigates the extent to which seismic motion and train-induced vibrations can be distinguished. While current technology

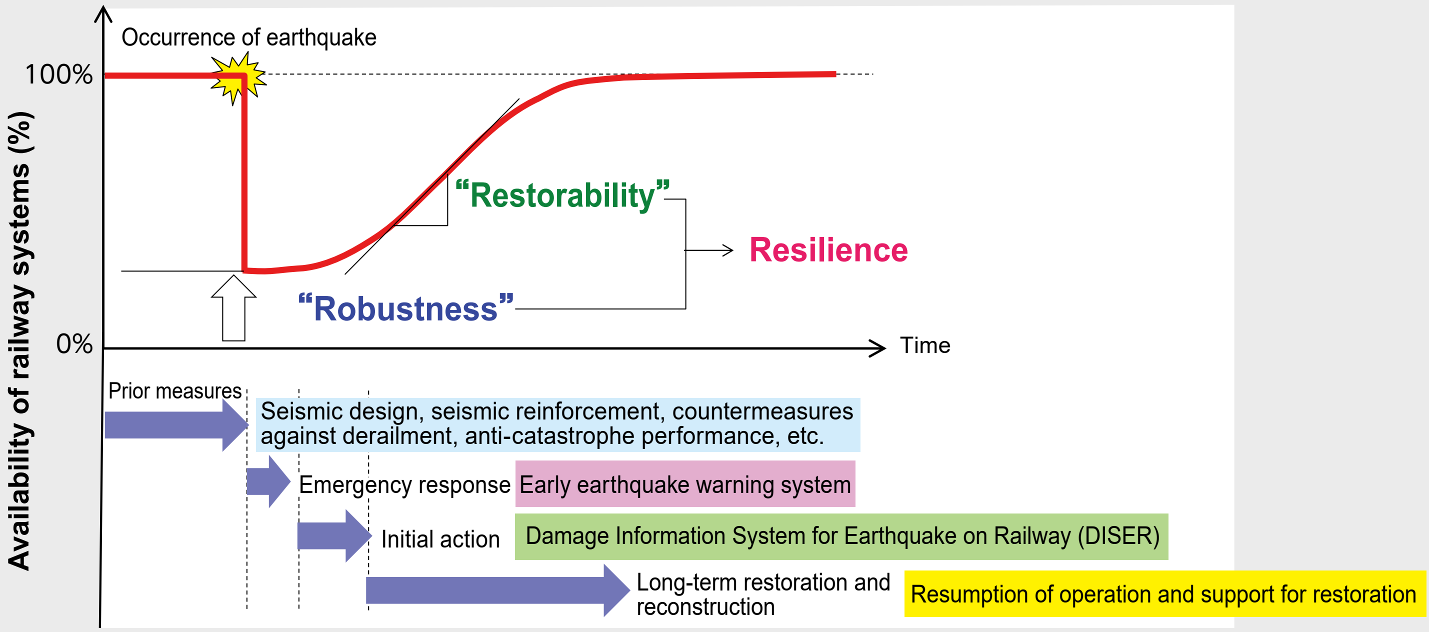
Example of seismic reinforcement for railway structures

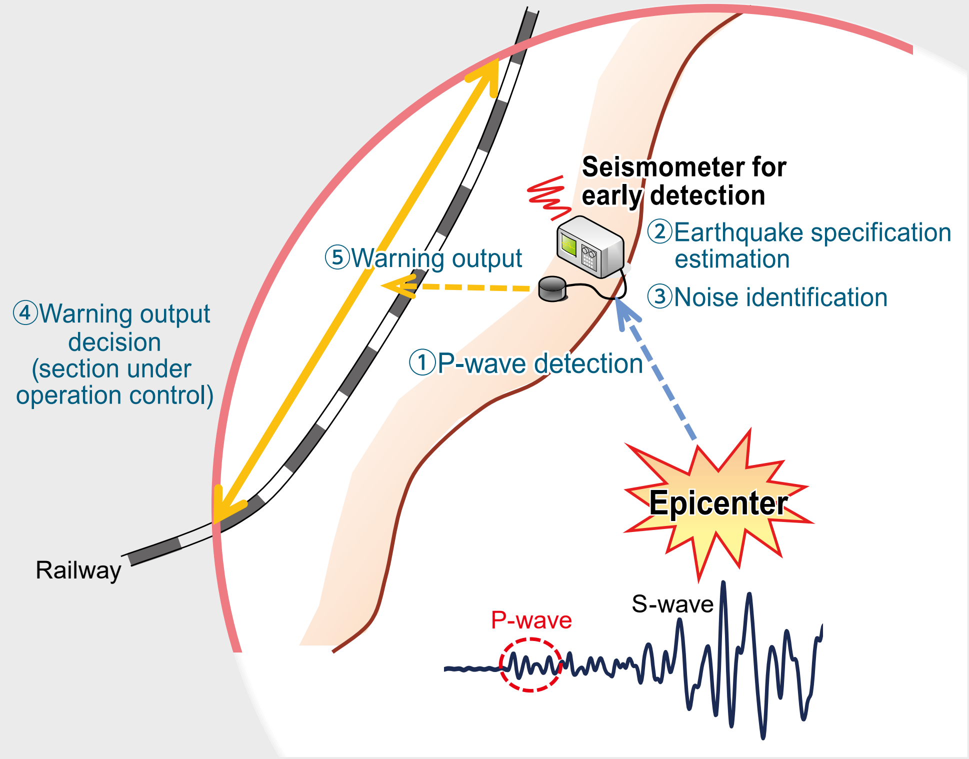
Seismometers used in railways

* CNN

A CNN (Convolutional Neural Network) is a mathematical model inspired by neural circuits in the human brain. It is primarily composed of processes such as convolution (feature extraction) and pooling (reducing computational complexity), enabling it to perform advanced recognition and classification tasks.

