International Railway Research Board

INTERNATIONAL UNION OF RAILWAYS

IRRB WEBINAR

AUTONOMOUS TECHNOLOGIES IN RAIL
ANTICIPATING EXPECTATIONS

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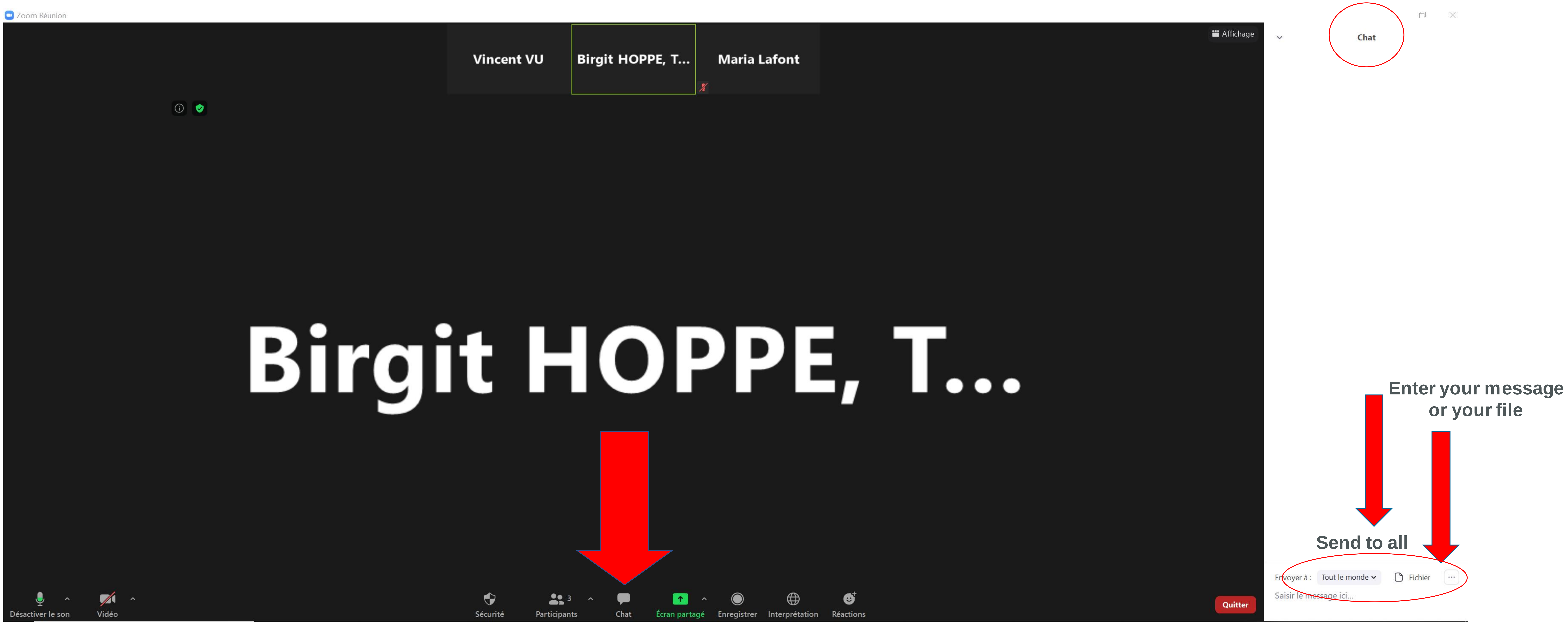

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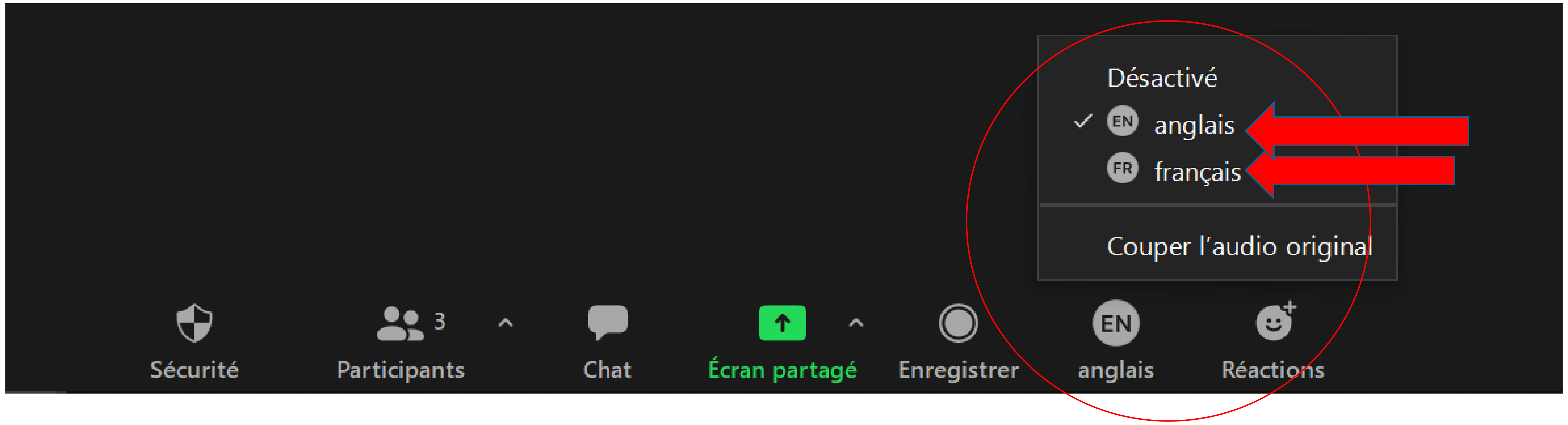

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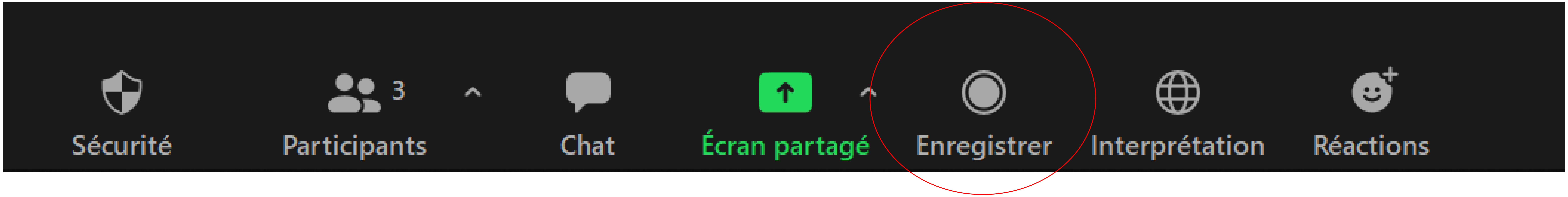

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IRRB

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Agenda

Agenda

13:00 – 13:05 : Opening – Welcome- Introduction

Mr Vladimir Andreev – UIC IRRB Chairman, Head of the Technical Policy Department JSC « Russian railways » (Russia)

13:05 – 13:15 : Moderator's Word of Introduction

Dr Boris Lapidus – Honorary IRRB Chair, Chair of the Joint Scientif Council of JSC « Russian railways » (Russia)
Mr Christian Chavanel - Director of the UIC Railway System Department (France)

13:15 – 13:35 : 1. Challenges, opportunities and perspectives of rail automation in Australia. The experience of Rio Tinto group

Mr Lido Costa – Principal Auto Haul, Auto Haul and Rail Productivity, Rio Tinto Group (Australia)

13:35 – 13:55 : 2. The application of ATO for China High-Speed Railway Lines **application of ATO for China High-Speed Railway Lines »**

Mr Zhao Yang – Senior Researcher, Director of Chief Engineer Office, Research Institute CARS (China)

13:55 – 14:15 : 3. SNCF Autonomous Train Programme

Ms Gemma Morral-Adell – SNCF Innovation and Projects Directorate (France)

14:15 – 14:35 : 4. Delivering sustainable/digital/automated service-oriented rail system to European citizens

Ms Lea Paties – Programme Manager at the Shift2Rail Joint Undertaking (Belgium)
Mr Benoît Bienfait - Main Line ATO Design Authority at Alstom (Belgium)

14:35 – 14:45 : Coffee break

14:45 – 15:05 : 5. Challenges, opportunities and perspectives of rail automation and autonomation in the Russian Federation. Experience of the RZD Holding »

Mr Pavel Popov – Deputy Director General – JSC NIIAS, RZD Holding (Russia)

15:05 – 15:25 : 6. « Challenges, opportunities and perspectives of rail automation and autonomation. Experience of the AAR »

Mr Gary Fry – Vice President for Research and Development, AAR, Transportation and Technology Center (USA)
Mr Thomas Nast - Principal Investigator II, TTCI (USA)

15:25 – 15:55 : Panel discussion

Dr Boris Lapidus – Honorary IRRB Chair, Chair of the Joint Scientif Council of JSC « Russian railways » (Russia)
Mr Christian Chavanel - Director of the UIC Railway System Department (France)
Speakers and Participants

15:55 – 16:00 : Closing remarks

Mr Vladimir Andreev – UIC IRRB Chairman, Head of the Technical Policy Department JSC « Russian railways » (Russia)

Opening – Welcome - Introduction

Mr Vladimir Andreev

UIC IRRB Chairman Head of the Technical policy Department JSC « Russian Railways » (RZD)

Moderator’s Word of Introduction

Dr Boris Lapidus

Honorary IRRB Chairman, Chair of the Joint Scientific Council of JSC “Russian railways”

Mr Christian Chavanel

Director of UIC Railway System Department

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“Challenges, opportunities and perspectives of rail automation in Australia. The experience of Rio Tinto group”

Mr Lido Costa

Principal Engineer AutoHaul – AutoHaul and Rail Productivity, Rio Tinto Group, Australia

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“The application of ATO for China High-Speed Railway Lines”

Mr ZHAO Yang

Senior Researcher, Director of Chief Engineer Office, Signal and Communication Research Institute, CARS

The Application of ATO for China High-speed Railway Lines

Zhao Yang

Signal and Communication Research Institute, CARS

TABLE OF CONTENTS

1. Introduction

Automatic Train Opration（ATO） can effectively ensure safety, saving energy conservation, Increase efficiency, reduce driver labor intensity, and improve passengers experience which is the important sign of high-speed railway intelligence.

