ACTIVITIES. 1

Safety Innovations Using Radio-based Train Control System

Digital Technology Applications and Ongoing Partnership

Railways have been playing an increasingly important role within the mobility infrastructure, with safety and reliability enhancement being among the challenges that have arisen along with capacity improvement. To overcome these challenges, JR East and Hitachi have used digital technology to develop an innovative train control system called ATACS. In this article, three people who have been involved in the development project over many years talk together about a variety of topics, including how they went about the collaborative creation of this train control system that has an important role in safety, and the plans for a future in which ATACS will serve as a key technology.

Resolving Challenges Facing Railway Infrastructure

In November 2017, an innovative new train control system commenced operation on the Saikyo Line of East Japan Railway Company (JR East) (see Figure 1). Called the Advanced Train Administration and Communications System (ATACS), this system works in a fundamentally different way to the railway signaling systems that have been developed and used for over 140 years. One of the factors behind why the core system for ensuring safety is now undergoing changes is the issue of ongoing maintenance, including the problem of ageing infrastructure, something that has become a society-wide concern in recent years.

JR East began developing ATACS in 1995, using the Computer and Radio-aided Train Control System (CARAT) developed by the Railway Technical Research Institute as a base and taking over its research and development in preparation for deployment.

One of the major differences between ATACS and previous train control systems lies in the use of track circuits. Legacy systems have used track circuits (electrical currents in the track) to determine train position and signals to notify the driver of the following train about whether they are permitted to enter a section of track and at what speed. As this involves dividing the track into sections based on the location of the signals and only permitting one train at a time in each section (called a "block section"), it requires the installation of a considerable amount of wayside equipment along the track, including track circuits, signals, and cables. This also makes changes to train service frequency costly in time and money because it requires physical work to rearrange the block sections. Another problem at metropolitan and other locations with high traffic density that need to operate efficiently is that they require large amounts of wayside equipment, with track circuits needing to be installed at short intervals.

ATACS, in contrast, is much less costly to install and requires less maintenance because it is a

simple system that does not require track circuits. Yuichi Baba (Deputy General Manager, Tokyo Electrical Construction and System Integration Office, East Japan Railway Company) who has been involved in the development since the beginning, explained as follows.

"Railway signaling systems have been based on track circuits ever since the technology was first introduced in the USA in 1872. Although track circuits have done a good job of ensuring safety over their long history of use, they also suffer from a high rate of faults due to their vulnerability to weather and other environmental factors in their outdoor location. As legacy systems have not included backup equipment, faults can easily lead to train service interruptions, often resulting in inconvenience to passengers. Aware of the dramatic advances in information and communication technology (ICT) that were taking place at the time we began developing ATACS, we decided to take advantage of this latest technology to switch to a different system."

In other words, the development of ATACS was launched with the aim of further improving user convenience as well as to improve reliability and cut life cycle costs.

Yuichi Baba
Deputy General Manager, Tokyo Electrical Construction and System Integration Office, East Japan Railway Company

Figure 1 | **Saikyo Line where ATACS was Installed**

The Saikyo Line that runs from the south of Saitama into Tokyo has been transporting passengers from the metropolitan region to work, school, and elsewhere since it commenced operation in 1985.

