Introduction of Automatic Train Operation system in JAPAN

Current state of ATO in Japan
Newly developed intermittent type ATP-based ATO system

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Current state of ATO in Japan

1-1 Grade of Automation by IEC 62267
1-2 Outline of typical ATO lines in Japan
1-3 Comparison with ATO introduction status in Japan and overseas
1-4 Future development of ATO in Japan

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2-4 Commencement of commercial operation as GoA 2

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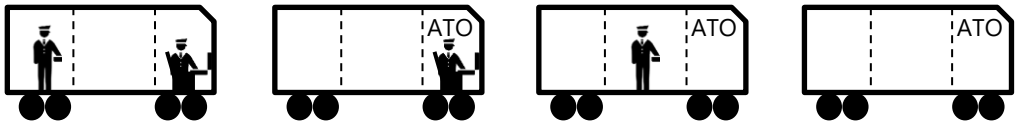
Grade of Automation by IEC 62267

Railway applications
– Automated urban guided transport (AUGT)
– Safety requirements

Basic functions for each GoA

Automated Train Operation



Basic Functions	GoA 0	GoA 1	GoA 2	GoA 3	GoA 4
	TOS On-site	NTO Non-automated	STO Semi-automated	DTO Driverless	UTO Unattended
Ensuring safe movement	Staff	Staff/System	System	System	System
Driving	Staff	Staff	System	System	System
Supervising guideway	Staff	Staff	Staff	System	System
Supervising passenger transfer	Staff	Staff	Staff	Staff/System	System
Dealing with emergency	Staff	Staff	Staff	Staff	System/OCC

Staff: responsibility of operation staff (may be realized by technical system)
System: realized by technical system **OCC**: Operation Control Center

Outline of typical ATO system in Japan

About 40 lines (more than 700 km) in operation as ATO

Currently Introduction case	GoA 2	GoA 3	GoA 4
	STO Semi-automated	DTO Driverless	UTO Unattended
Japan	**30 lines** Marunouchi line Tsukuba Express Etc.	**1 line** Disney resort line	**9 lines** Yurikamome Port liner
Overseas	**About 350 lines** RATP line 3, 5 Etc.	**About 10 lines** BART Etc.	**About 140 lines** RATP line 1, 14 Nuremberg U2, U3 Etc.

Current ATO preconditions in Japan

- Introduced continuous type ATP called Automatic Train Control, ATC
- Physically separated from outside
  by dedicated elevated tracks, underground tracks and platform screens

Outline of typical ATO system in Japan

Introduction example: Marunouchi line, Tokyo Metro


Partial-height platform screens

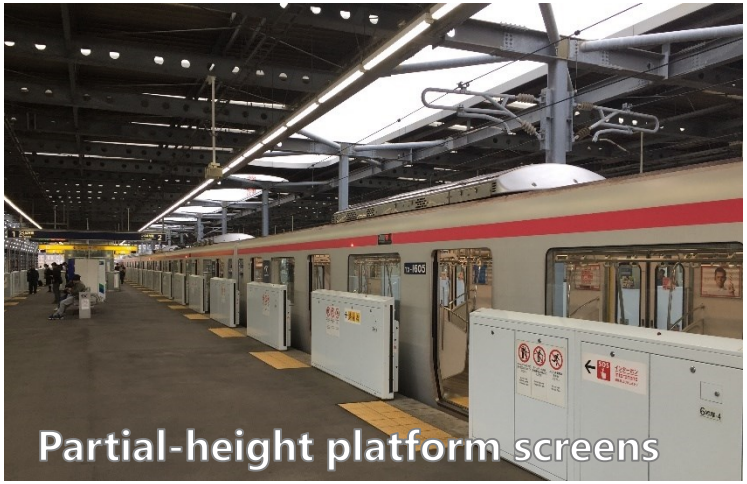

Beacons of on-board and ground

Marunouchi line, GoA 2 with ATC

between Ogikubo and Ikebukuro via Shinjuku,
Nakano-sakaue and Honancho (branch line)
27.4 km (Number of stations: 28), Maximum speed: 75 km/h