The application of ATO in the Pearl River Delta Intercity Railway and the Beijing-Zhangjiakou High-speed Railway further improved the safety and automation level of train operation.

1. Introduction

In order to meet the operation requirements of the Pearl River Delta intercity railway , China Railway began to develop ATO system in 2011. Considering the operation characteristics of intercity railway and meeting the requirements of cross line operation, ATO is superimposed on CTCS-2 system.

In 2015 , Pilot test for CTCS2+ATO

In 2016 , Put into operation

As the CTCS2+ATO system of the intercity railway in the Pearl River Delta has been used well, China Railway began to develop the CTCS3+ATO system for high-speed railways in 2017.

In 2018 , Pilot test for CTCS3+ATO

In 2019 , Put into operation

2. CTCS2+ATO for Intercity Railway

main technical features

Technical features of C2 + ATO

- GOA 2
- GSM-R/CSD
- Independent ATO and ATP
- Real-time Plan adjustment
- Interoperation with CTCS2
- Automatic Door Control

2. CTCS2+ATO for Intercity Railway

On March 30, 2016, the Pearl River Delta Intercity Dongguan Huizhou line and Guangzhou Foshan Zhaoqing line were successfully put into operation, and the automatic driving technology was applied to the 200km / h Railway.

Up to now, 459 km of intercity railway has been built in the Pearl River Delta, and more than 40 trains equipped with CTCS2 + ATO system have been put into operation.

3.CTCS3+ATO for High-speed Railway

The functions of the automatic driving system include **automatic departure, automatic interval operation, automatic stop at station, automatic door opening and protection**, and **door / platform door linkage control.**

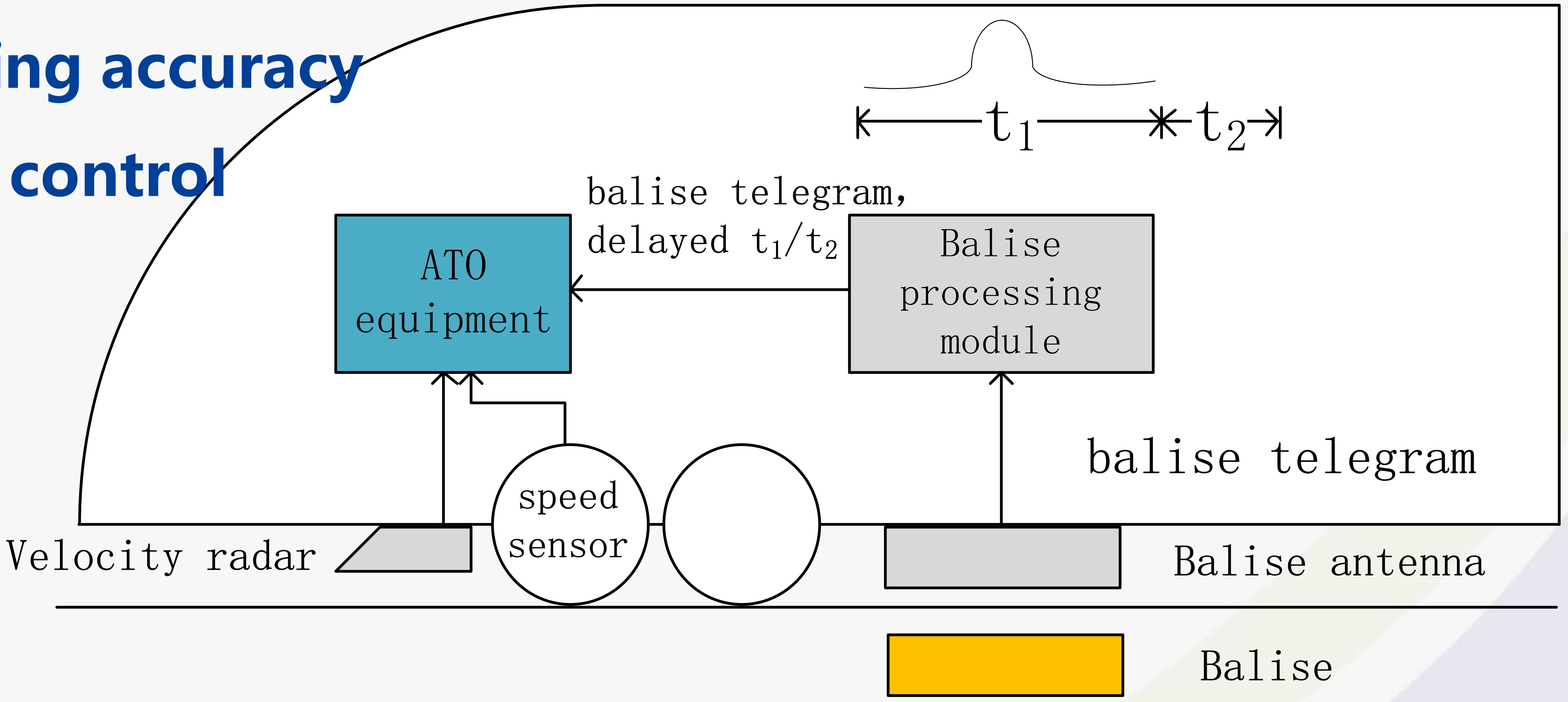
- Automatic station departure
- Interval automatic operation
- Automatic stop at station
- Automatic door opening and protection
- Door / platform door linkage control

