# Recent Research and Development of Signalling and Operation Systems Technology Division

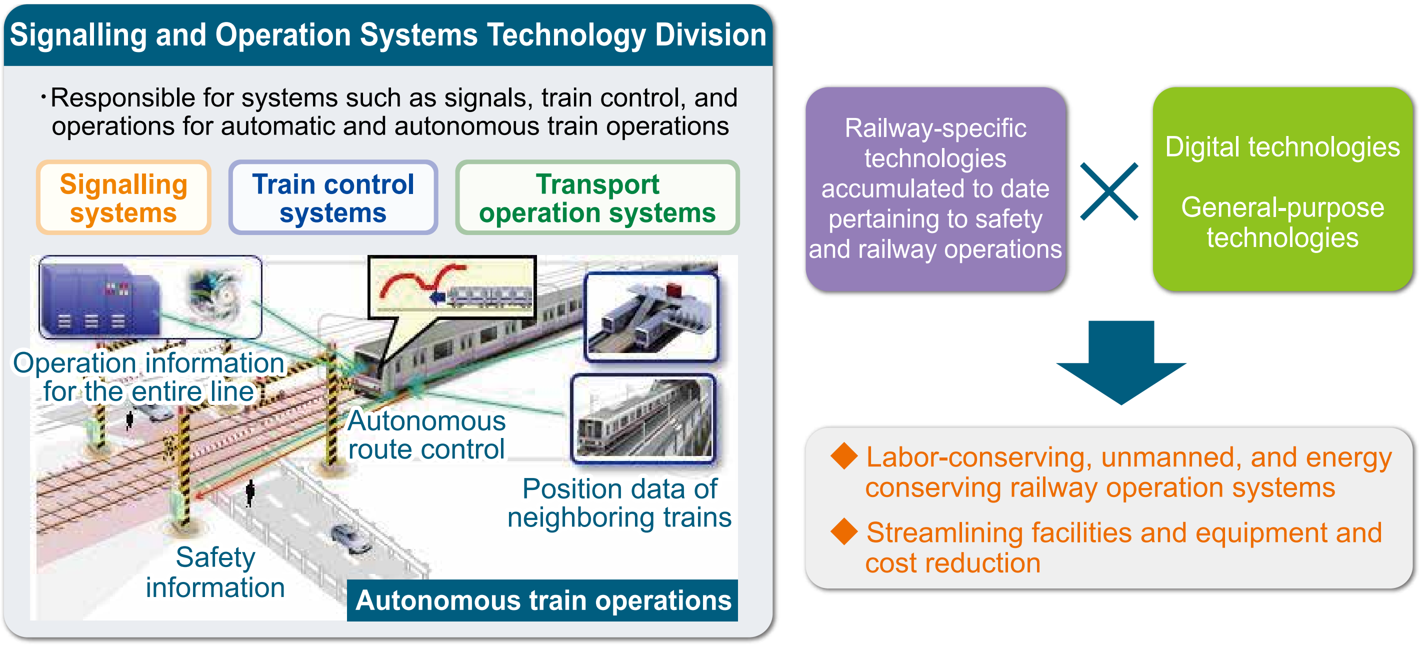
The Signalling and Operation Systems Technology Division (S&O div.) conducts research and development on signalling safety and train control systems, both essential for ensuring safe and stable railway transport. Additionally, the division explores operations planning and management, typically including timetables, vehicles, and crew scheduling. Moreover, to establish innovative railway systems in the future, we are actively involved in research and development activities that integrate Information and Communication Technologies (ICT) and other cutting-edge digital technologies with existing railway-specific technologies pertaining to safety and railway operations. In this section, we present the approaches most recently used in our research and development endeavors.