Resilience and countermeasures against earthquakes





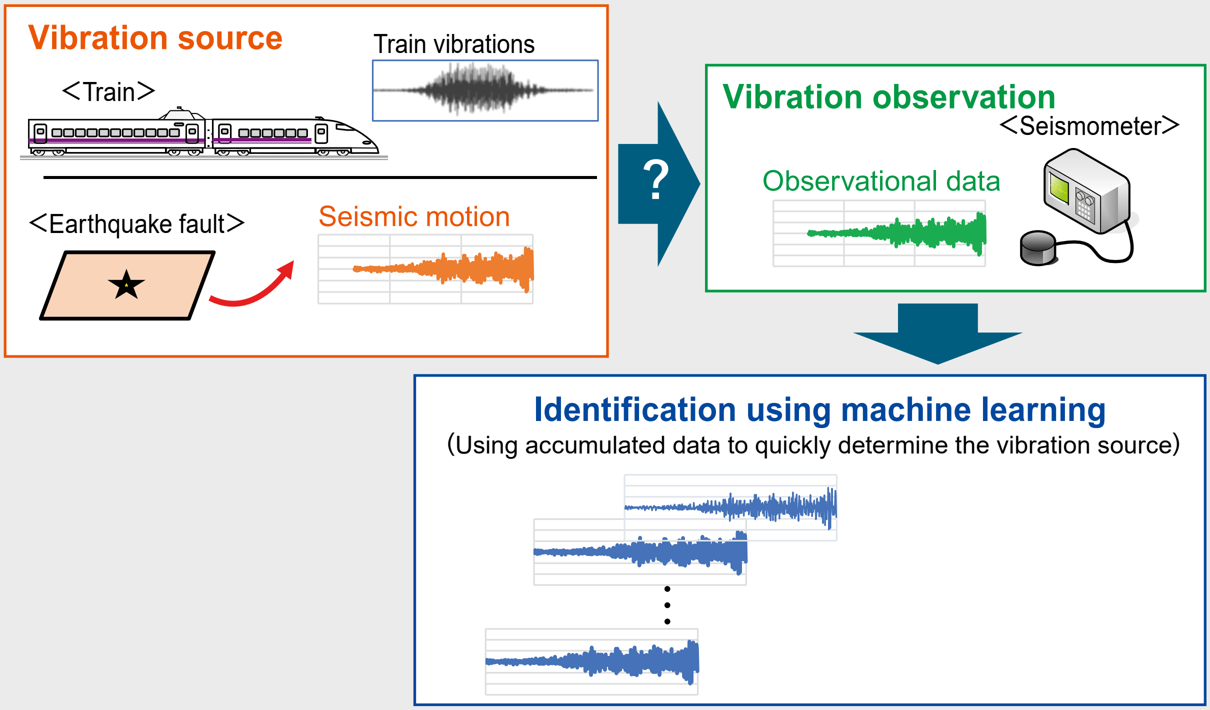
Early earthquake warning system

achieves a discrimination rate of approximately 90% for both train-induced vibrations and seismic motion, the machine learning-based method demonstrates a remarkably high discrimination rate of over 99% for both types of vibrations.

Improving Restorability of Railway Systems

One of the key measures to enhance resilience is the early restoration of functions lost due to earthquakes. Restoring railway operations to normal as quickly as possible after an earthquake—such as promptly resuming train services that were halted during the seismic event and rapidly repairing damaged infrastructure—is critically important for maintaining the normal functioning of society. The Center for

Noise identification using machine learning



Examples of noise identification based on machine learning

Vibration data (1 s)	Determination results			Discrimination rate (%)
	Determined as train vibrations	Determined as seismic motion	Classified as others	
Train vibrations	3959	2	2	99.90
Seismic motion	0	3797	4	99.89

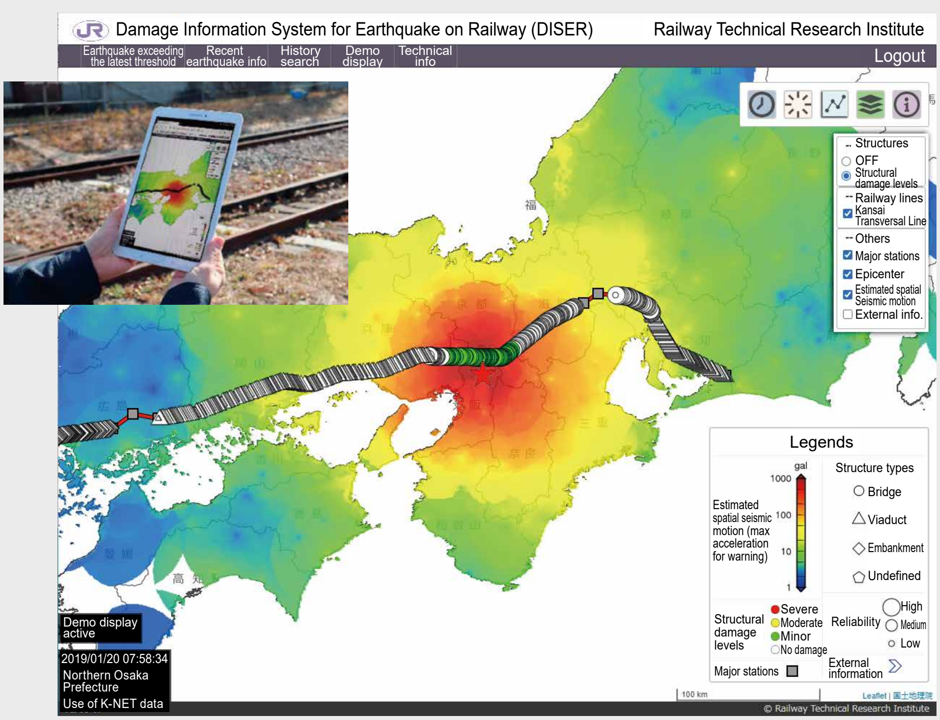
Railway Earthquake Engineering Research is actively conducting research aimed at achieving such post-earthquake "restoration."

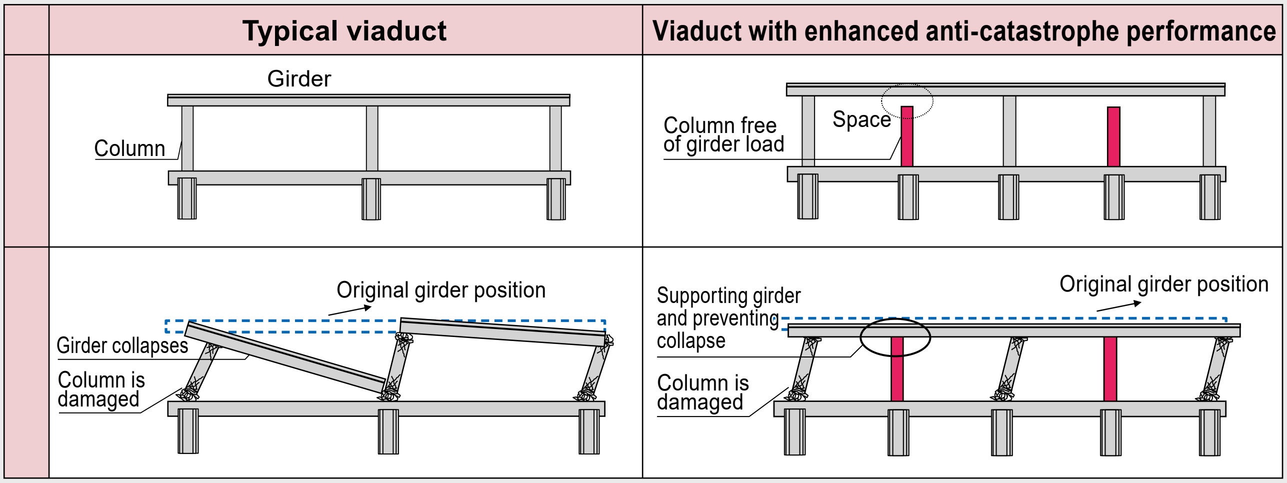
To ensure safe operation after an earthquake, it is necessary to confirm the conditions of various elements of the railway system, including structures and equipment involved in train operation. For this purpose, the Center has developed the Damage Information System for Earthquake on Railway (DISER)[4], a system that quickly provides information on earthquake shaking and the condition of structures along railway lines. The figure titled *Damage Information System for Earthquake on Railway (DISER)* shows an example of the system's output. DISER utilizes the nationwide earthquake observation network operated by public institutions in Japan (approximately 1,000 observation points) to promptly deliver information on shaking along railway routes shortly after an earthquake occurs, thereby supporting efficient inspections and the resumption of train operations following train stoppages.