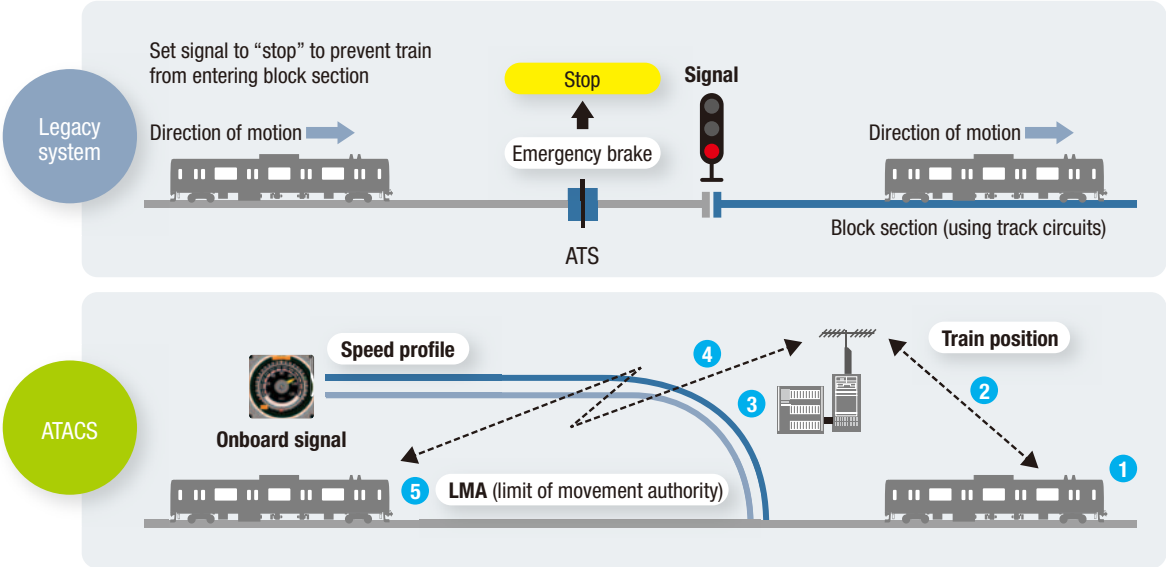
Transition from Wayside Equipment to ICT as Basis of System

Instead of track circuits, ATACS works by having moving trains determine their own location on the track and using radio communications to transfer information bidirectionally between train and wayside to control things like train deceleration and stopping (see Figure 2).

The overall system has a safe configuration that eliminates the lack of backup equipment by providing redundancy for each of its three parts, namely the offboard systems that include Train existence Supervision Equipment, System Management Terminal, and Ground Controller; the onboard systems that include onboard train

Figure 2 | Comparison of ATACS and Legacy System

ATACS is a new radio-based train control system that tracks the location of in-service trains without the need for track circuits and uses radio communications for their control.



ATACS: advanced train administration and communications system ATS: automatic train stop
Source: Yuichi Baba, "Outline of Advanced Train Administration and Communications System," Railway Journal, No. 534, p. 91 (Jan. 2012) in Japanese.

Eiji Sasaki
Senior Engineer, Transport Management Systems & Solution Department, Transportation Systems Division, Railway Systems Business Unit, Hitachi, Ltd.

control, driver cabin displays at the front and rear of the train, and the communication equipment that links these together; and the radio communications systems that include the base stations and onboard radio units (see Figure 3).

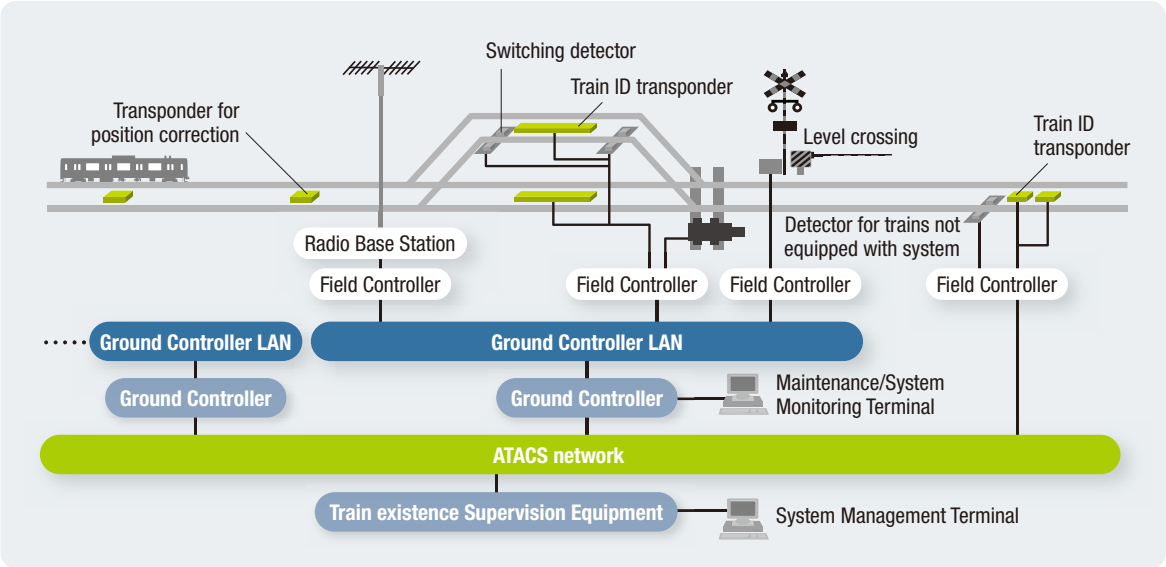
A number of vendors also participated in the development of this unprecedented system, including Hitachi, which is recognised for its many years of experience as a railway system integrator.