**Dr. Hideki Arai**
Director,
Head of Signalling and Operation Systems Technology Division

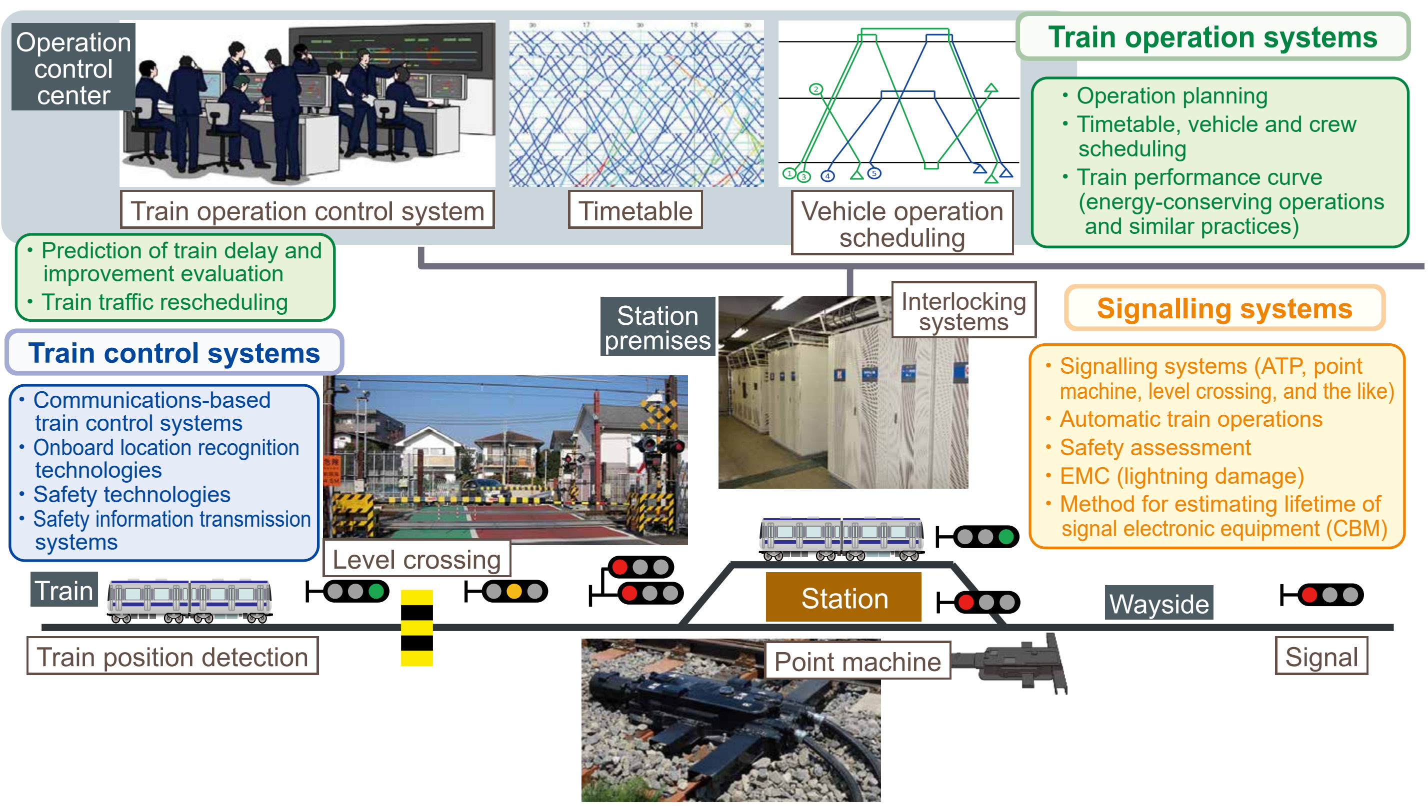
## Introduction

Recent progress in digital technologies and their rapid integration heighten our expectations for safer and more advanced railway operation control. Amid such expectations, the S&O div. was established in the organizational reform of the Railway Technical Research Institute (RTRI) on April 1, 2022. The institute serves as a core research hub for developing innovative railway systems based on digital technologies, focusing on automatic and autonomous railway systems (*Responsibilities of Signalling and Operation Systems Technology Division*)[1]. The S&O div. consists of three laboratories: Signalling Systems, Train Control Systems, and Transport Operation Systems. These laboratories are engaged in research and development pertaining to signalling safety systems, communications-based train control systems, automatic train operations, operation planning, train performance curves (including energy-saving operations), and train rescheduling after a schedule disruption (*Overview of areas within the responsibility of S&O div*).