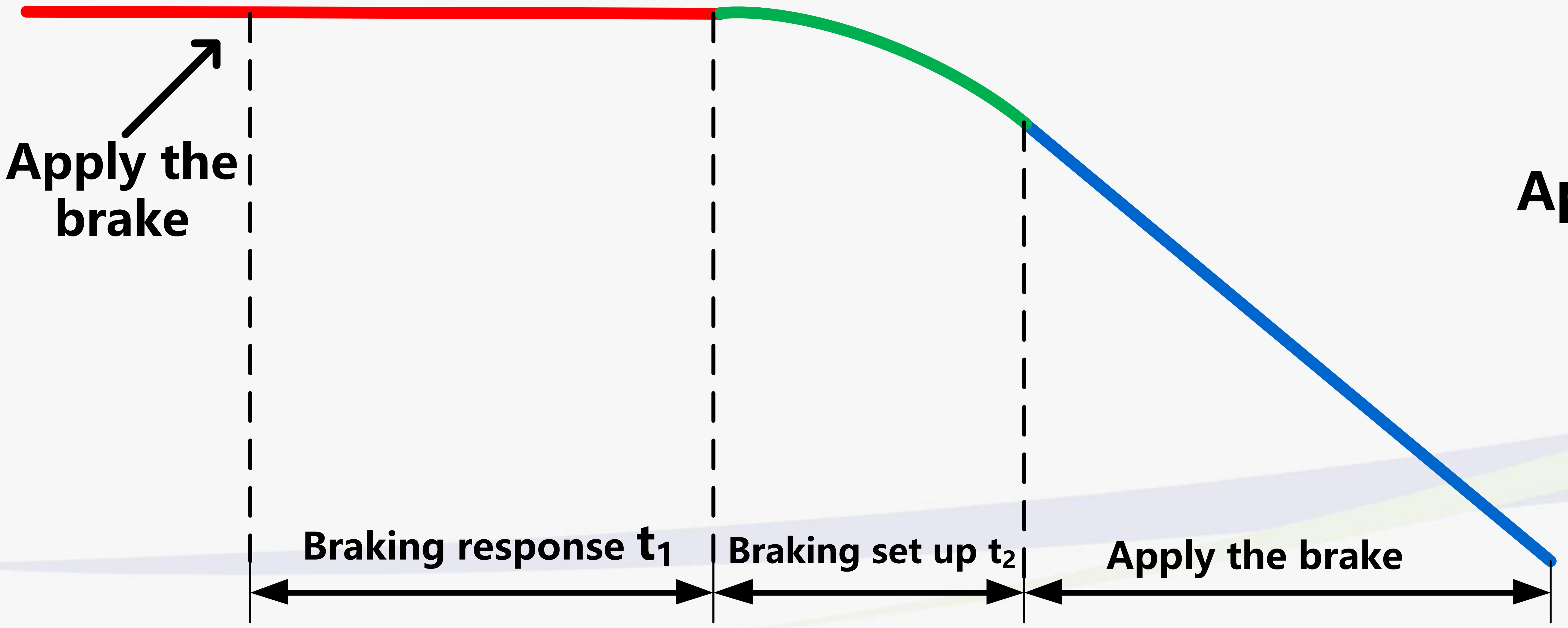
3.CTCS3+ATO for High-speed Railway

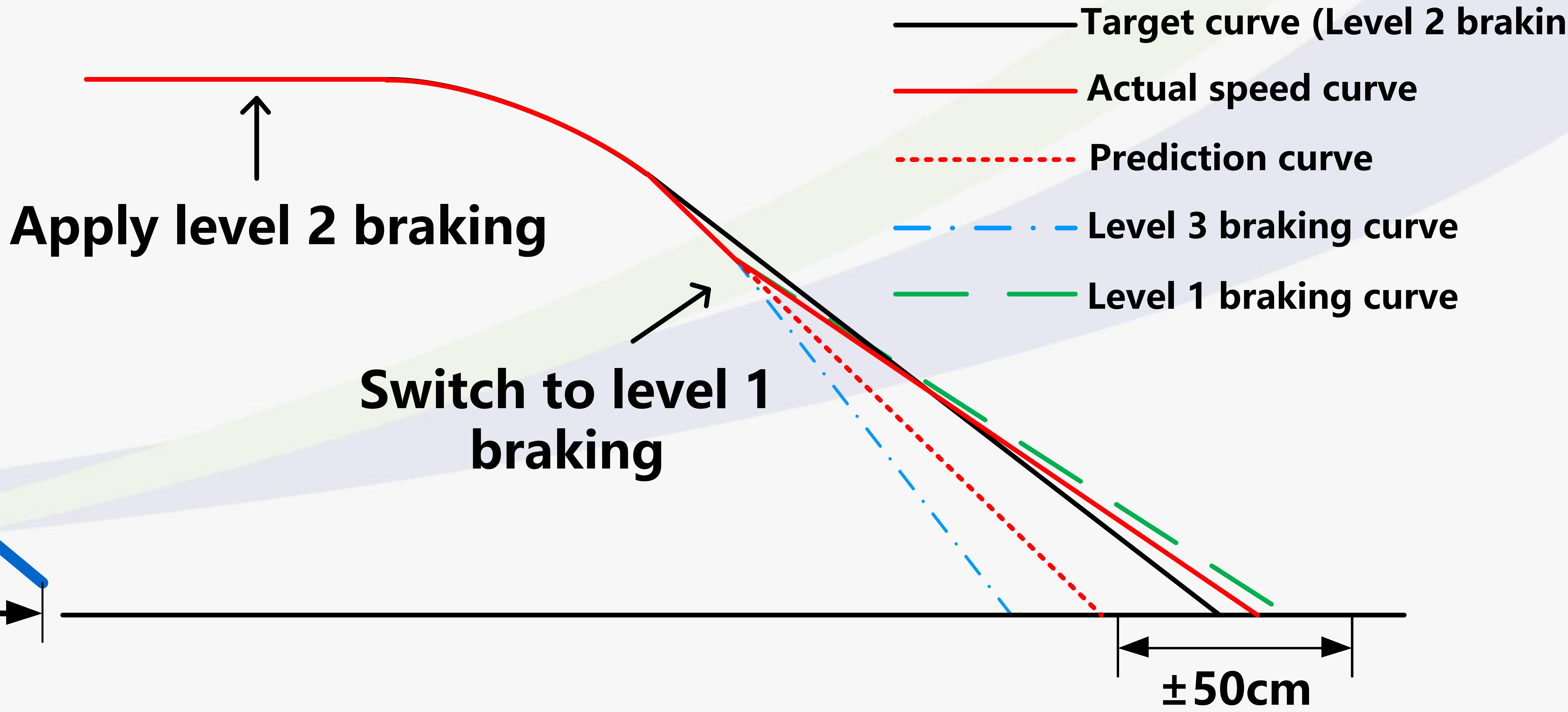
Accurate stopping

- **Four key technologies**
  - **Accurate stopping**
  - **Smooth train control**
  - **On-time operation**
  - **Energy conservation**