Mr. Baba commented that, "At a time when the international market was dominated by overseas vendors known as the 'big three,' the aim was for Japanese companies to work together to come up with a system that would also be capable of use outside Japan."

Eiji Sasaki (Senior Engineer, Transport Management Systems & Solution Department, Transportation Systems Division, Railway Systems Business Unit, Hitachi, Ltd.), who had a leading role in the project for Hitachi, recalled the

Figure 3 | **Offboard System Configuration**

The offboard systems include Train existence Supervision Equipment, System Management Terminal, and Ground Controller.



ID: identification LAN: local-area network

Source: Yuichi Baba, "Outline of Advanced Train Administration and Communications System," Railway Journal, No. 534, p. 92 (Jan. 2012) in Japanese.

situation as follows.

"Hitachi's role in the system upgrade, which demanded groundbreaking technical innovations, was to build the offboard systems. As a broad-based electrical manufacturer with expertise in conventional computer control technology and communications, we were acutely conscious that we needed to do all we could to make the project a success."

The first stage of the project from 1997 involved the testing of basic functions. This was followed by the testing of application functions in the second stage that commenced in 2000. In both cases, the testing was conducted on the Senseki Line in Miyagi Prefecture. Despite being outside the major centres, the Senseki Line provided suitable conditions for developing ATACS, which is intended for use on metropolitan railway lines, including a mix of above-ground and underground track and the use of direct current power feed.

Knowledge and Technology Brought in to Overcome Difficulties

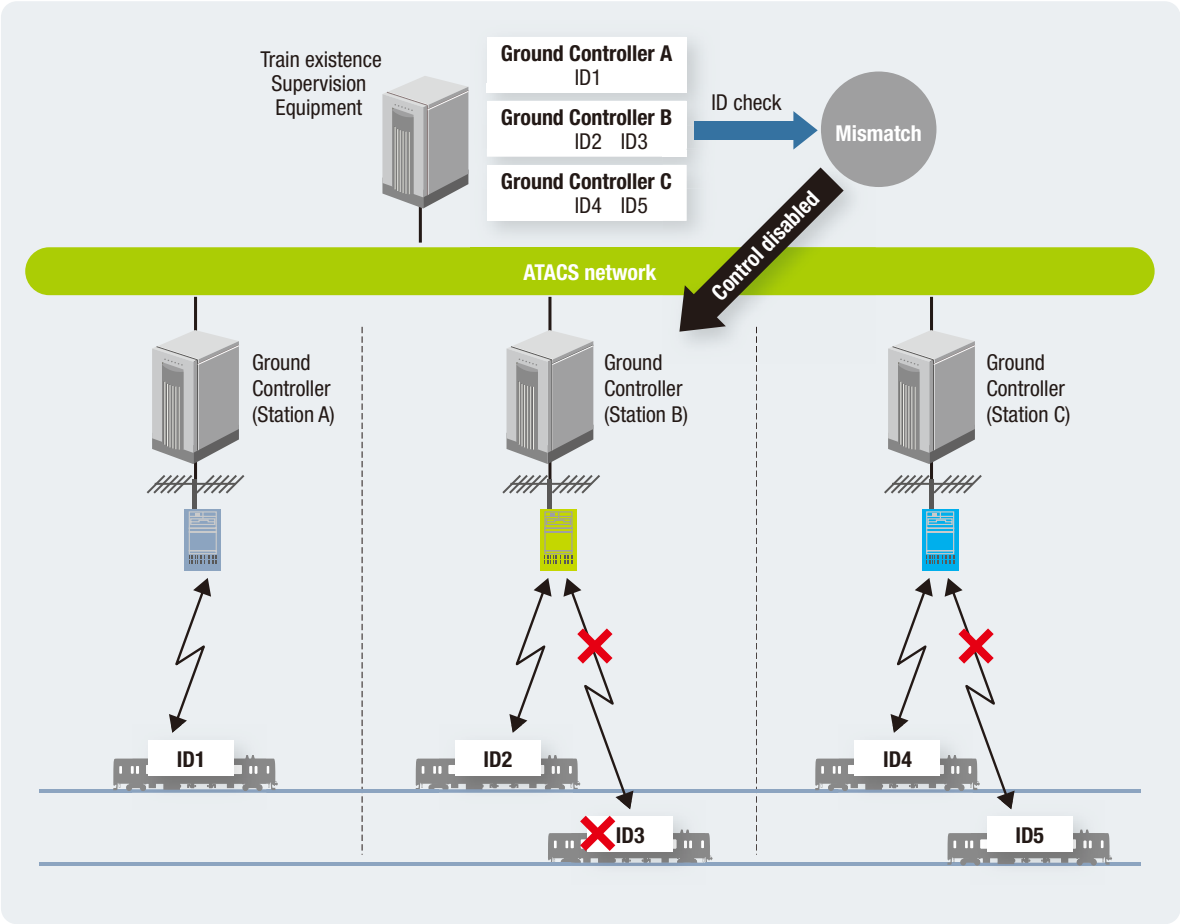
Safety was the top priority for the ATACS development, something that was evident in the development of the radio systems.