Herein, we present the latest approaches used in our research and development efforts to achieve the autonomy of train operation systems. Additionally, we demonstrate methods for applying cameras and image processing units of Commercial Off-The-Shelf (COTS) to signalling systems. Furthermore, we introduce methods for quantitatively estimating the lifetime of electronic equipment in preparation for the future implementation of Condition-Based Maintenance (CBM) of signalling systems using electronic equipment.




**Responsibilities of Signalling and Operation Systems Technology Division**




**Overview of areas within the responsibility of S&O div**

## Research and Development for Future Autonomous Train Operations

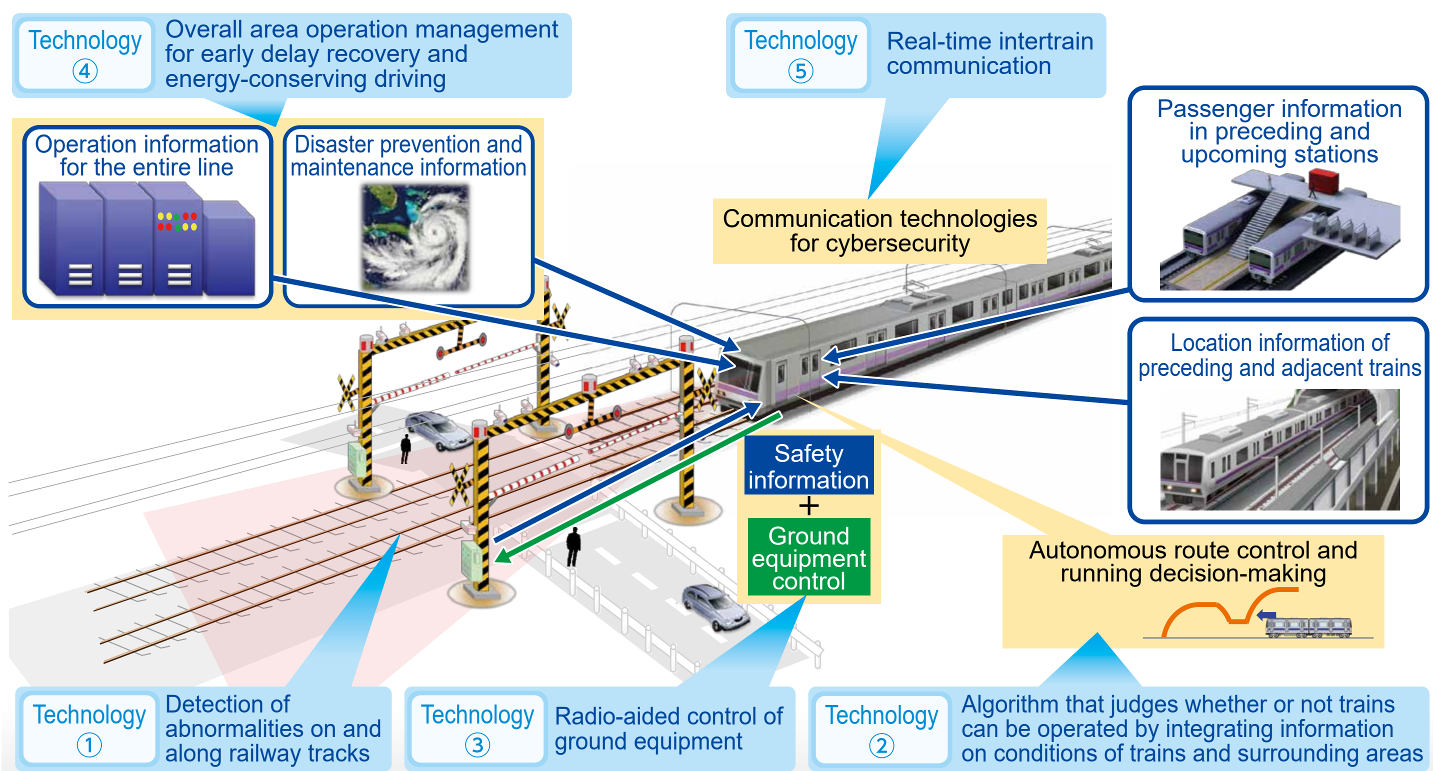
Under the RESEARCH 2025 strategic plan — the basic five-year plan of the RTRI from FY 2020 to FY 2024— the institute has been actively engaged in the research and development of autonomous train operations as a primary concern for the future. As part of these efforts, the S&O div. has promoted the research and development of autonomous train operations.