Outline of typical ATO system in Japan

Introduction example: Tsukuba Express line, MIR

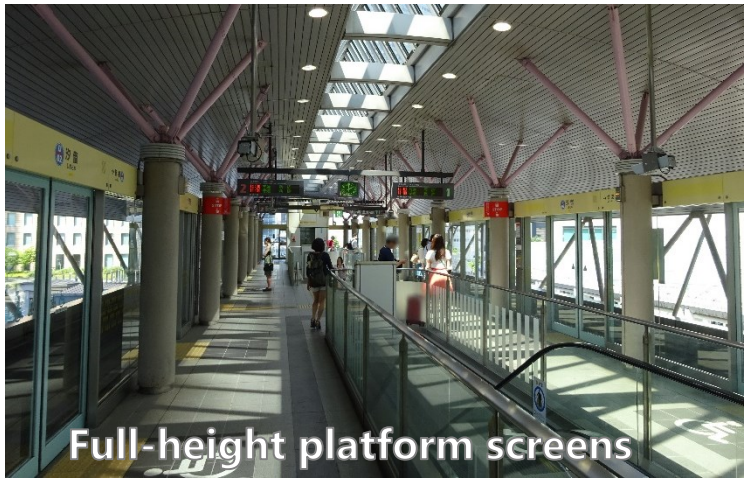

Partial-height platform screens


Beacons on the ground

Tsukuba Express line, GoA 2 with ATC
between Akihabara and Tsukuba
58.3 km (Number of stations: 20),
Maximum speed: 130 km/h

Outline of typical ATO system in Japan

Introduction example: Yurikamome



Yurikamome, GoA 4 with ATC

between Shimbashi and Toyosu

14.7 km (Number of stations: 16), Maximum speed: 60 km/h

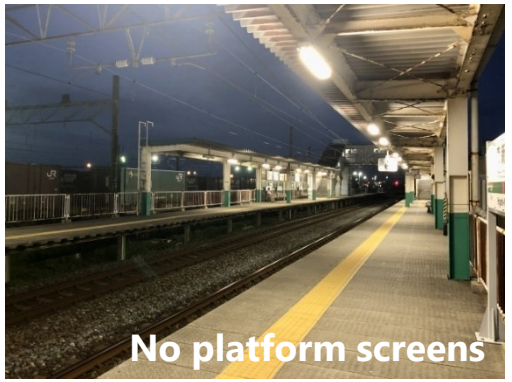
Upper left photo: Shiodome station platform
https://en.wikipedia.org/wiki/Shiodome_Station#/media/File:Shiodome-Sta-Yurikamome-Platform.JPG

Comparison with ATO introduction status in Japan and overseas

Current status of introduction in Japan

- ATO include GoA 4 have a long history – *first GoA 4 example in the world*
- About 40 lines operated mainly in subway (GoA 2) and AGT (GoA 4)
- No example of ATO in a general lines[1)]

1) General lines: not separated from outside
Ex. with level crossings, without platform screens



Current status of introduction in overseas

- GoA 2 is progressing not only in subway but also urban railways
- More than 100 lines operated mainly in subway (GoA 3 and GoA 4)

Ref.1 Aoyagi: "Efforts for automatic driving in railways and the concept of safety and reliability " Reliability Forum 2021, REAJ (in Japanese)

Future development of ATO in Japan

Driverless operation in general lines, aiming for GoA 3 and 4

☐ Need to sort out new requirements that are different from AGT

AGT
with ATC
Ex. Yurikamome

General lines
with ATC
Ex. Yamanote line

Physical separation from guideway	▶	Physical barriers along track Track intrusion detection
Full-height platform screens	▶	Partial-height platform screens Track intrusion detection
Prevention of physical obstacles to adjacent lines	▶	Derailment detection or detection of obstacles to adjacent lines
Without level crossings	▶	Warning detection Detection of obstacles
Evacuation taxiway for easy evacuation	▶	Automatic stopping avoiding places for difficult evacuation

Replaced by equal or better safety

*Currently, **driverless operation** in general lines is one of the topics in the study group of Ministry of Land, Infrastructure, Transport and Tourism (MLIT) And this topic is beginning to be considered by JR East*

Ref.1

Future development of ATO in Japan

Aiming to realize new definition “GoA 2.5”

☐ Reduction of train operating costs to maintain rural lines

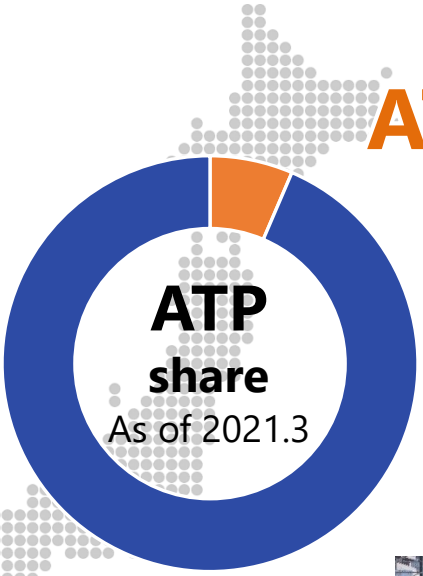
Realizing ATO based on intermittent type ATP called ***Automatic Train Stop, ATS***