Even when structural reinforcement is implemented as a seismic countermeasure, the possibility of an earthquake exceeding the seismic motion assumed at the design stage cannot be completely ruled out. The Center is advancing studies aimed at enabling railway functions to recover as quickly as possible even in the event of unexpectedly large earthquakes and has been among the first in the railway field to adopt the concept of "anti-catastrophe performance[5]." This concept involves taking measures to ensure that even if an earthquake beyond the assumed level occurs, it does not cause catastrophic damage.

The figure titled *Structure with enhanced anti-catastrophe performance* shows an example of measures to improve anti-catastrophe performance[6]. The viaduct on the left represents a typical structure, whereas the viaduct incorporates enhancements for anti-catastrophe performance. The upper section illustrates the normal condition, while the lower section depicts the anticipated scenario during an extraordinary massive earthquake exceeding design assumptions. Compared with a typical viaduct structure, the enhanced structure includes several red columns that are not connected to the girders. This design feature is the key point of this countermeasure method. Looking at the assumed situ-

Damage Information System for Earthquake on Railway (DISER)
(Note: The actual interface of DISER is in Japanese.)





Structure with enhanced anti-catastrophe performance

ation of a massive earthquake, the columns of a typical viaduct may be damaged, and the girders could potentially collapse. In contrast, although the columns of a viaduct with improved anti-catastrophe performance are damaged, the red columns support the girders and prevent collapse. In this way, anti-catastrophe performance prevents the collapse of viaducts, thereby reducing damage to vehicles, structures, and equipment beneath the viaduct. It also significantly reduces the time and cost required for restoration. Thus, the Center for Railway Earthquake Engineering Research is conducting R&D to enhance anti-catastrophe performance and prepare for worst-case scenarios, aiming to advance railway safety measures against massive earthquakes that exceed design assumptions and to enable the early restoration of railway functions.

Conclusions

As examples of our R&D activities, we have introduced technologies for detecting earthquakes more quickly and stopping trains safely, as well as technologies for restoring normal conditions as rapidly as possible. Since the Center strives to develop better solutions, these R&D efforts will never truly come to an end. In addition, the Center is engaged in various other initiatives to ensure safe and reliable railway systems against earthquakes. These include the development of seismic performance evaluation methods, countermeasures for structures and ground, and damage prediction using simulations. For more details, please visit the Center for Railway Earthquake Engineering Research website: https://www.rtri.or.jp/rd/ division/rd61 (in Japanese).

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Vehicle Technology Division

Dr. Tadao TAKIGAMI
Director,
Head of Vehicle Technology Division

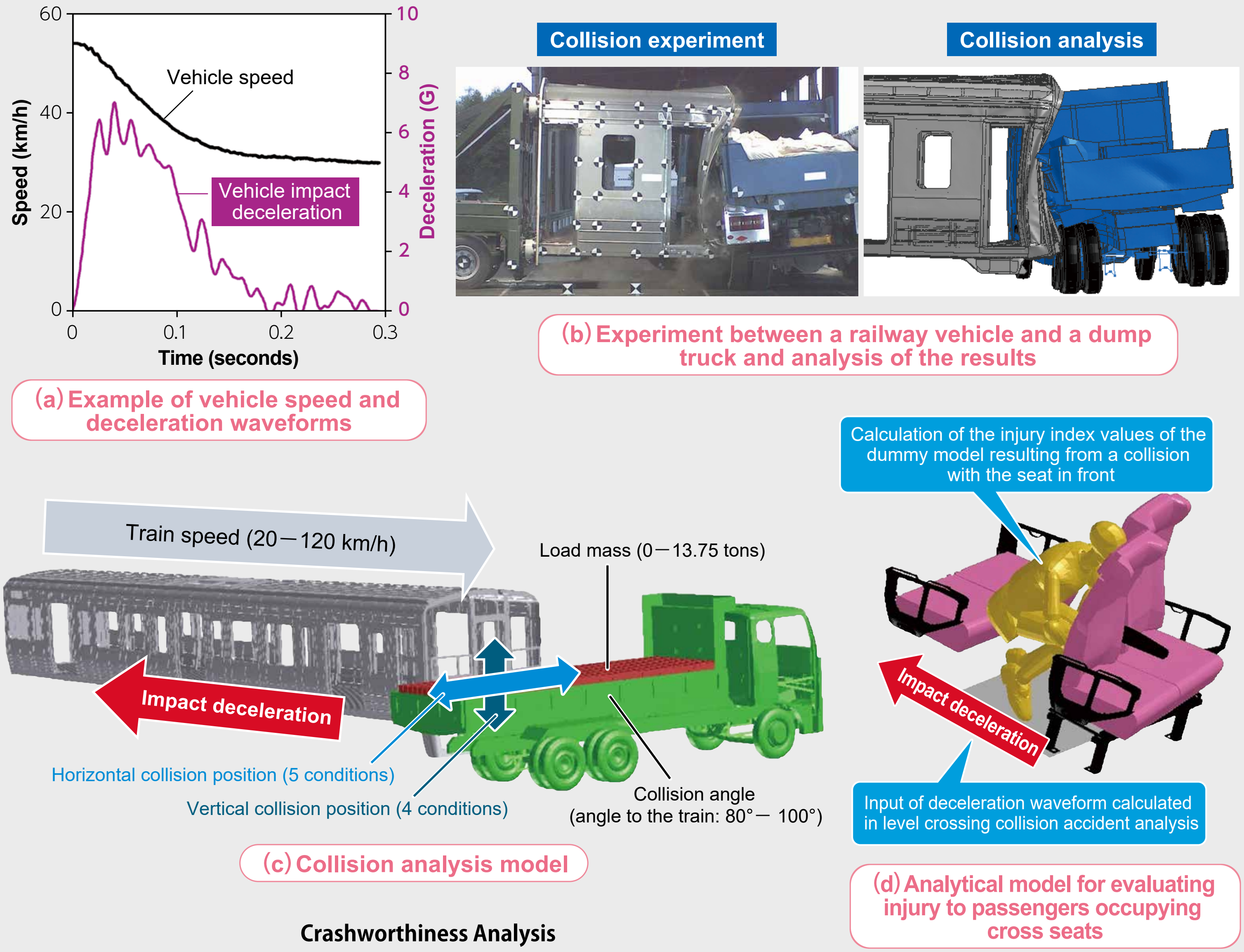
At the Vehicle Technology Division, our research and development (R&D) focuses on enhancing the safety of railway vehicles. Our work includes developing and evaluating methods to prevent derailments, mitigate collisions, and improve fire safety. We also advance R&D aimed at reducing labor requirements in vehicle maintenance by leveraging digital technologies. In parallel, we are developing energy-saving and decarbonization solutions, along with innovations to enhance passenger comfort, such as improved ride quality. This article highlights some of our recent R&D initiatives.