Autonomous train operation systems enable driverless trains to run safely and flexibly while controlling wayside signalling systems based on information related to conditions on and along railway tracks, passenger flow, disaster prevention, maintenance, and power consumption. The S&O div. is actively engaged in research and development to foster essential technologies for constructing autonomous train operation systems (*Autonomous train operations*)[2], including:

(1) Detection of abnormalities on and along railway tracks using images and Light Detection And Ranging (LiDAR).
(2) Technologies that integrate onboard information about the conditions on and along railway tracks, as well as those of trains, automatically make onboard judgments about the feasibility of train operations.
(3) Onboard radio-aided direct control of ground signalling systems.
(4) Train traffic rescheduling technologies are required to remediate schedule disruptions— including preventing the spread of delays and early delay recovery— and automatic train operation management technologies are required for energy-conserving operations in wide areas.
(5) Real-time intertrain communication technologies with due consideration to cybersecurity.

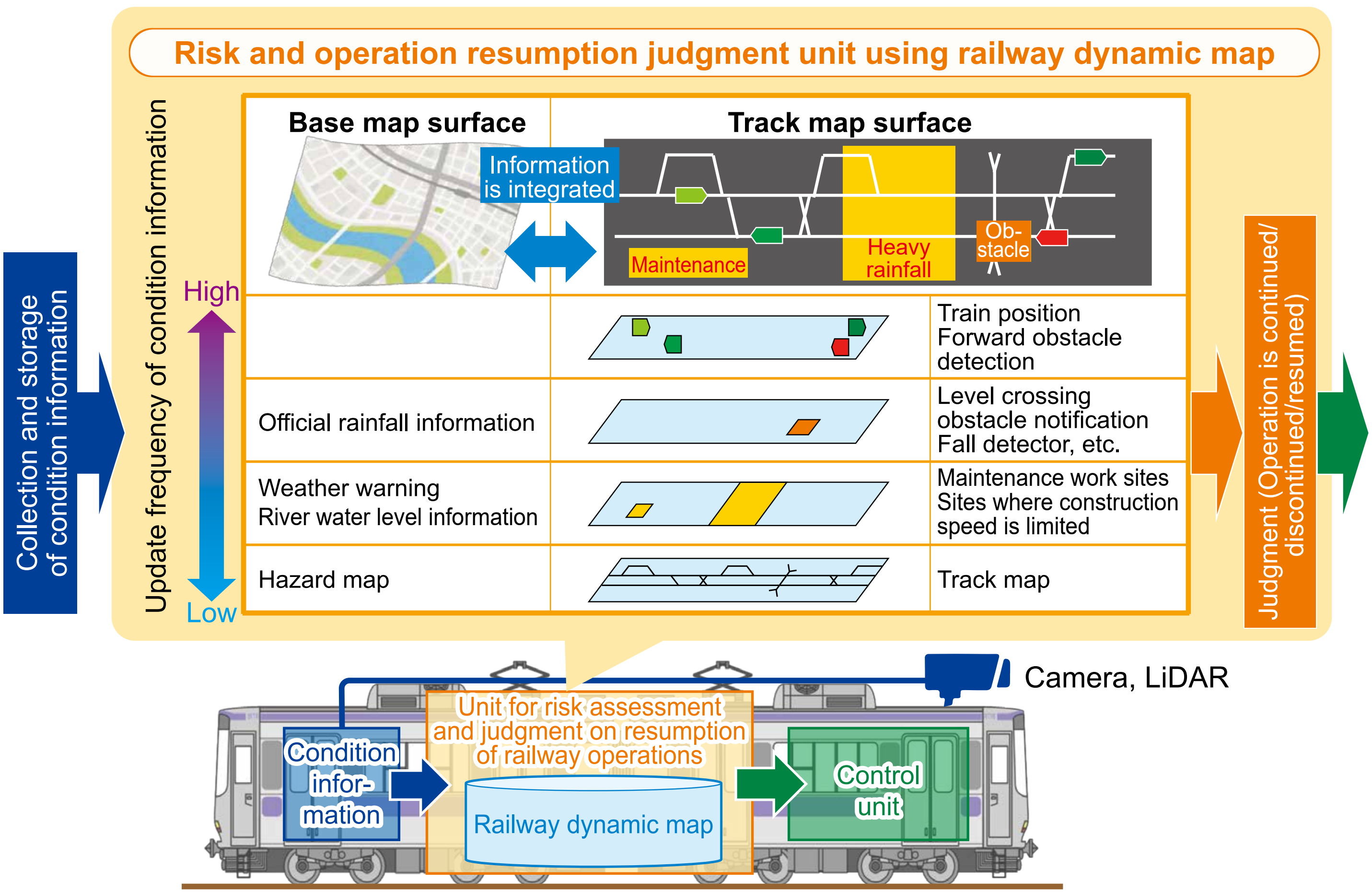
Implementing the aforementioned technologies will facilitate autonomous operations on general railway lines with level crossings as well as highly automated driving using less wayside equipment.