- **Improve positioning accuracy**
- **Optimize parking control**







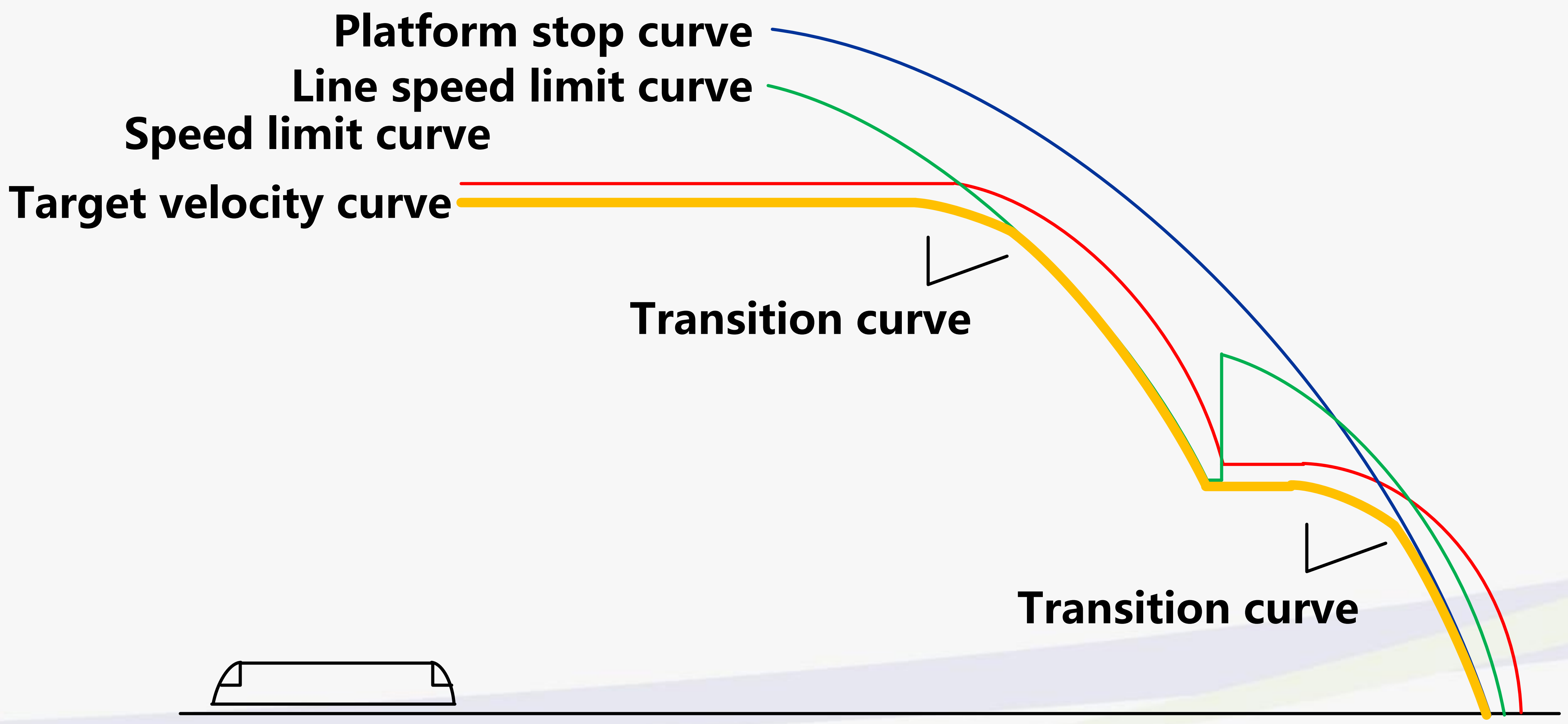
3.CTCS3+ATO for High-speed Railway

Smooth train control

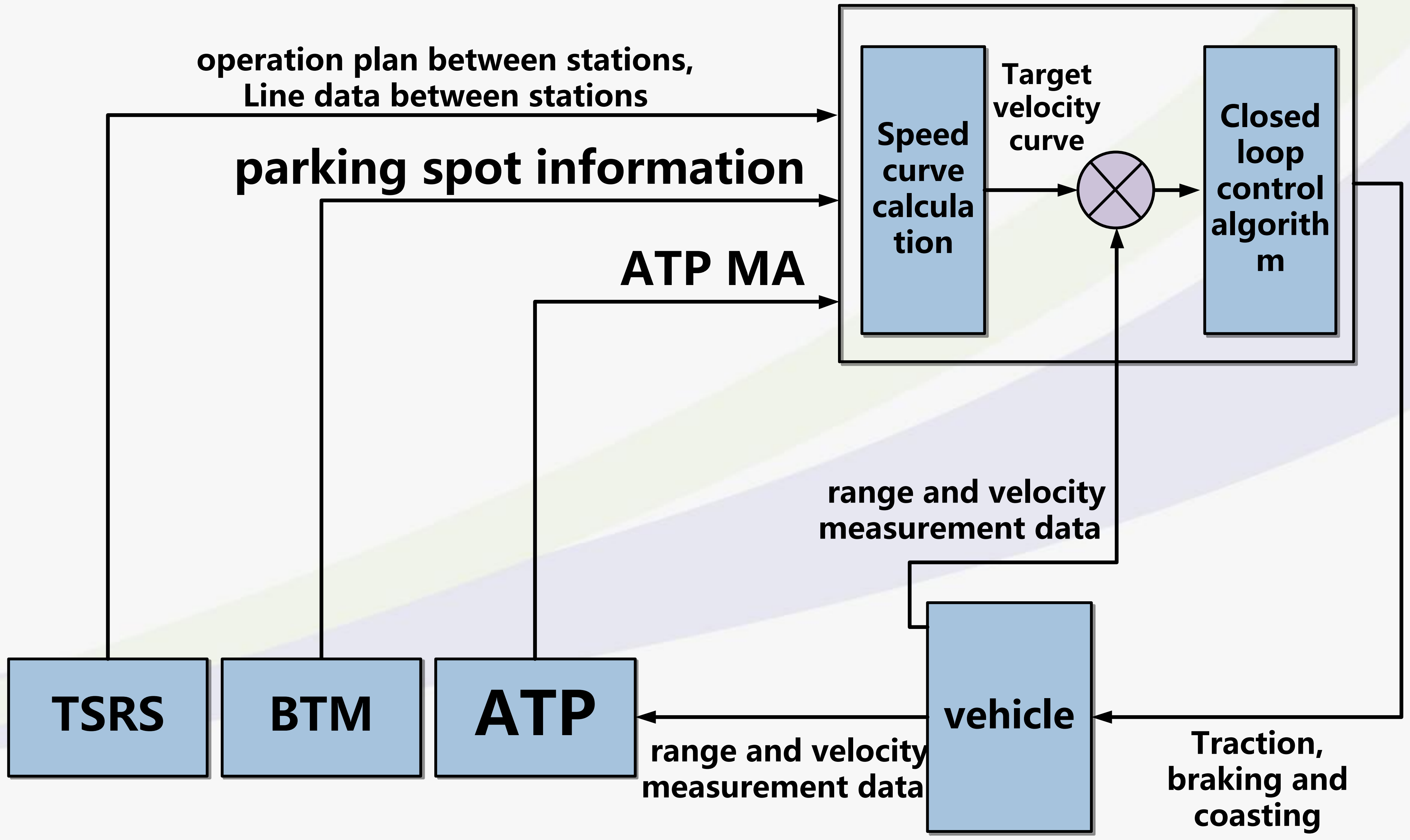
- **Four key technologies**
  - Accurate stopping
  - Smooth train control
  - On-time operation
  - Energy conservation

◆ Target velocity curve calculation

◆ Target velocity curve following



Target velocity curve calculation

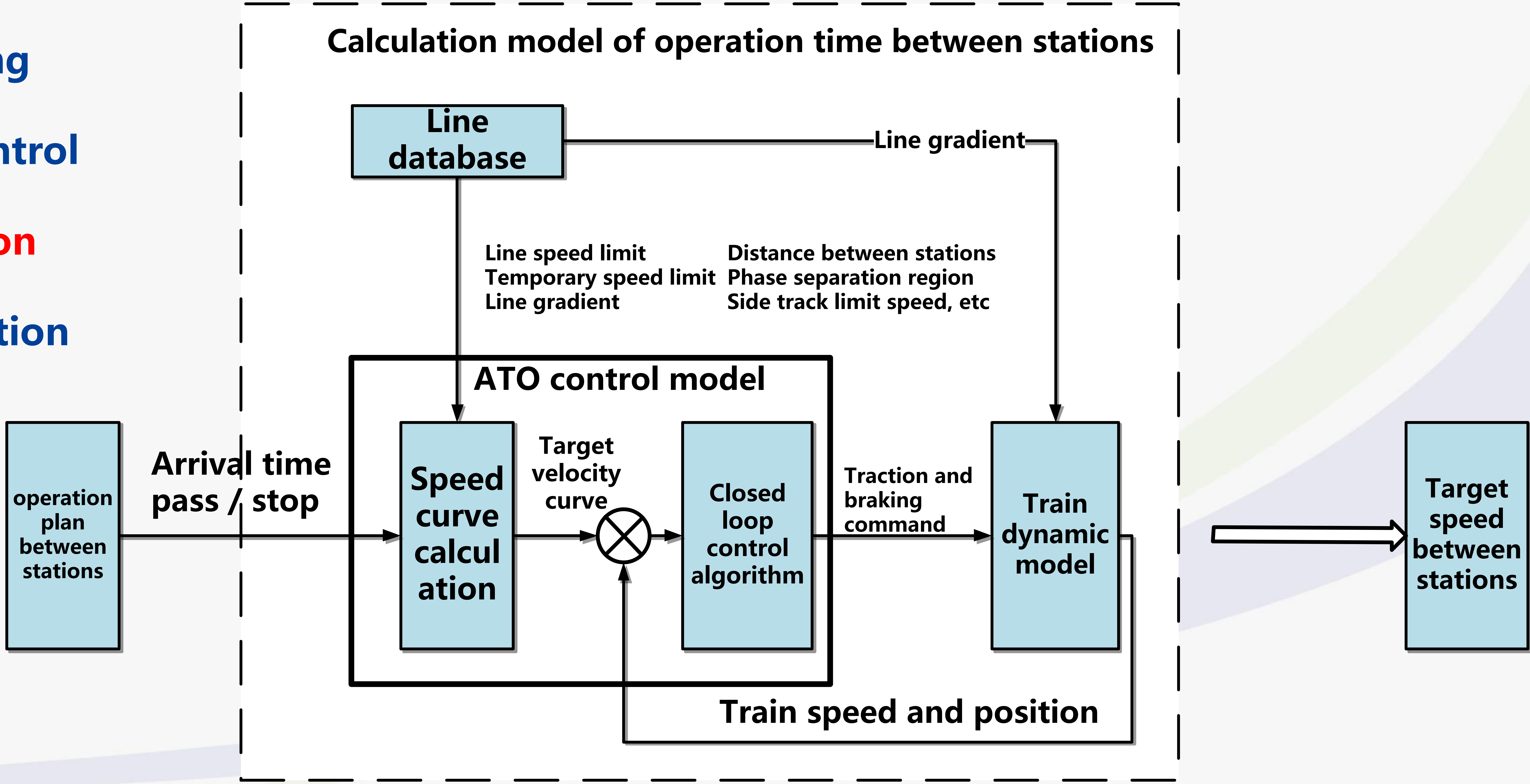


ATO control algorithm

3.CTCS3+ATO for High-speed Railway

On-time operation

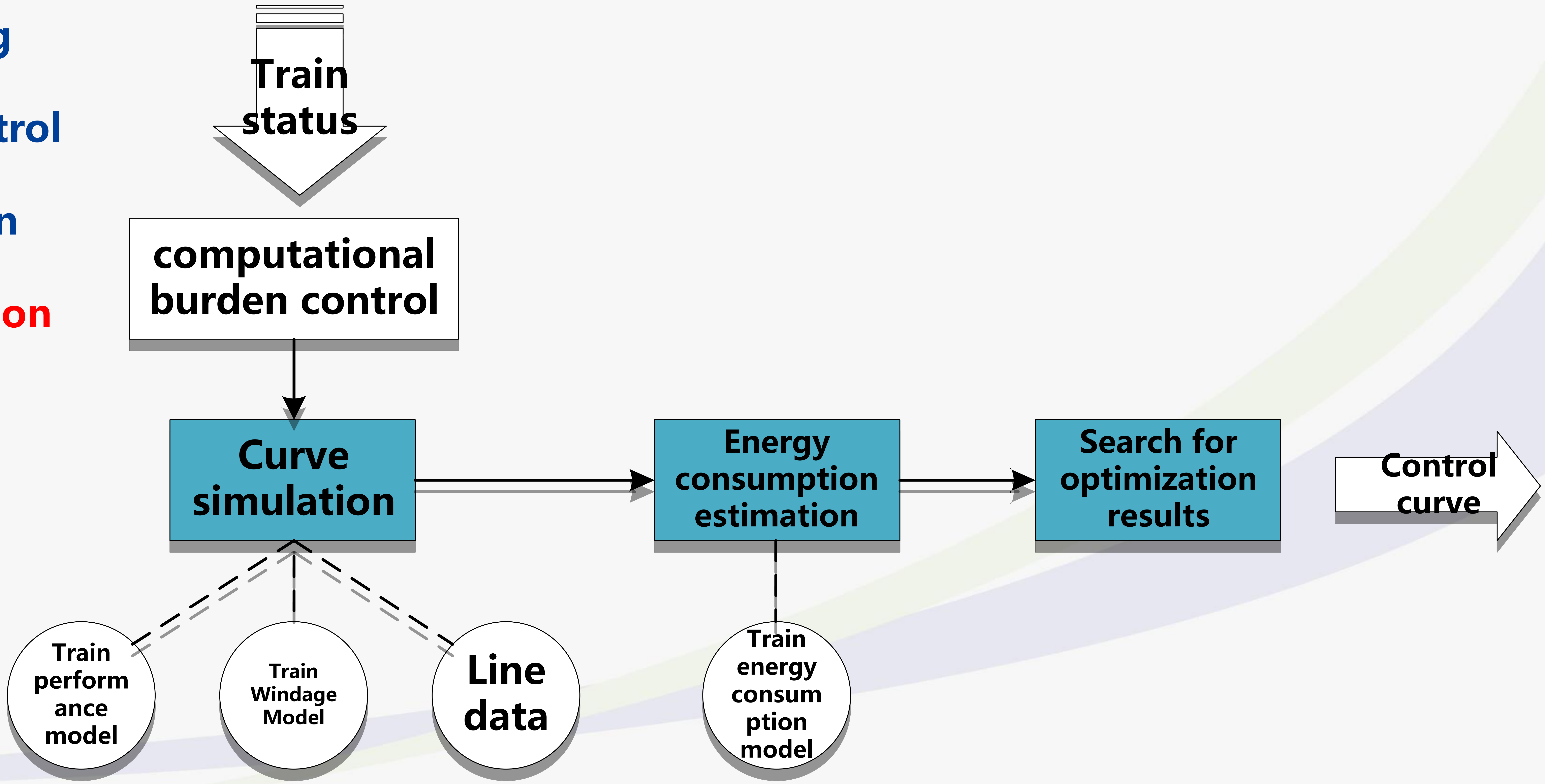
- Four key technologies
  - Accurate stopping
  - Smooth train control
  - On-time operation
  - Energy conservation