Introduction

Improving operational safety—particularly by preventing derailments, collisions, and fires—remains the highest priority in the R&D of railway vehicles. In addition, lessons from the COVID-19 pandemic have heightened the demand to reduce operating costs by improving labor efficiency in vehicle maintenance. Furthermore, achieving carbon neutrality by 2050 requires continued efforts in energy conservation and decarbonization for railway vehicles. To ensure that railways remain a preferred mode of transportation, continuously enhancing passenger convenience and comfort is also essential. This article presents representative examples of R&D initiatives at the Vehicle Technology Division that address these vehicle-related challenges.

Crashworthiness Analysis[1)]

One of the key challenges in improving safety is developing collision analysis models and evaluation methods that account for collisions between trains and road vehicles at level crossings. Because preventing road vehicles—including automated ones—from entering level crossings is practically impossible, evaluating passenger safety in such scenarios is crucial. To assess safety, clarifying the relationship between the impact deceleration experienced by the railway car body during a collision (*Crashworthiness Analysis (a)*) and the severity of injuries sustained by passengers is necessary. Based on past level-crossing collision accidents, we developed a collision analysis model simulating a dump truck–train collision and conducted physical collision experiments between a leading railway vehicle and a dump truck for comparative verification (*Crashworthiness Analysis (b)*). These experiments significantly improved the accuracy of the model. Using the validated model, we carried out collision analyses under various conditions, including different collision speeds, dump truck masses, impact positions, and collision angles. The results allowed us to calculate the resulting deceleration of the railway car body and better understand its effect on passenger safety (*Crashworthiness Analysis (c)*). Furthermore, by using the obtained impact deceleration, we analyzed the impact on a passenger seated on a cross seat that was thrown from the seat and collided with the seat in front, and calculated the severity of passenger injuries (specifically, the force applied to the femur)

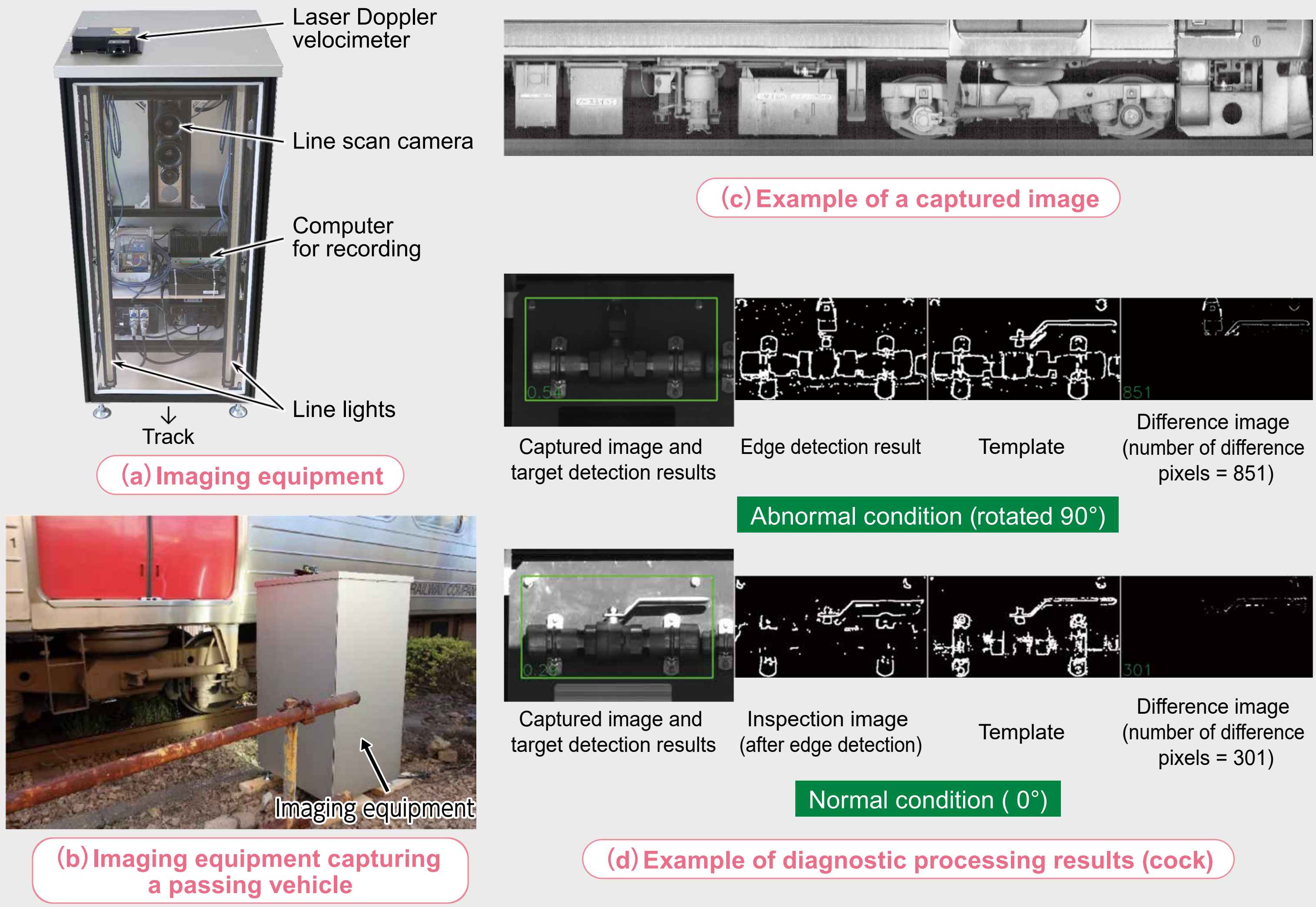


Crashworthiness Analysis

(*Crashworthiness Analysis (d)*). From these analysis results, we proposed that the integrated value of the impact deceleration—roughly corresponding to the velocity at which a passenger collides with the seat in front—is an appropriate evaluation index for passenger safety. Moving forward, we plan to analyze the entire train set, including coupling sections, to further refine the evaluation.