As an illustration of the aforementioned technology (2), we introduce an onboard automatic judgment method for the re-




**Autonomous train operations**

sumption of railway operations utilizing a railway dynamic map. Current decision-making processes require operation commanders at operation control centers to determine whether train operations can be resumed for wide-area operations involving numerous trains. When immediate decisions are necessary, train crews can decide on the resumption of operations. In current autonomous train operation systems, each train must collect various types of condition information required for operation decisions and automatically perform onboard risk judgment and decision-making for resuming railway operations. We developed a railway dynamic map as a basis for conducting onboard risk judgments and making decisions to resume operations (*Automation of risk and operation resumption judgment using railway dynamic map*)[3]. The railway dynamic map, which consists of a base map and track map, is classified hierarchically according to the update frequency of various types of condition information. The railway dynamic map, capable of transitioning between a base map and a track map, can integrate railway-specific kilometrage-based and public condition information based on the position on the map (e.g., weather information) and chronologically manage the integrated information. When abnormalities occur in the condition information on and along railway tracks as well as on weather-related condition information such as rainfall amount and wind speed, the detected information is stored in the railway dynamic map. Then, each train can search for and identify abnormalities in its running route on the map based on its current position. We will continue to work toward innovative automatic risk avoidance during operation and automatic decision-making for resuming train operations based on the railway dynamic map.




**Automation of risk and operation resumption judgment using railway dynamic map**

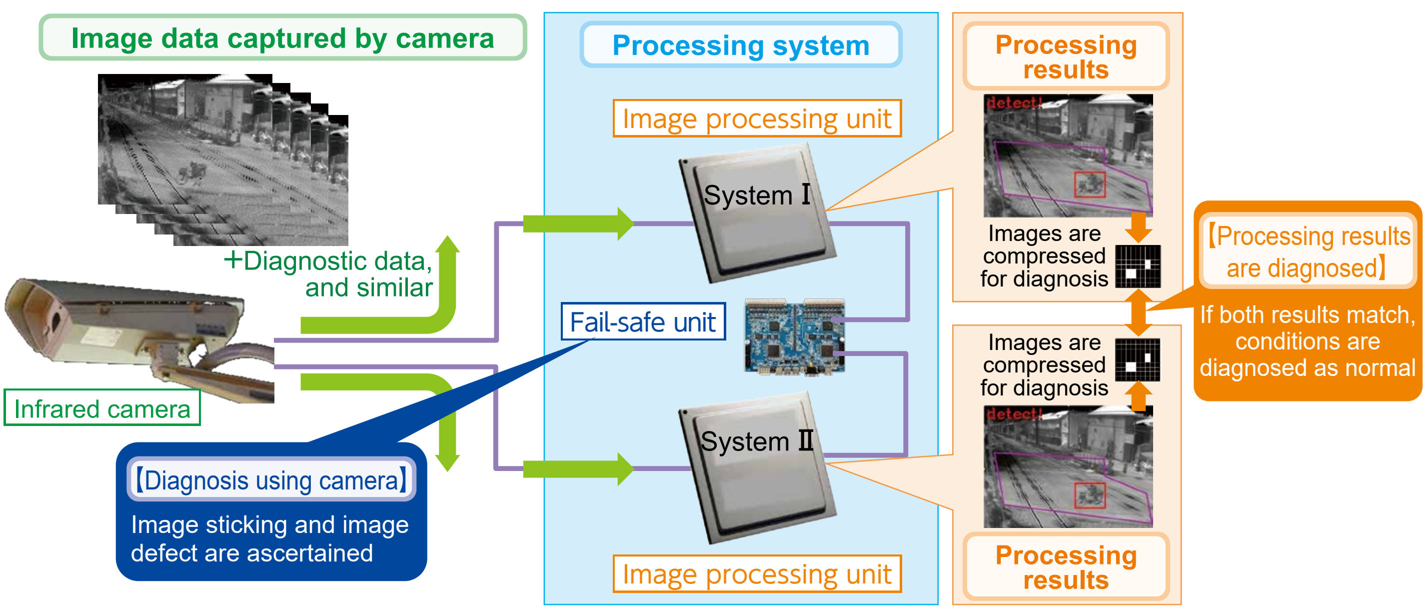
## Method for Ensuring Safety in the Integration of COTS Equipment to Signalling Systems