- In current Ministerial Ordinance in Japan,
  GoA 3 and GoA 4 are assumed to be performed by ATO system under protection of ATC
- Introducing ATC would entail a huge amount of investment costs to replace ATS

Greater Tokyo, Osaka & JR Central lines
ATS-P

Other conventional lines
ATS-S, ATS-Ps, etc.

JR Hokkaido & Kyushu lines
ATS-DN, ATS-DK



AGT
ATC

Senseki & Saikyo lines
ATACS

Subway
ATC

Yamanote line
D-ATC

Future development of ATO in Japan

Aiming to realize new definition “GoA 2.5”

☐ Reduction of train operating costs to maintain rural lines

ATO with staff who does not have driver's license

- Staff who is not required the driver's license is placed at front end of the train instead of the licensed driver
- **Staff at the front** end is in charge of roles such as stop operation and evacuation guidance in emergencies

Basic Functions	GoA 2	GoA 2.5	GoA 3	GoA 4
	STO Semi-automated	Not defined in IEC 62267	DTO Driverless	UTO Unattended
Ensuring safe movement	System	System	System	System
Driving	System	System	System	System
Supervising guideway	Driver	**Staff**	System	System
Supervising passenger transfer	Driver/Conductor	**Staff**	Staff/System	System
Dealing with emergency	Driver/Conductor	**Staff**/OCC	Staff	System/OCC

*Currently, a type of the train operation tentatively called **GoA 2.5**, is one of the topics in the study group of Ministry of Land, Infrastructure, Transport and Tourism (MLIT)*

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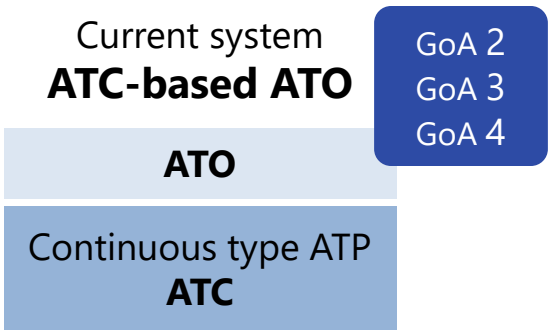
Concept of intermittent type ATP-based ATO system

Background and purpose

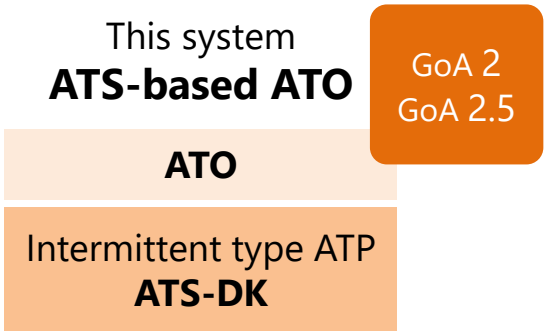
☐ Reduction of train operating costs to maintain rural lines

Realizing ATO based on intermittent type ATP

- Based on ATS-DK introduced in Kyushu Railway Company (JR Kyushu) general lines
- Reducing cost by utilizing established ATS for automatization of driving operation