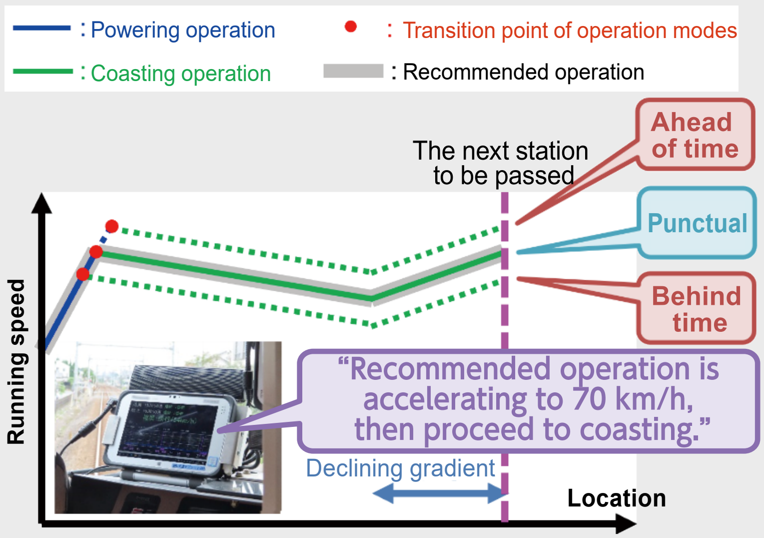
Visual Inspection System for Vehicle Underbody[2)]

Periodic inspections are essential to ensure the safe operation of railway vehicles. To reduce the labor required for these routine inspections while maintaining inspection quality, RTRI has developed a visual inspection system for vehicle underbodies. Conventionally, inspection conducted on the entire vehicle without removing parts involves inspectors approaching the vehicle to visually check the mounting conditions and any damage to the onboard equipment. To automate this inspection process, we first developed a device capable of capturing side images of the vehicle's underbody while the vehicle is in motion (*Visual Inspection System for Vehicle Underbody (a)*). A laser Doppler velo-

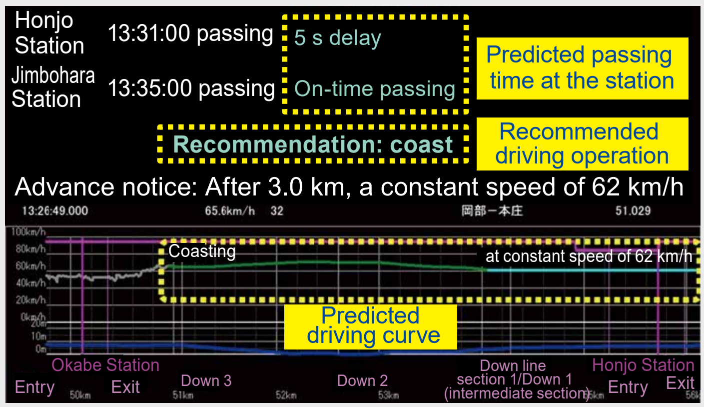


Visual Inspection System for Vehicle Underbody

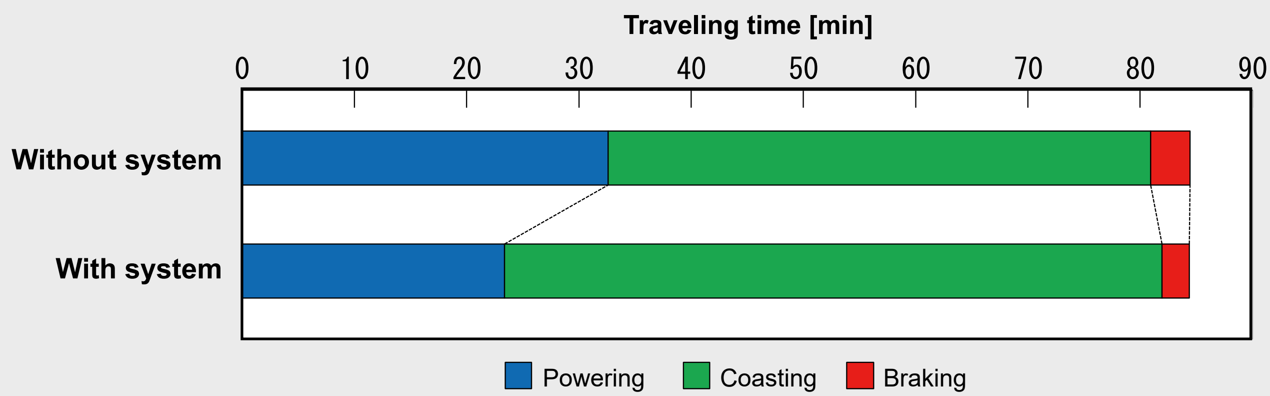
cimeter was used to measure the vehicle's passing speed, allowing the scan sensor camera to capture images in synchronization (*Visual Inspection System for Vehicle Underbody (b)*). This approach enabled us to obtain high-resolution, continuous images (*Visual Inspection System for Vehicle Underbody (c)*) that are unaffected by variations in vehicle speed. In addition, the system can automatically recognize vehicle identification numbers from the captured images. As an application example, we demonstrated the automated diagnosis of the cock handle angle under the test vehicle (*Visual Inspection System for Vehicle Underbody (d)*). The target inspection area was extracted from the images, and edge (contour) detection was performed to assess the handle's position. The luminance difference between the extracted image and a prepared normal image (template) was calculated, with areas differing from the normal highlighted in white. The number of white pixels was then counted. If this count was below a specified threshold, the condition was judged as normal; if it exceeded the threshold, it was judged as abnormal. In addition to diagnosing the cock handle angle, we have confirmed that this system can accurately detect missing bolts,



(a) Image of speed transition estimation



(b) Example screen of driver advisory system



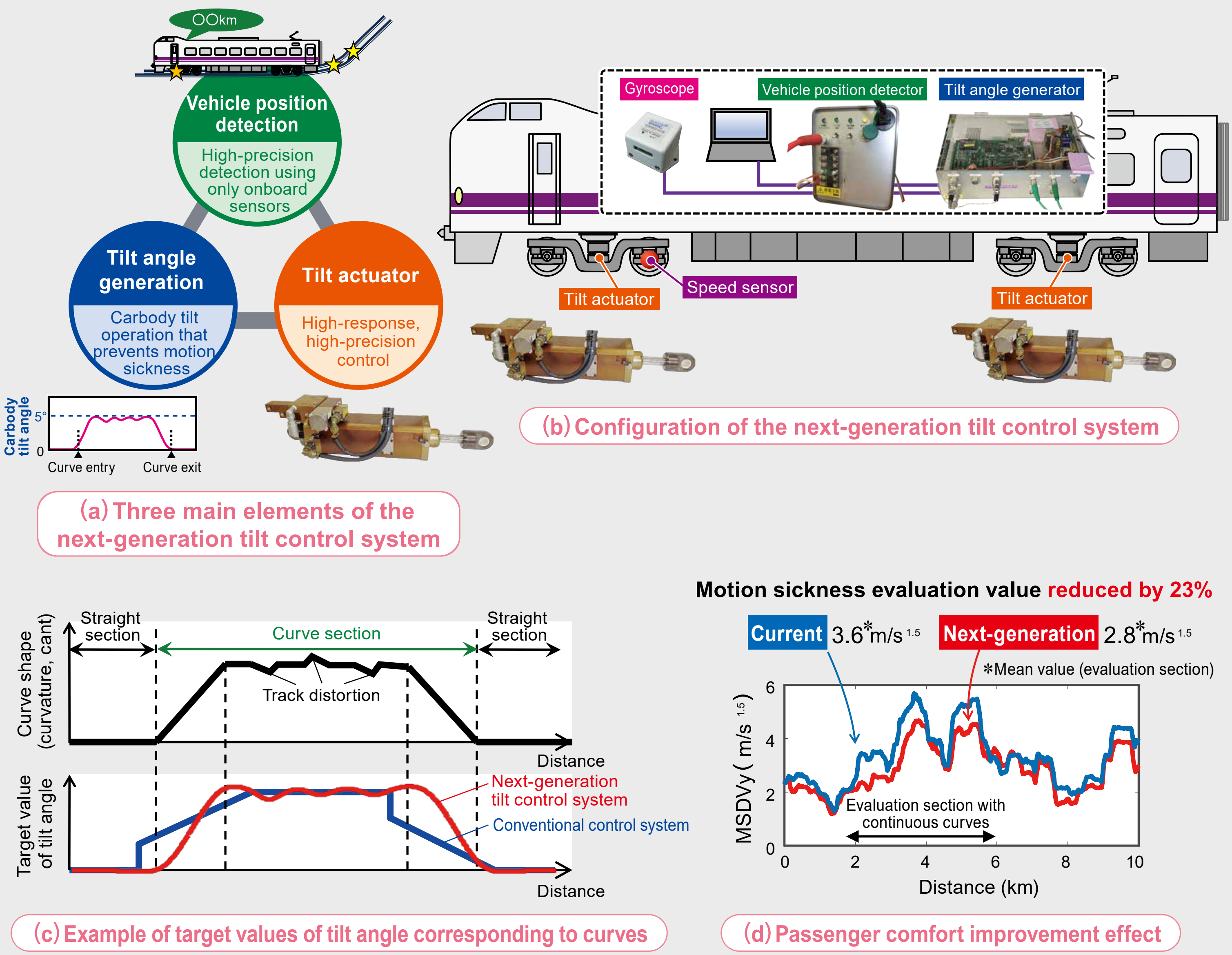
(c) Comparison of traveling time with and without driver advisory system