3.CTCS3+ATO for High-speed Railway

Energy conservation

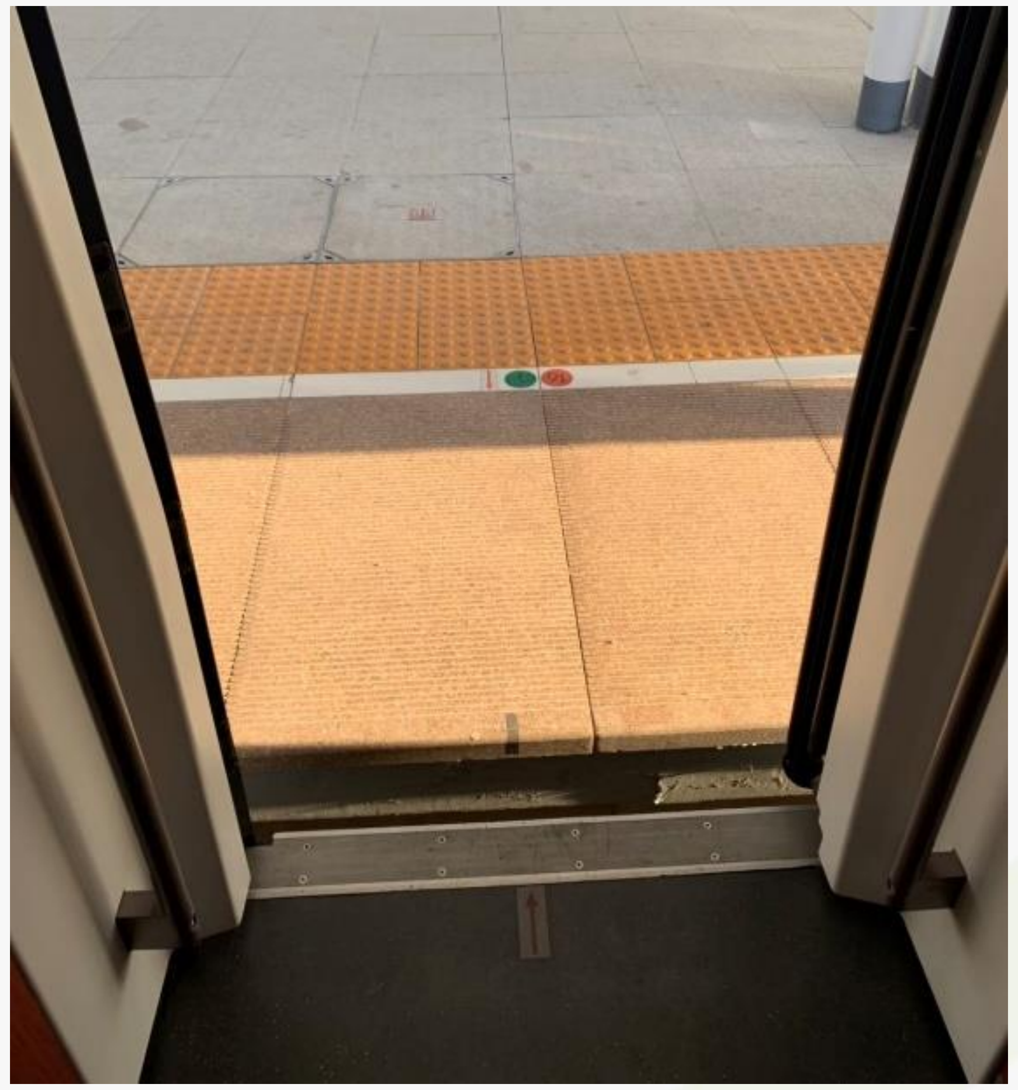
- **Four key technologies**
  - Accurate stopping
  - Smooth train control
  - On-time operation
  - Energy conservation



3.CTCS3+ATO for High-speed Railway

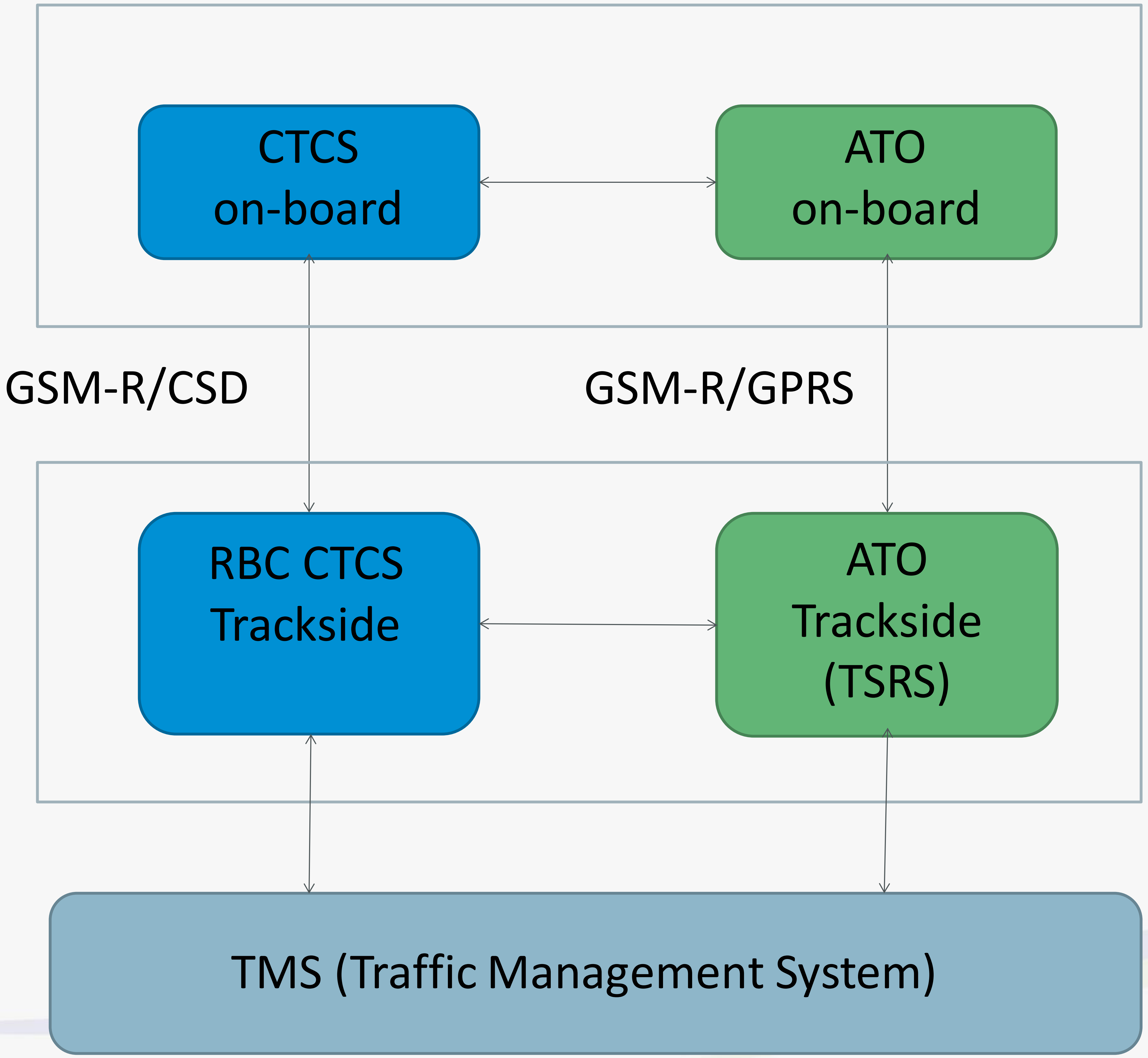
Compared with the traditional manual driving, the advantages of ATO system are as follows:

- Enhance capacity
- Improve punctuality
- Improve passenger comfort
- Optimising traction energy
- Reduce driver's work intensity



3.CTCS3+ATO for High-speed Railway

ATO system structure



Compared with C2 + ATO, C3 + ATO is optimized as follows:

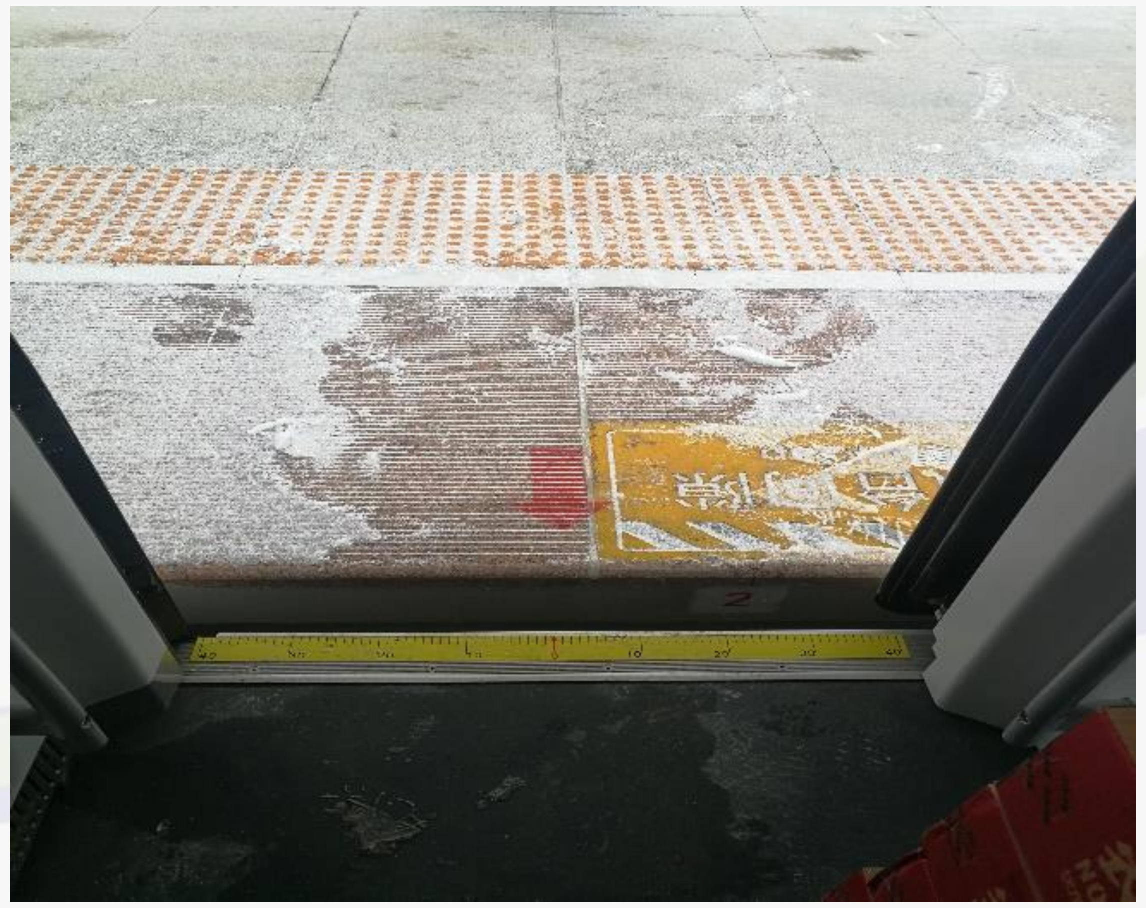
- **Trackside system structure**
- **Use redundant structure**
- **Track to train communications channel**
- **Driving strategy**
- **Interface to vehicle**

4.Beijing-Zhangjiakou High-speed Railway

Beijing-Zhangjiakou HSR is an important part of both the fast track linking Beijing with the western China and rest of northern China and Beijing-Tianjin-Hebei inter-city HSR network. It is also a major transport infrastructure serving the Beijing Winter Olympic Games in 2022.The length of the line is **174km** , and the operation speed is **350 km / h**。

4.Beijing-Zhangjiakou High-speed Railway

Starting from December 31, 2019, EMUs equipped with **CTCS3+ATO** equipment are operating on the Beijing-Zhangjiakou High-speed Railway. During this period, the ATO equipment operates stably and functions normally. The maximum operating speed is **350km/h**, the accurate stopping rate is **100%**, and the punctuality rate is **100%** .



5.Future development

The goal of future railway development is to be more safe, efficient, intelligent and green, which is also the purpose of applying ATO system.

The future development directions of ATO include:

- Research on Optimized Vehicle Control Strategy
- Autonomous driving of freight trains
- Fully aware fully automatic driving (GOA3, GOA4)
- Dispatching command and operation control integration

……

The main problems in the realization of GOA3 and GOA4

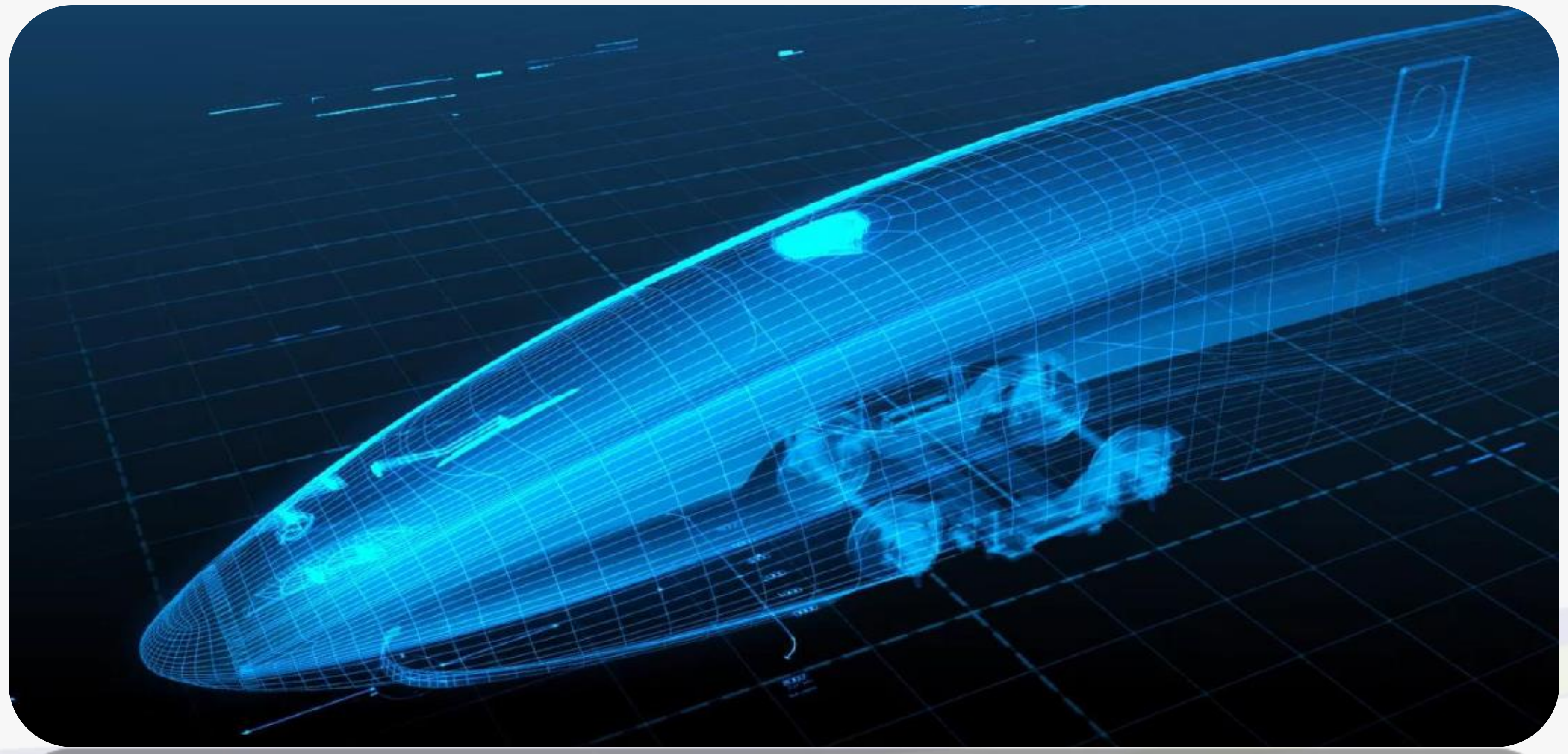
—— Environment perception and state detection