Target: AGT, subway, urban lines



Target: rural lines, established ATS lines

Realizing ATO with staff at front end without driver's license

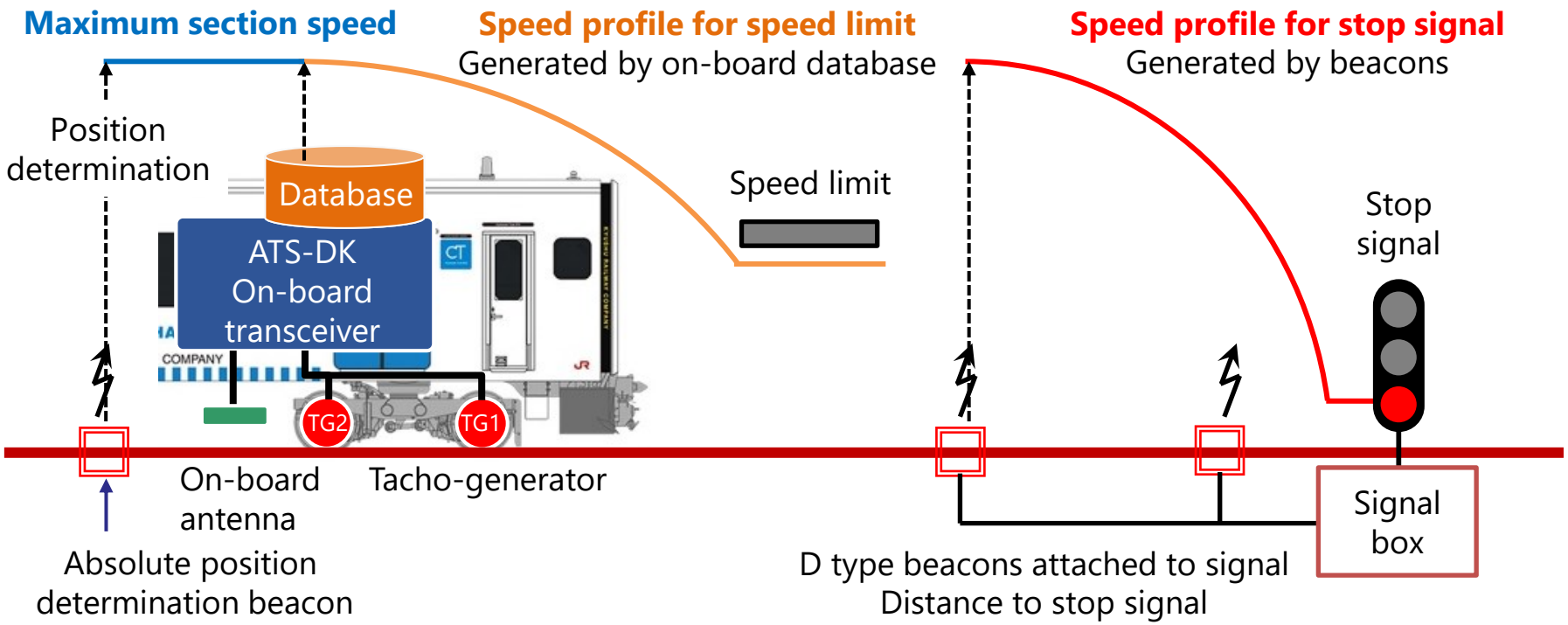
- Staff at the front end is in charge of roles such as stop operation and evacuation guidance in emergencies

Development of ATS-DK based ATO system equivalent to GoA 2.5

Concept of intermittent type ATP-based ATO system

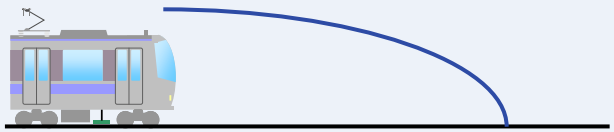
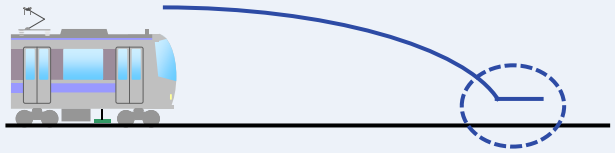
Outline of ATS-DK

- Introduced in JR Kyushu general lines
- Intermittent type ATP with permissible speed profile
- Continuous detection of absolute position for using on-board database



Concept of intermittent type ATP-based ATO system

Comparison with ATC-based ATO

Key difference	ATC	**ATS** with permissible speed profile
Speed check	**Verification from 0 km/h** 	**No verification from 0 km/h** 
Control information update frequency	**Continuous signal transmission by rails etc.** 	**Intermittent signal transmission by beacons** 