Communications-based train control (CBTC) systems are being adopted around the world, primarily for subway, monorail, and other urban railway services. While CBTC, like ATACS, uses radio communications for train control, it typically uses conventional broadband wireless, namely 2.4-GHz-band Wi-Fi*. In contrast, ATACS achieves highly reliable transmission thanks to the development of a radio communication system based on proprietary standards that operates on the dedicated frequencies allocated for train control. The system has also been designed to function in an open urban environment, with encryption

* Wi-Fi is a registered trademark of Wi-Fi Alliance.

Figure 4 | Tracking Function Overview

Because ATACS uses onboard equipment to determine train position, if the ability to determine the location of all trains is lost due to the failure of onboard control or Ground Controller, there is a risk of collision with other trains the position of which is unknown. Accordingly, to ensure that train tracking can be fully and easily restored when recovering from a fault, a design has been adopted in which positions can still be determined even if some equipment fails.



Source: Yuichi Baba et al., "Safety and Reliability of New Radio Based Train Control System in ATACS," The Journal of Reliability Engineering Association of Japan, Vol. 39, No. 4 (Consecutive Vol. 236), p. 210 (2017) in Japanese.

and other measures being used to guard against interference, tapping, spoofing, jamming, and other human-derived threats as well as natural forms of interference such as static.

Meanwhile, one of the major challenges of the project was how to maintain safety in the event of a problem on the system. Consideration of this issue began once basic development of ATACS had completed and the viability of a train control system that uses radio communications had been determined. Unfortunately, it also became apparent as this work progressed that safely restoring the system after a fault was going to be extremely difficult. This difficulty related to problems caused by the loss of track circuits. It became clear that implementation of ATACS could not proceed unless this issue was resolved.

Mr. Baba recounted events by saying, "While the development team spent a lot of time looking for ways to overcome this, a definitive solution continued to elude them. Several months later, JR East staff finally came up with the idea that would form the basis of a solution. Utilizing this idea, they worked with Hitachi engineers on a detailed functional investigation and succeeded in getting the new function fully working. That was the moment we were convinced that ATACS would work in practice."

The new function formed part of the Train existence Supervision Equipment for which Hitachi

was responsible. In simple terms, it is a way to maintain safety when recovering the system from a fault by using the identification (ID) assigned to each train to reliably track its location even if some devices are out of service (see Figure 4). With this function being based on a new approach, JR East and its suppliers worked through a process of trial and error and pooled their know-how to come up with a way of maintaining safety throughout the system.