Although cameras and image-processing units of COTS are often used as obstacle detection devices owing to their increasing sophistication and cost-effectiveness, improving safety measures against failures has become an issue because COTS equipment cannot self-diagnose failures. To solve this issue, we developed a method for diagnosing failures in image-processing units and cameras by combining COTS equipment with the fail-safe units of signalling systems (*Examples of the means of ensuring safety when applying COTS equipment to signalling systems*)[4]. Using this method, we can compress the results processed by image-processing units into images for diagnosis and determine similarities using fail-safe units. Moreover, we can diagnose abnormalities, such as images sticking in the fail-safe unit, by adding new camera functions. Specifically, a function to embed diagnostic data in image data and another one to output test patterns.

We validated the efficacy of the fault diagnosis functions through testing by prototyping a verification device equipped with this method and artificially inducing failures. This method is also applicable to the fault diagnosis of other COTS equipment. With a focus on reducing signalling equipment costs, we are committed to integrating railway-specific technologies with digital technologies. This includes ongoing research and development related to the safe use of cutting-edge digital technologies, such as ICT.

## A Method for Quantitatively Estimating the Lifetime of Signalling Equipment for Shifting to CBM

Signalling equipment comprises numerous electronic devices whose deterioration — and indications of deterioration— are difficult to detect. Consequently, equipment replacement is programmed based on Time-Based Maintenance (TBM) policies that define different update cycles for each type of equipment. By contrast, instead of detecting short-term signs of electronic equipment failure, we aim to achieve CBM. This approach involves conducting long-term lifetime estimation by considering the remaining life and degradation levels of electronic equipment, as well as sensing the operating environmental conditions. In this regard, we identified temperature and humidity as the major causes of equipment deterioration and developed a method for quantitative lifetime estimation based on sensing these variables (*Methods for estimating the lifetime of electronic equipment*). Furthermore, we found that lifetime estimation is possible using weather data released by the Japan Meteorological Agency, corresponding to the equipment location. Additionally, a software tool is being developed, which sequentially calculates and displays the estimated lifetime