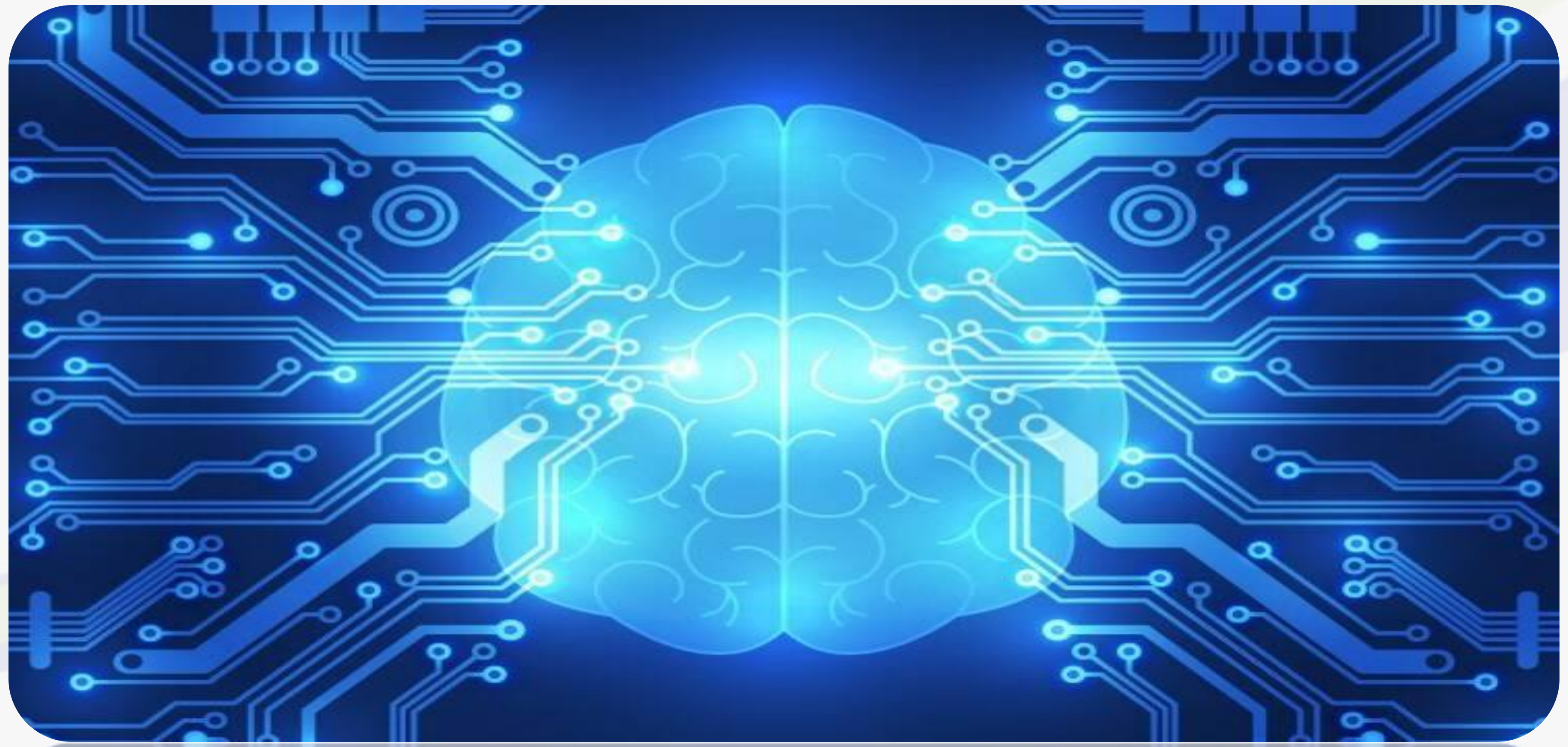
- Track environment perception
- Obstacle detection
- Person detection
- Vehicle equipment status detection

5.Future development

In the future, China railway will gradually realize the transformation from **manual driving** to **automatic driving** and then to **intelligent driving**.

- environment autonomous perception
- safety situation autonomous assessment
- equipment fault autonomous diagnosis





5.Future development

Cyber security in railway signaling

- Standards
- Solutions
- Integrating safety and security.

5.Future development

The integration of traffic management and train automation will be the further topic to research, which mainly focus on the coordinated control technology of train group.

- Intelligent driving system
- Traffic management system
- EMU control system
- Traction power supply system

5.Future development

With the rapidly development of high-speed railway in China, the rail automation and antonomation represented by ATO will have a broad prospect in the future.

THANK YOU!

“SNCF Autonomous Train Programme”

Ms Gemma Morral-Adell
SNCF Innovation and Project Directorate

Agenda

- SNCF’s Autonomous Train Program
- Current Projects
- Remote Driving Project
- Conclusions

The beginning of Autonomous Train program

In 2016 SNCF has launched a revolutionary program aiming to define its future railways system

Several game changers were identified:

- Automatisation of railway operations
    - A team of 14 people was staffed for the Autonomous Train Program
    - We adressed the conception of an autonomous train
    - We launched 4 projects between 2017 and 2018
- Emission-free trains
- Safety Train Localisation
- …

An autonomous train programme based on key choices

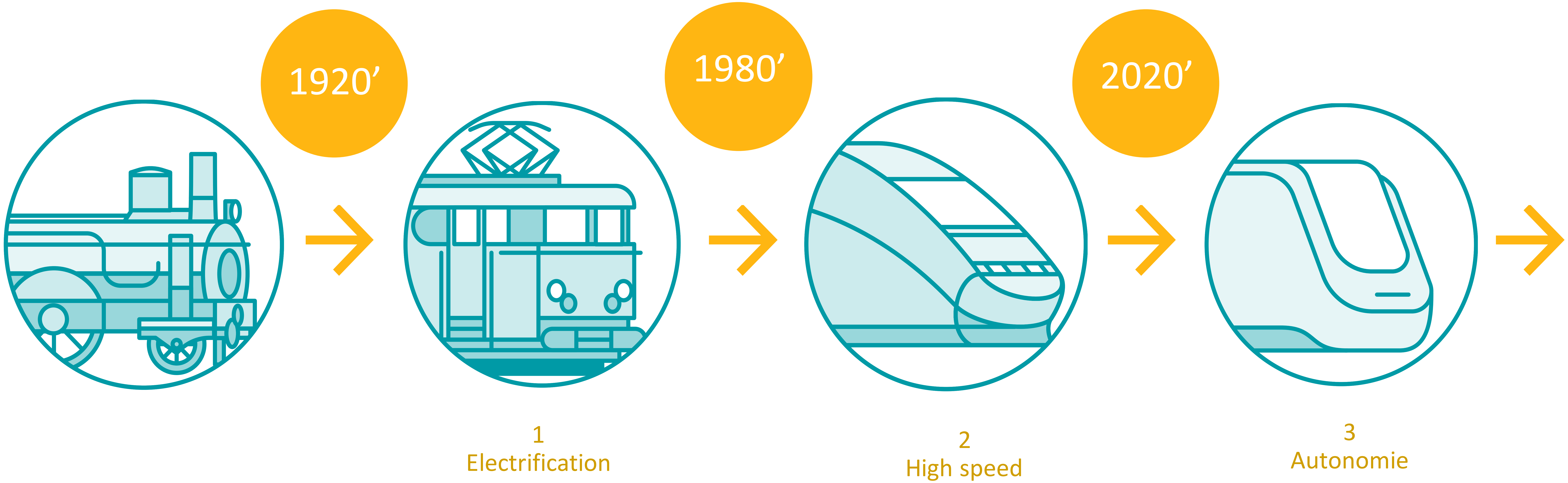
Creating an ecosystem with partners.

Considering all GoA and all types of signaling system (current and future).

Considering migration strategy to the future system and demonstrating safety and security from the outset.

Rolling out autonomous mobility solutions and functionalities for each of the different applications.