Numerous Benefits from Adoption of ATACS

Along with commencing trails of a prototype to verify the ATACS functions and safety in October 2003, JR East also set up a committee of experts from inside and outside the company to evaluate the system and verify its safety and other features (see Figure 5). This development, trial results, and the findings of the committee of experts culminated in October 2011 with ATACS entering service on the Senseki Line between Aoba-dori and Higashi-Shiogama. As noted above, ATACS also subsequently commenced operation on the Saikyo Line from November 2017.

Along with a reduction in the amount of offboard equipment, this also resulted in achieving the initial goal of greater safety. The redundancy built into the system is part of this, as is the ability of ATACS to prevent overspeed by having the onboard system calculate the speed profile to use for deceleration control and stopping the train at the location instructed via radio as well as controlling the train speed accordingly. Controlling the train on the basis of this speed profile also makes train driving easier and improves ride comfort. On the Senseki Line, ATACS also includes a world-first level crossing control function to optimize the length of time the crossing is closed.

Figure 5 | Testing of Train Interval Control during ATACS Development

During its development, ATACS underwent testing that took account of functionality and safety.

Source: Yuichi Baba, "Outline of Advanced Train Administration and Communications System," Railway Journal, No. 534, p. 93 (Jan. 2012) in Japanese.

Hitachi, meanwhile, has gained a wide variety of experience from its 20 years of involvement in the project.

As Mr. Sasaki commented, "Given that data handling is so important on the offboard systems for which we are responsible, we were able to make good use of the technologies and know-how of Hitachi, including data cross-referencing using multiple general-purpose computers in redundant configuration, networking, and equipment downsizing to allow installation in the limited space available alongside the railway tracks. We have also taken great confidence from the ongoing safe operation of this train control system that does not require track circuits."

This use of a train control system based on radio communications to improve functionality and deliver high levels of safety and reliability can be seen as part of a general trend. As ATACS is a "total system" with numerous functions that include train interval control, level crossing control, and temporary speed limits, it has also received recognition from outside Japan, including winning an Innovation Award from the International Union of Railways (UIC) in 2012.

Satoru Nagai
Department Manager, Transport Management Systems & Solution Department, Transportation Systems Division, Railway Systems Business Unit, Hitachi, Ltd.

Targeting Innovation in Railways as a Form of Mobility

Extending the installation of ATACS to other metropolitan railways is currently under consideration. Mr. Baba offered the following thoughts about its further potential.

"Amid the emergence of autonomous driving for automobiles, this is a time when railways, too, need to change. Given the ability of ATACS to provide reliable bidirectional communication between onboard and offboard systems and to add new functions through software, the system is likely to have a key role in transportation system innovation. Whereas our focus to date has been on getting ATACS up and running, the challenge now is to come up with all sorts of different ideas for how we can use it as a platform on which to add value. We hope to pick up the pace of collaborative creation with Hitachi so as to provide the best possible transportation systems."

Among the possibilities are integration with traffic management systems and use for condition-based maintenance (CBM). The Autonomous Decentralized Transport Operation Control System (ATOS) jointly developed by JR East and Hitachi operates in the Tokyo region. Its integration with ATACS would open up possibilities for improving scheduling prediction accuracy or the quality of traffic management by incorporating actual train position information. As ATACS is able to acquire a wide variety of information from trains in real time, another possibility is to monitor this data and use it for smart maintenance practices.

Satoru Nagai (Department Manager, Transport Management Systems & Solution Department, Transportation Systems Division, Railway Systems Business Unit, Hitachi, Ltd.), who had a coordinating role in the project for Hitachi, expressed his determination as follows.

"Hitachi is proud to have been involved in developing the world-leading ATACS train control system and we are looking forward to continuing our work with JR East on the next round of innovative systems. While the possibilities are numerous, including autonomous driving and the use of the Internet of Things (IoT) in equipment maintenance, I hope that Hitachi will be in a position to realise them as I believe that it is just such initiatives that correspond to our Corporate Credo of contributing to society through the development of superior, original technology and products."

While innovation is happening in the automotive industry with the shift to electric vehicles and autonomous driving, there is also no doubt that railways will continue to be an important platform for mobility within the infrastructure of society. Hitachi intends to continue taking up the challenge of meeting the increasingly diverse needs of users and the expectations of railway operators.