Energy-Saving Driver Advisory System

bent adjustment rods, and pipe deformations. By using this system, inspectors can assess vehicle conditions indoors by reviewing the captured images, eliminating the need to approach the vehicle closely. Furthermore, the system's automatic image diagnosis reduces reliance on manual labor, improving both the efficiency and reliability of underbody inspections.

Energy-Saving Driver Advisory System[3)]

We have developed a driver advisory system aimed at reducing the energy consumption during train driving operations while maintaining punctuality. Conventionally, train operation consists of three modes: powering (where the motor generates tractive force to accelerate), braking, and coasting (running by inertia without powering or braking). Train drivers manually select the appropriate mode based on factors such as timetables, speed limits,



Next-Generation Tilt Control System

and track gradients. The newly developed driver advisory system enhances this process by performing real-time simulations during travel. It estimates speed transitions at various points along the route under different driving patterns and then recommends the pattern that optimizes both energy efficiency and punctuality. Specifically, the system defines several candidate driving patterns from the train's current position to the next station. Using information such as train mass, running resistance, track gradients, current position, and current speed, it predicts the speed profile for each candidate pattern (*Energy-Saving Driver Advisory System (a)*). For each candidate driving pattern, the system selects the one that most closely matches the scheduled passing time at the next station while minimizing energy consumption. The recommended pattern is then presented to the driver in real time through a tablet display (*Energy-Saving Driver Advisory System (b)*) and voice guidance. Effectiveness verification tests were conducted by comparing actual running data with and without the use of the driver advisory system. The results confirmed an energy-saving effect ranging approximately from 4% to 14%, depending on the route. In the case studied, the reduction in energy consumption was attributed to decreased powering and increased coasting (*Energy-Saving Driver Advisory System (c)*). Ongoing efforts focus on expanding the system to additional lines and vehicle types to develop it into a practical tool for widespread deployment.

Next-Generation Tilt Control System[4)]

When trains travel at high speeds through sections with numerous curves, passengers experience centrifugal force due to the lateral acceleration of the carbody. To mitigate this effect and improve ride comfort, tilting vehicles are commonly used. The basic tilting mechanism, known as "natural tilting", relies solely on centrifugal force. However, the mainstream approach is "controlled natural tilting", which adds pneumatic actuators to suppress the phase lag of the tilting motion. Aiming to suppress the characteristic slow, low-frequency oscillations of tilting vehicles and provide a smoother, more comfortable ride, we have developed a next-generation tilt control system. This system integrates three key technological elements, as illustrated in *Next-Generation Tilt Control System (a)*.

First, to ensure that the train body tilts at precisely the right time on curves, continuously and accurately determining the train's running position is essential.

For this purpose, we devised a self-position detection technique using a gyro sensor and a speed sensor installed on the vehicle (*Next-Generation Tilt Control System (b)*). These sensors measure the curvature of the track during travel, and by comparing the measurements with pre-recorded data, the system accurately determines the train's position. Based on the detected position, the system calculates the ideal tilt angle (target tilt value) by accounting for the curvature, cant of the upcoming curve, and the train's running speed (*Next-Generation Tilt Control System (c)*). This target value closely follows the actual track geometry, including any irregularities. In addition, the system cancels low-frequency oscillations caused by centrifugal force and track irregularities, thereby reducing motion sickness—a common drawback of tilting vehicles. To realize such precise control, we developed a high-response pneumatic actuator capable of achieving the ideal tilt angle in real time. The performance of the next-generation tilt control system, which integrates these technologies, was successfully verified through running tests. The maximum error in vehicle position detection was ± 2 meters, ensuring sufficient accuracy for tilt control. Furthermore, the Motion Sickness Dose Value along the y-axis (MSDVy)—an index reflecting the degree of motion sickness—was reduced by approximately 23% compared with the conventional control system (*Next-Generation Tilt Control System (d)*). The next-generation tilt control system has been installed on JR West's 273 series Yakumo Limited Express and is now in operation on commercial lines.

Conclusions

In this article, we introduced recent initiatives undertaken by the Vehicle Technology Division, including crashworthiness analysis, visual inspection systems for vehicle bodies and underbodies, energy-saving driver advisory systems, and next-generation tilt control systems. To ensure the long-term sustainability of railways, we remain committed to advancing vehicle technologies through R&D that enhances safety, reduces maintenance costs, promotes energy efficiency and decarbonization, and improves passenger comfort.

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RTRI Develops New Master Plan RESEARCH 2030

The Railway Technical Research Institute (RTRI) developed its medium-term action plan, "Master Plan—Creating sustainable railway systems—RESEARCH 2030," for the five years from FY2025 to FY2029, an outline of which is presented herewith. The full text can be viewed on the website (at present only available in Japanese) of RTRI.

Introduction

The steady implementation of "Sustainable Development Goals (SDGs)" is being called for as social issues such as global environmental problems become more apparent. For the realization of a sustainable society, efforts are being made in various fields to achieve both economic development and resolution of social issues through systems that integrate cyberspace and physical space at an advanced level.

The environment surrounding the society, economy, and railways in Japan has been changing at an accelerated pace since the spread of the COVID-19 pandemic. Social issues such as climate change, the increased necessity of realizing carbon neutrality, and the decline in the working-age population have become more severe and complex. Specifically in the railway industry, labor shortages, aging infrastructures, and the business continuity of regional railway companies are urgent issues. On the other hand, technological innovation, particularly in digital technologies, is progressing rapidly in every field. The railway industry is also advancing in the utilization of such cutting-edge technologies, and collaborative efforts with railway companies and related organizations have become essential to address the increasingly complex challenges.