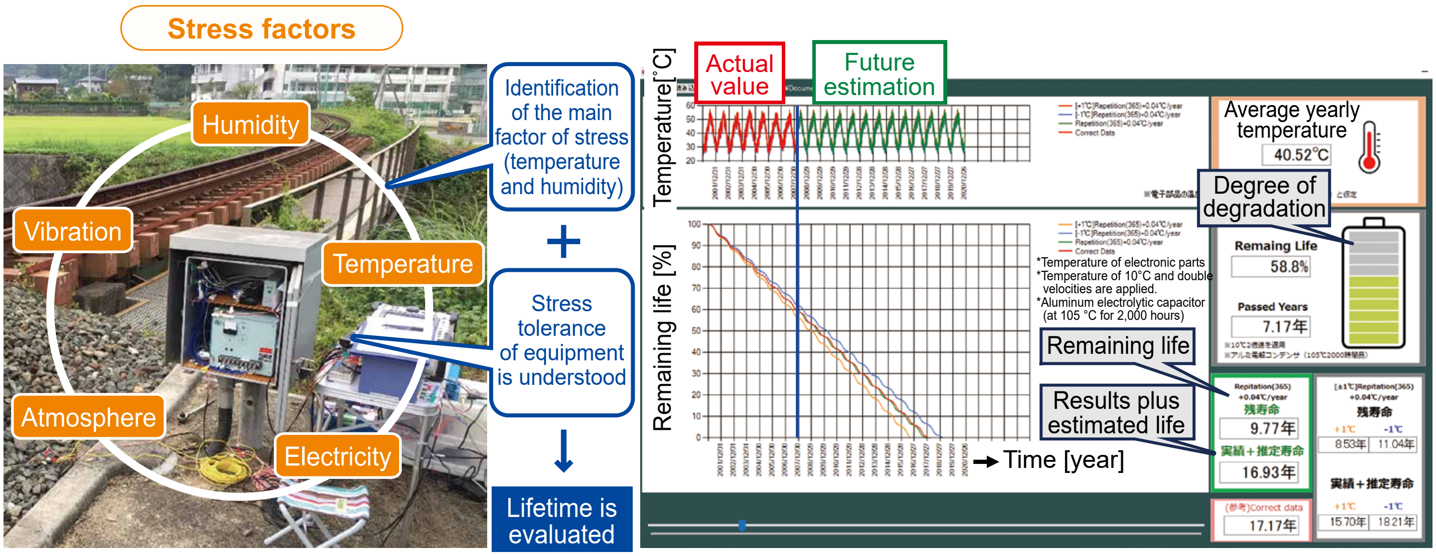



**Examples of the means of ensuring safety when applying COTS equipment to signalling systems**

based on sensed operation environmental conditions (*Methods for estimating the lifetime of electronic equipment*)[5] to enable a more judicious replacement of signalling systems using electronic equipment.

## Conclusions

We provided examples of the latest research and development approaches of the signaling and operation systems. Furthermore, we are currently conducting research to develop methods for predicting train delays using machine learning, automatically creating operation and management plans for scheduling vehicles and crew, and efficiently using regenerative braking energy. For more information on other research and development achievements, please refer to the RTRI website (https://www.rtri.or.jp/rd/division/rd47/). The S&O div. is committed to the advancement of research and development for improving railway safety, reliability, convenience, and energy conservation.




**Methods for estimating the lifetime of electronic equipment**

## References


1) Railway Technical Research Institute: Introduction of the Organization of the Railway Technical Research Institute, Ascent, No. 13, pp. 2-5, 2023.
2) Hideki ARAI, Mitsuyoshi FUKUDA: Trends in Research and Development Activities Related to Railway Signalling and Telecommunication Systems, Quarterly Report of RTRI, Vol. 64, No. 2, pp. 77-80, 2023.
3) Yuki OTA, Hideki ARAI, Takayasu KITANO, Yuki SAKURAI, Shunsuke SOGA: Development of On-board Risk Assessment Method based on “Railway Dynamic Map” for Autonomous Train Operation, Proc. of ASPECT 2023, IRSE, 2023.
4) Akihiro GION, Takeshi ICHIKAWA, Hiroki MUKOJIMA, Nozomi NAGAMINE, Mitsuyoshi FUKUDA, Tomonori ITAGAKI: Configuration and Safety Confirmation Method of Image Processing System Applicable to Signalling Systems, Quarterly Report of RTRI, Vol. 64, No. 2, pp. 90-95, 2023.
5) Hiroyuki FUJITA, Kentaro TSUBAKI, Ken TAKASAKI, Naoyuki OKO: Lifetime Estimation of Electronic Signalling Equipment Based on Sensing Data from Usage Environment, Quarterly Report of RTRI, Vol. 64, No. 2, pp. 96-102, 2023.