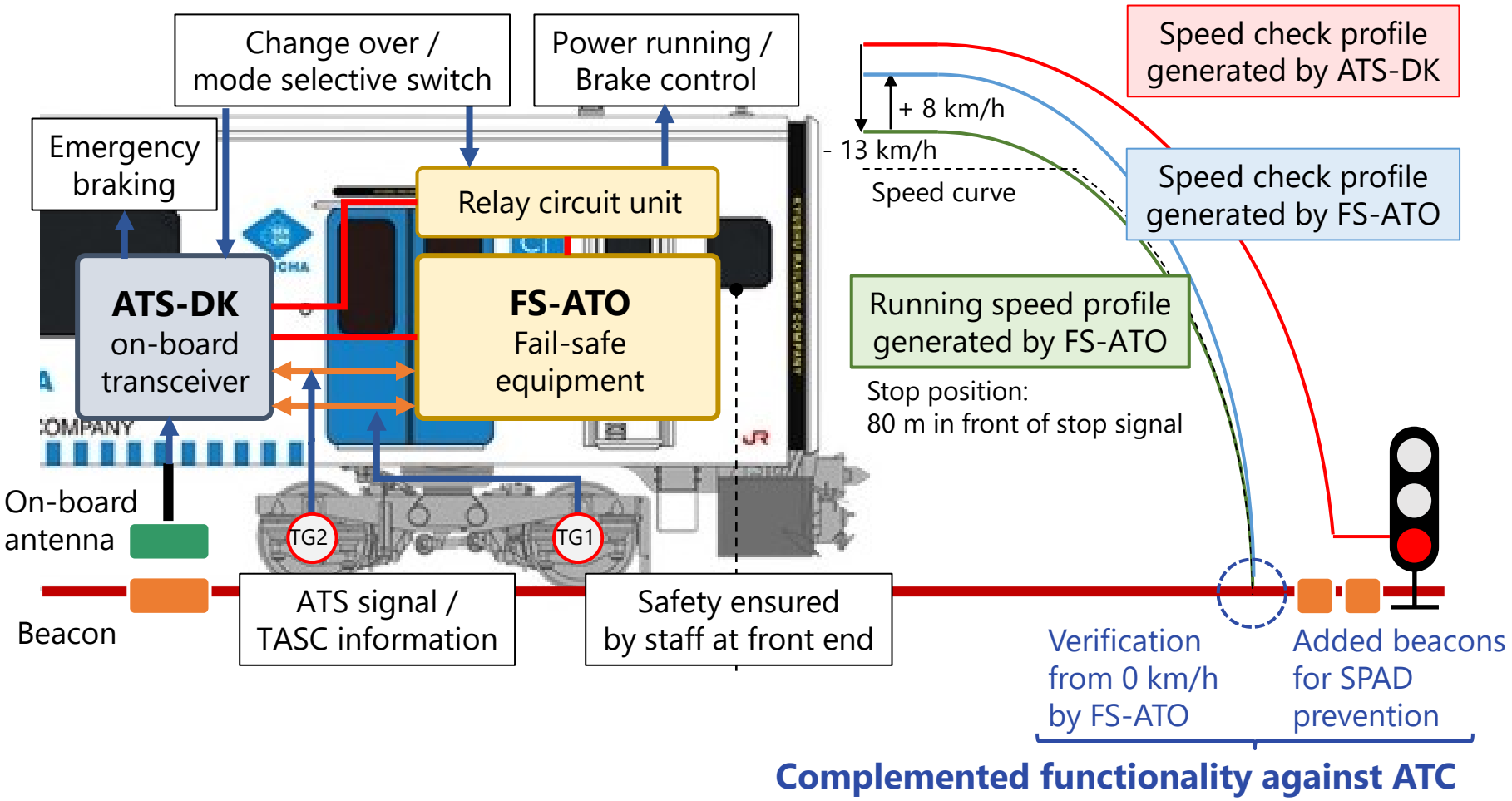
- Two main impacts of the above differences for control functions
  1. Departure control from stopped state
  2. Response to sudden signal changes to stop in emergency and the like

Ensuring the required safety by complementing functionality

System overview

System configuration

☐ Added new ATO equipment and beacons to existing ATS-DK equipment



System overview

Method of achievement for function complement

☐ Introducing fail-safe ATO on-board equipment called FS-ATO

Ensuring required safety by whole system with combination of FS-ATO and ATS-DK

- This concept is different from the current ATO and indicates one direction for realizing ATO without redesigning of existing ATS

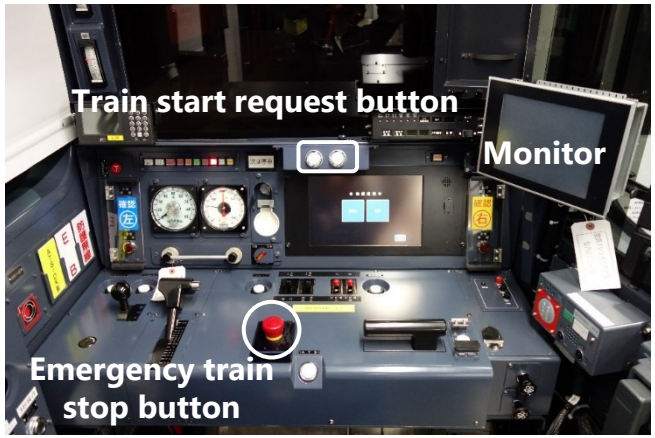
	ATC-based ATO	**ATS-based ATO** Combination of ATS-DK and FS-ATO
Automatic operation function	**ATO** Equipment and function are not required to be safety-related	**FS-ATO** Safety-related fail-safe equipment is applied and performs the part of safety-related functions
Safety function	**ATC** Equipment and function are required to be safety-related	**ATS-DK** Safety-related fail-safe equipment is applied and performs the part of safety-related functions required as ATS