Based on the above circumstances, we formulated the Master Plan RESEARCH 2030 as an action plan to achieve our vision, "We will develop innovative technologies to enhance the rail mode so that railways can contribute to the creation of a happier society."

Basic Policies

For the "creation of sustainable railway systems," RTRI defined the following five basic policies (*Basic policies*).

Activities under RESEARCH 2030

(1) Research and Development

(a) R&D aims, pillars, approach, etc.

- RTRI established four R&D aims and three pillars of R&D to guide our activities (*R&D aims and pillars*).
- When setting R&D projects, based on our roadmaps that include activities ranging from basic research to applied technology development, we will set up R&D projects to seamlessly promote R&D by accurately setting milestones.
- At the stage of development for practical use, we will actively support the development of laws, regulations, and technical standards, which are necessary for the social implementation of our innovative technologies.
- Our core R&D technologies serve as a driving force to elucidate the real nature of various railway-specific issues and to

Basic policies

(1) Improving safety with an emphasis on improving resilience against intensifying natural disasters ・R&D for enhancing the resilience of railway systems against natural disasters, preventing failures of ground and vehicular equipment, and taking countermeasures against their aging ・Promoting diagnostic guidance on investigations of damage and causes of disasters and accidents, and proposals of their recovery methods and prevention measures
(2) Improving productivity and decarbonization of railway systems ・R&D that contributes to the improvement of productivity and decarbonization of railway systems through the active use of cutting-edge Information and Communication Technologies (ICTs) ・Supporting the development of relevant laws, regulations, and technical standards, which are required for the social implementation of our R&D outcomes
(3) Providing solutions to various issues in railway technologies by demonstrating our collective strength ・Establishing interdisciplinary research systems ranging from basic research to applied development to provide solutions to railway-specific issues ・Focusing our resources on the core technologies for R&D, which serve as a driving force to elucidate the real nature of various railway-specific issues and to find solutions for them
(4) Enhancing the global presence of Japanese railway technologies ・Technical collaboration with overseas railway operators and research institutes for stimulating R&D activities ・Strategically engaging in standardization activities as a base for international standardization
(5) Creating a vibrant workplace where each employee can experience self-realization ・Creating a workplace that fosters well-being where diverse values are respected and each employee can experience self-realization

find solutions for them. We will focus our resources on such core technologies for enhancing the sophistication thereof.

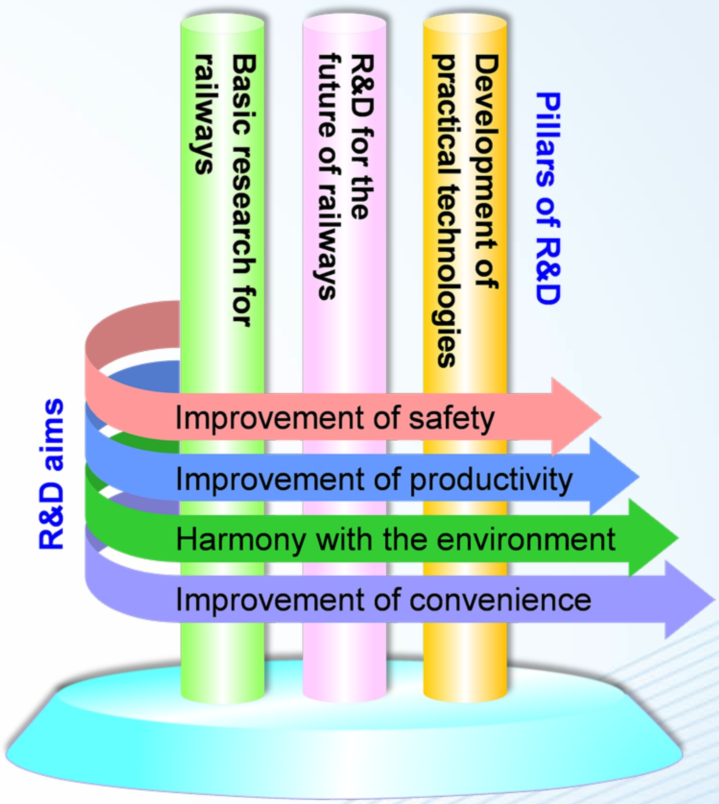
- By promoting technical collaboration across different technical fields and with railway companies, as well as facilitating data sharing and coordination, we will create new values, improve the quality of R&D outcomes, and shorten development periods.
- We will modularize our R&D outcomes as appropriate and promote social implementation in stages.

(b) R&D for the future of railways

We will address five major research themes: "Enhancement of resilience against intensifying natural disasters," "Sophistication of automatic train operation," "Labor saving in maintenance," "Decarbonization of railway systems," and "Elucidation of railway-specific phenomena through simulation" (*R&D for the future of railways*).

(c) Development of practical technologies

To provide timely and accurate practical outcomes, we will



R&D aims and pillars

implement projects for rapid resolution of various issues in railway operations, promoting R&D objectives such as "Improvement of safety" and "Improvement of productivity."

(d) Basic research for railways

In basic research, which is the basis for innovative railway technologies such as those for elucidating railway-specific phenomena, we will advance challenging projects with high technical complexity and the potential to significantly impact railway operations if research outcomes are put to practical use.

(2) Diagnostics advisory

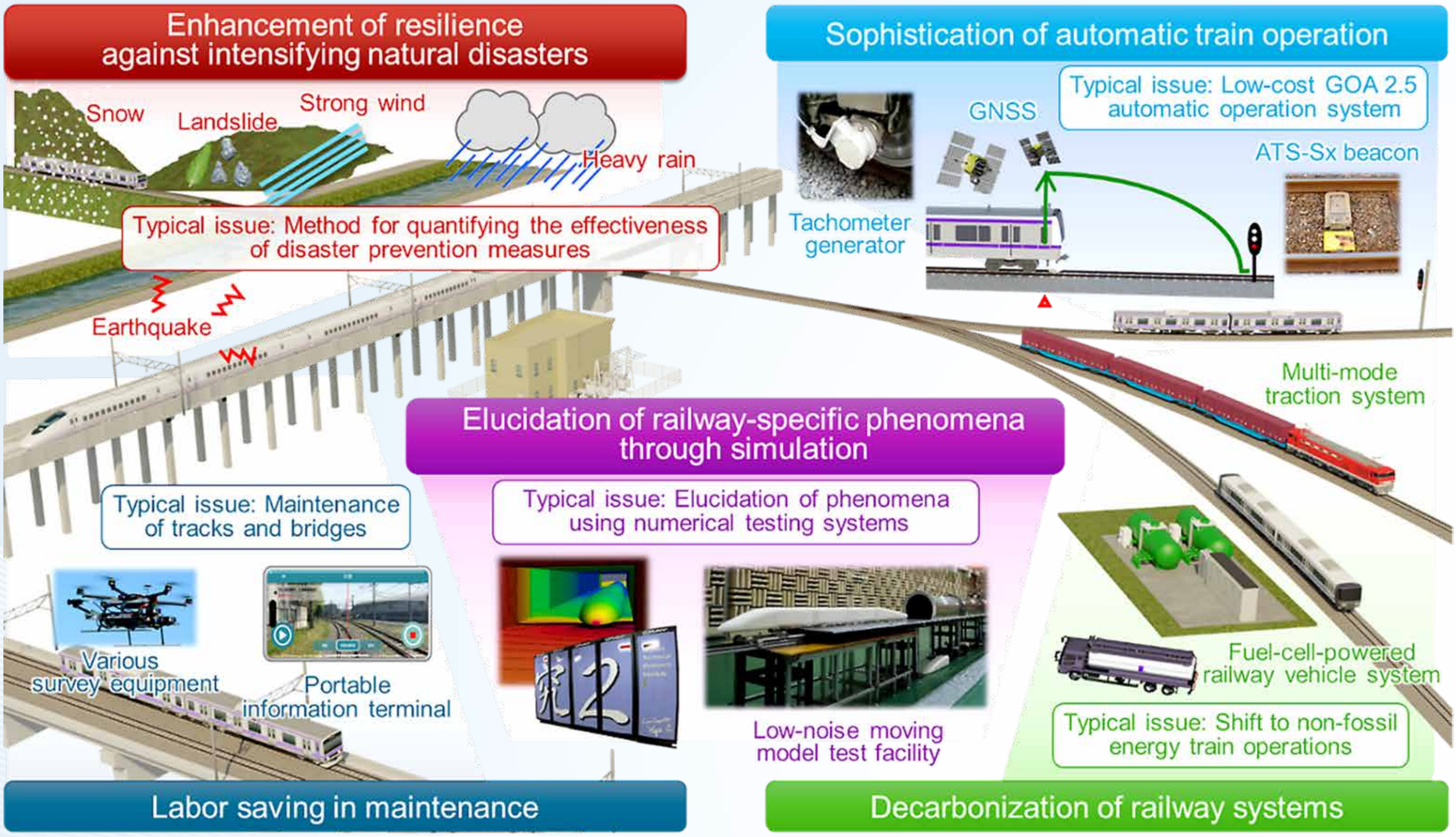
We will respond promptly, accurately, and meticulously to requests from railway companies. In particular, when providing support in response to disasters, accidents, and equipment failures, we will conduct swift investigations and propose recovery methods and prevention measures.

(3) International standards

We will promote strategic international standardization activities through the ISO (International Organization for Standardization) and IEC (International Electro-technical Commission), proposing to standardize new work items relating to technical fields in which Japan has an advantage, and incorporating Japanese design philosophies and technologies into standards proposed by other countries.

(4) International activities

We will promote and expand collaborative research with overseas universities, research institutes, etc. to stimulate our R&D activities. We will also actively support global expansion of Japanese railway companies.



R&D for the future of railways

Management

RTRI will strive for sound and appropriate business management through initiatives such as promoting legal compliance and strengthening information management. Moreover, we will aim for vibrant business management such as by creating a workplace that fosters well-being where each employee can experience self-realization.

Conclusions

In response to increasingly serious, apparent, and complex challenges, RTRI will promote various activities to create a safe, secure, smart, environmentally friendly, and sustainable railway system in the future.

We will advance R&D by detailing its objectives and providing roadmaps for social implementation. While maintaining close collaboration with railway companies and other organizations, we will fulfill our role as a leader and driver of technological innovation. We will also strive to sophisticate our R&D core technologies, leading to the creation of breakthrough innovations.

Based on the vision “We will develop innovative technologies to enhance the rail mode so that railways can contribute to the creation of a happier society,” RTRI will devote its full efforts to executing its activities.

RTRI and DZSF Sign Comprehensive Agreement to Strengthen Railway Research Cooperation

On July 18, 2025, the Railway Technical Research Institute (RTRI) concluded a comprehensive agreement with the German Centre for Rail Traffic Research (known in German as Das Deutsche Zentrum für Schienenverkehrsforschung, DZSF) at the RTRI headquarters in Tokyo to enhance future collaboration between the two institutes.

Purpose of the Agreement

The agreement aims to promote beneficial cooperative programs for advanced and practical R&D in the field of railways while leveraging the R&D capabilities and testing facilities of RTRI and DZSF, thereby contributing to the development of railways as well as academic and technological progress in both Japan and Germany.

Activities to Be Implemented under the Agreement

(1) Collaborative research
(2) Reciprocal visits by researchers and engineers
(3) Exchanging information in preparation for future collaborative research, and holding seminars for strengthening relations through presentation of research outcomes and information exchange

The above (1) Collaborative research and (2) Reciprocal visits by researchers and engineers will be conducted in the fields of climate change, automatic train operation, digital maintenance, decarbonization, and train-animal collisions, which are key focus areas for both institutes.

The next seminar is scheduled to be held at DZSF in 2027.

Comments from the Representatives on the Agreement

Dr. Ikuo Watanabe, President of RTRI

We are delighted that RTRI has formalized the agreement with DZSF. Our Master Plan, RESEARCH 2030 sets 'Creating sustainable railway systems' as a core goal. Among our fundamental policy objectives are enhancing resilience to intensifying natural disasters, improving productivity and achieving decarbonization of railway systems—challenges we share with DZSF. The agreement represents an important milestone, allowing us to collaboratively address these issues and pioneer a sustainable future for railways.

Partnering with DZSF, a research institute from Germany, a major railway nation, holds great significance for us. Moving forward, through collaborative research and personnel exchanges, we will leverage each other’s expertise and insights to pursue further innovation and advancement in railway technology.

Prof. Eckhard Roll, Director of DZSF

We are greatly honored to enter the agreement with RTRI. Despite geographical and cultural differences, Japan and Germany face many common challenges in the railway sector. We hope the agreement will mark a significant first step toward meaningful bilateral cooperation.

Prof. Eckhard Roll, Director of DZSF (left) and Dr. Ikuo Watanabe, President of RTRI (right) shake hands after signing the comprehensive agreement

Collaboration with RTRI will undoubtedly strengthen R&D efforts in rail traffic for both countries. We are convinced that sharing scientific knowledge, data, and experience to address common challenges faced by both countries—such as demographic changes, aging infrastructure, and climate change—is of great value for the sustainable development of railway systems.

About DZSF

The German Centre for Rail Traffic Research (DZSF), headquartered in Dresden, Saxony, Germany, was established in 2019 as a national research institute evolving from the research activities of the Federal Railway Authority (Eisenbahn-Bundesamt, EBA). With approximately 70 staff members, DZSF conducts R&D covering 15 or more diverse fields. It operates an open digital test field utilizing active rail lines near Dresden. DZSF also provides scientific advice to the Federal Ministry for Digital and Transport (Bundesministerium für Digitales und Verkehr, BMDV) on maintaining and enhancing the safety of railway transportation, particularly regarding responses to advancements in digitalization such as cybersecurity.

For more details, visit: https://www.dzsf.bund.de/DZSF/EN/TheDZSF/dzsf_node.html

Railway Technical Research Institute