Functional verification tests

Test method

☐ Carried out with mass-produced prototype equipment

Phase	Test type	Periods	Location	Contents
1	Factory test	Aug. ’19	Manufacturer’s factory	Functional verification with simulator
2	Static test	Aug. ’19	Rolling stock depot	Combination test with vehicle, Input / output confirmation
3	Running test 1	Sep. – Oct. ’19	Rolling stock depot	Basic function, reproduction anomaly in test track
4	Running test 2	Oct. – Nov. ’19	JR Kashii Line between 3 stations	Basic function, reproduction anomaly in commercial line



Functional verification tests

Test results

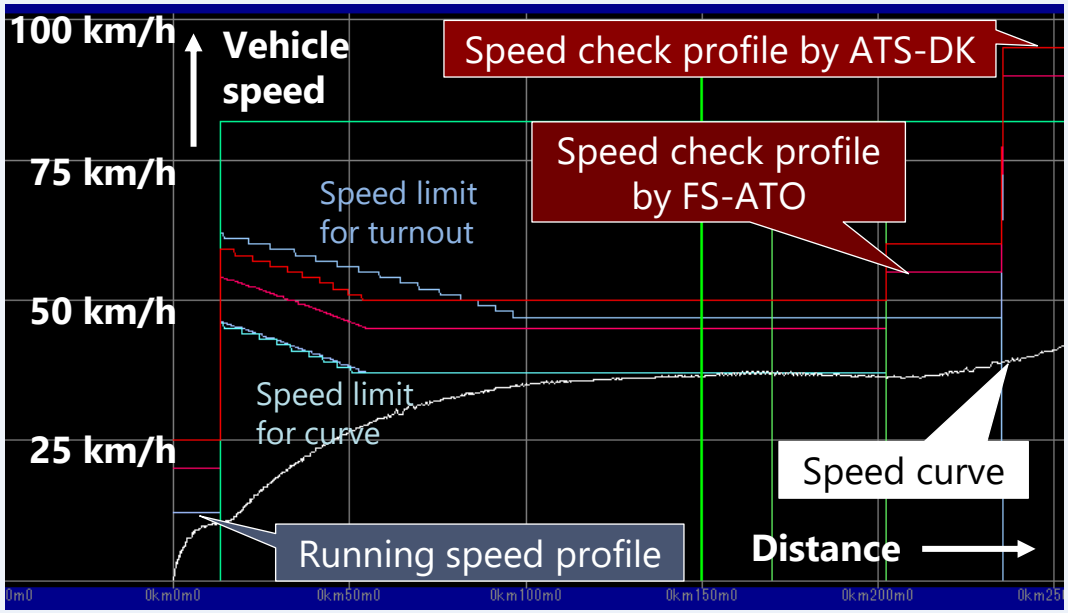
- Control function of safety and operation
- Distance calculation and stop position accuracy

No problem in practical use because the functions of this system were operating according to the specifications through functional verification tests

Example of control state at departure from first station

Verified following functions
by analyzing operation status record
data of ATS-DK and FS-ATO equipment

- Speed profile generation
- Receiving beacon information
- Automatic running control
- Distance calculation accuracy



Commencement of commercial operation as GoA 2

Verification of control stability

- 2,500 km running test
- 1,000 station stops

Tuning and verification of stop position accuracy, driving time, and ride quality were carried out

Commercial operation as GoA 2 for proving runs

- Since the end of 2020
- A licensed driver has been onboarding a commercial train on JR Kashii line for proving runs toward the realization of GoA 2.5

Conclusions

Current state of ATO in Japan

- ATO include GoA 4 have a long history – *first GoA 4 example in the world*
- About 40 lines operated mainly in subway (GoA 2) and AGT (GoA 4)
- No example of ATO in a general lines

In the future

- Driverless operation in general lines, aiming for GoA 3 and 4
- Aiming to realize new definition "**GoA 2.5**"