SNCF is preparing for the 3rd railway revolution



4 Grades of Automation

Controlled
manual driving

Automatic
braking and acceleration

Automatic driving
with train crew on board

Fully
autonomous trains

Remote driving

GoA : Grade of Automation

A whole mobilized ecosystem

Research institutes

Public authorities

Industry & Start-ups

European bodies & partners

Current projects

Ms Gemma Morral-Adell
SNCF Innovation and Project Directorate

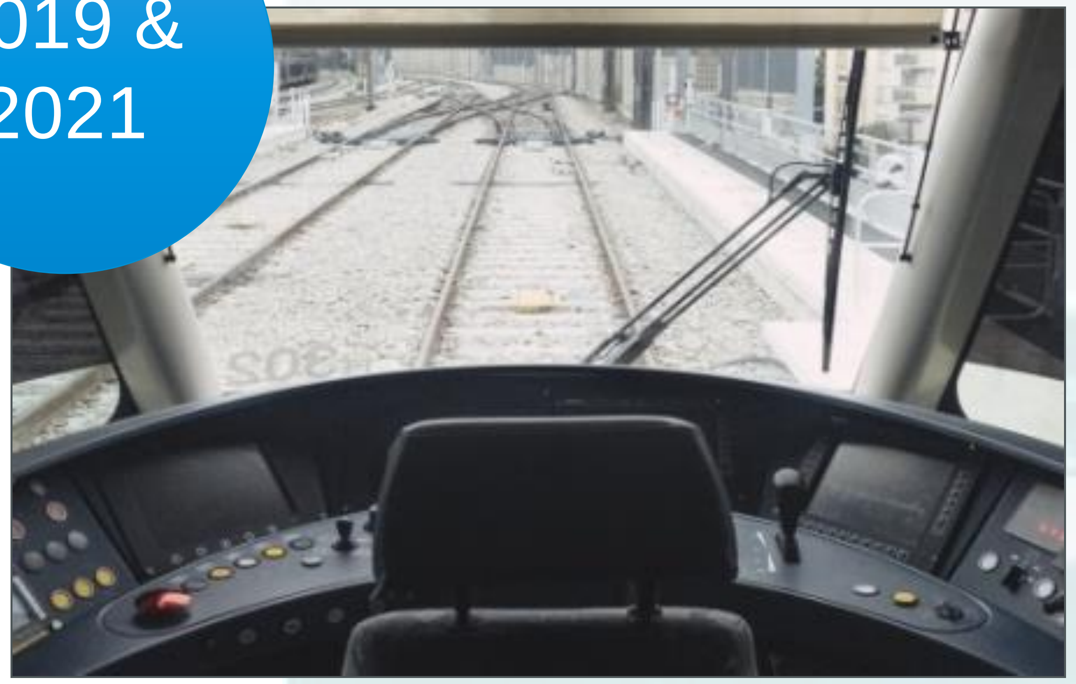
On-going projects within the program

2019 & 2022

Signalling and obstacle detection

GoA1 GoA2 GoA3 GoA4

2019 & 2021



Remote driving

GoA1+ GoA2 GoA3 GoA4

2021 & 2023

Autonomous passenger trains

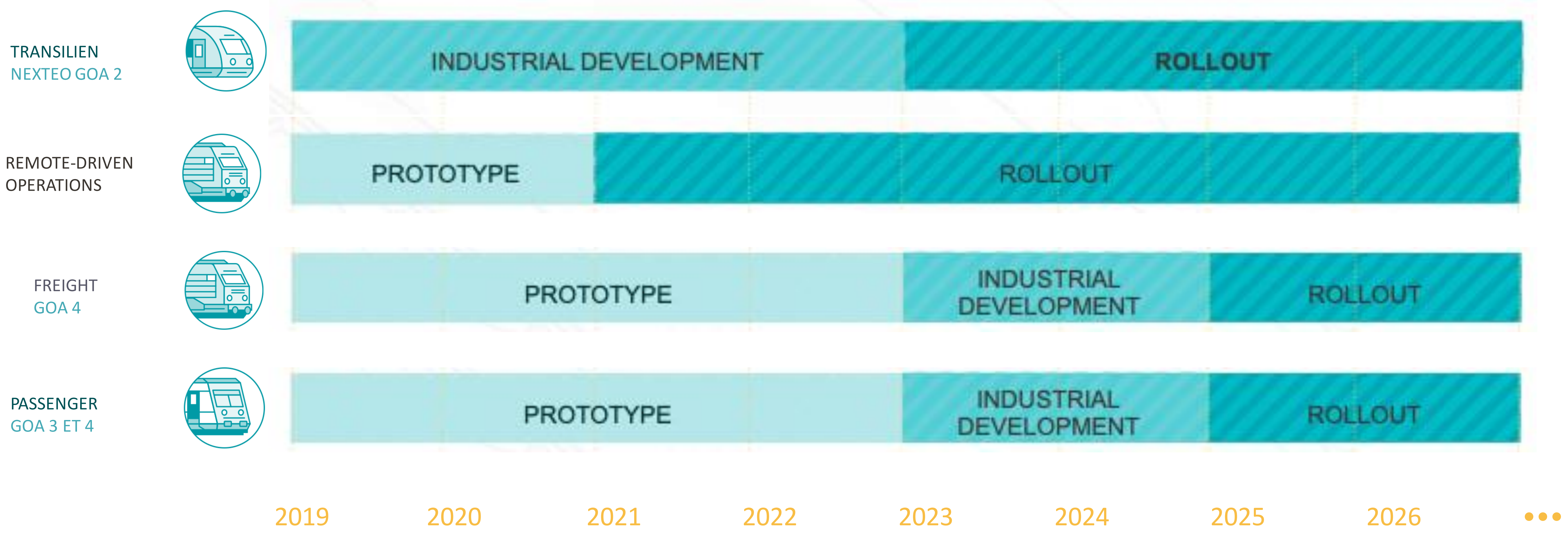
GoA1 GoA2 GoA3 GoA4

2021 & 2023

Autonomous freight trains

GoA1 GoA2 GoA3 GoA4

From prototype to rollout under a decade



Three targeted lines where to deploy GoA2 (and beyond) over ERTMS in the following years in France

Remote-driving projects

Ms Gemma Morral-Adell
SNCF Innovation and Project Directorate

Remote driving project: TC-Rail

Main information

- Project title (French project) : TC-Rail (TéléConduite sur Rail) – **Railways Remote Driving**
- Duration: 42 months (3,5 years) from **October 2017** to end of **April 2021**
- 12 Workpackages: including theoretical work such functional analysis, system definition & architecture, ergonomics & vision specifications, cyber and safety analyses and on-field realisations

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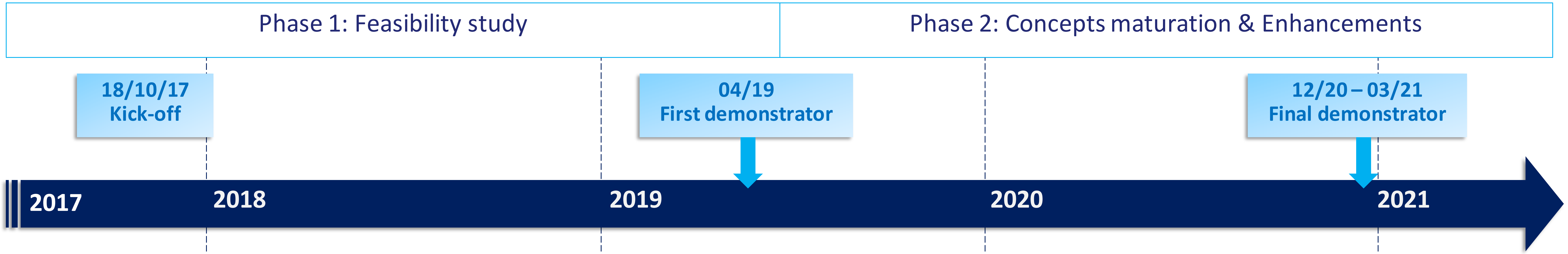


Target use cases for SNCF

Enhanced flexibility for railways operations
to improve the Quality of Service

1

Technical movements in depots and stations

- Any type of train, no passenger
- Short distances (1 – 10 km)
- Low speed (30 km/h, 70 km/h sometimes)

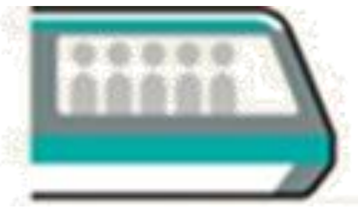
2

Freight's last miles

- Medium distances (1 – 30 – 60 km)
- Medium speed (up to 100 km/h)

3

GoA4



FULL AUTOMATIC OPERATION

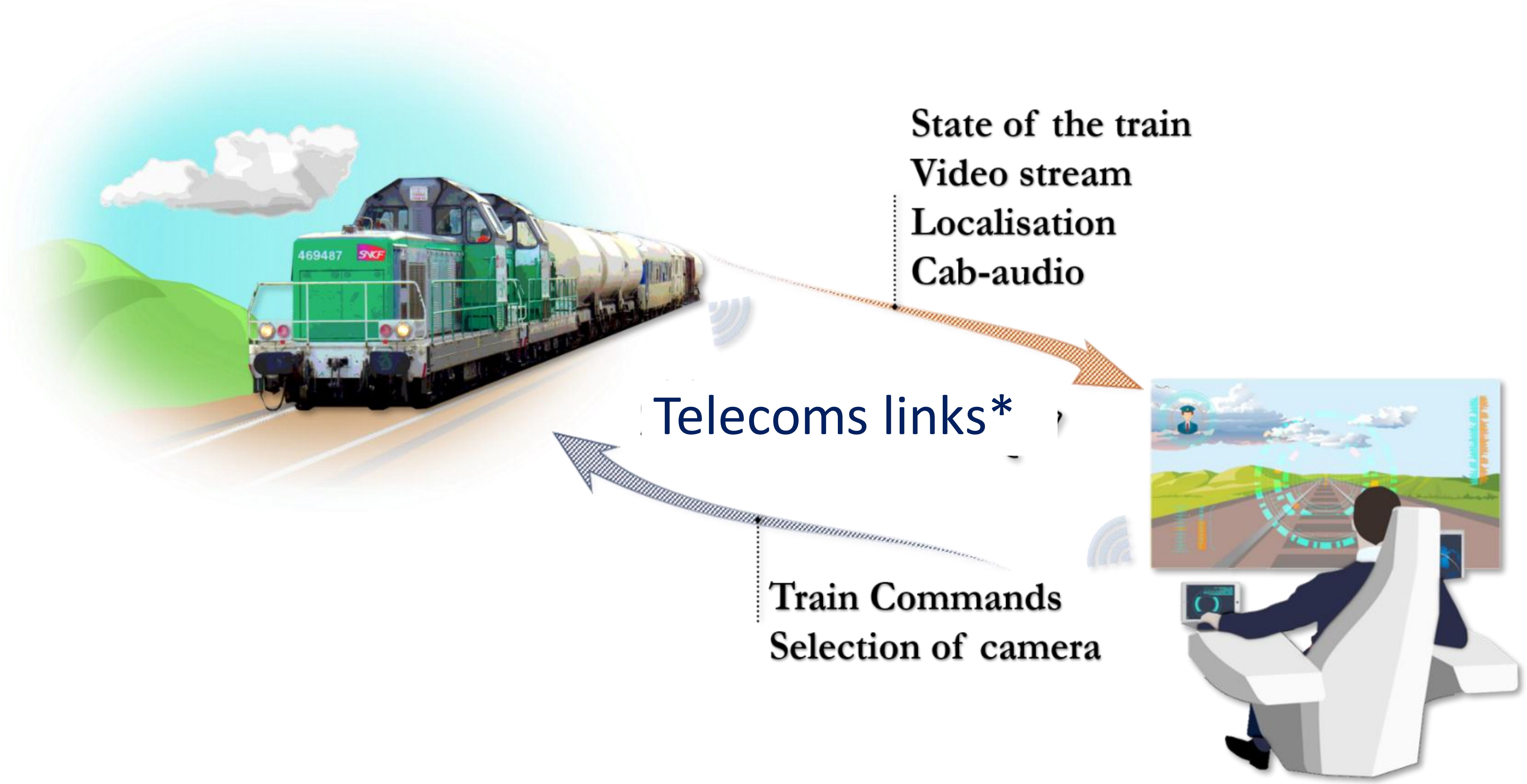
Fallback mode for Autonomous Train

- Any type of train, with passenger
- Short/medium distances
- Low/Medium speed

Prototype approach

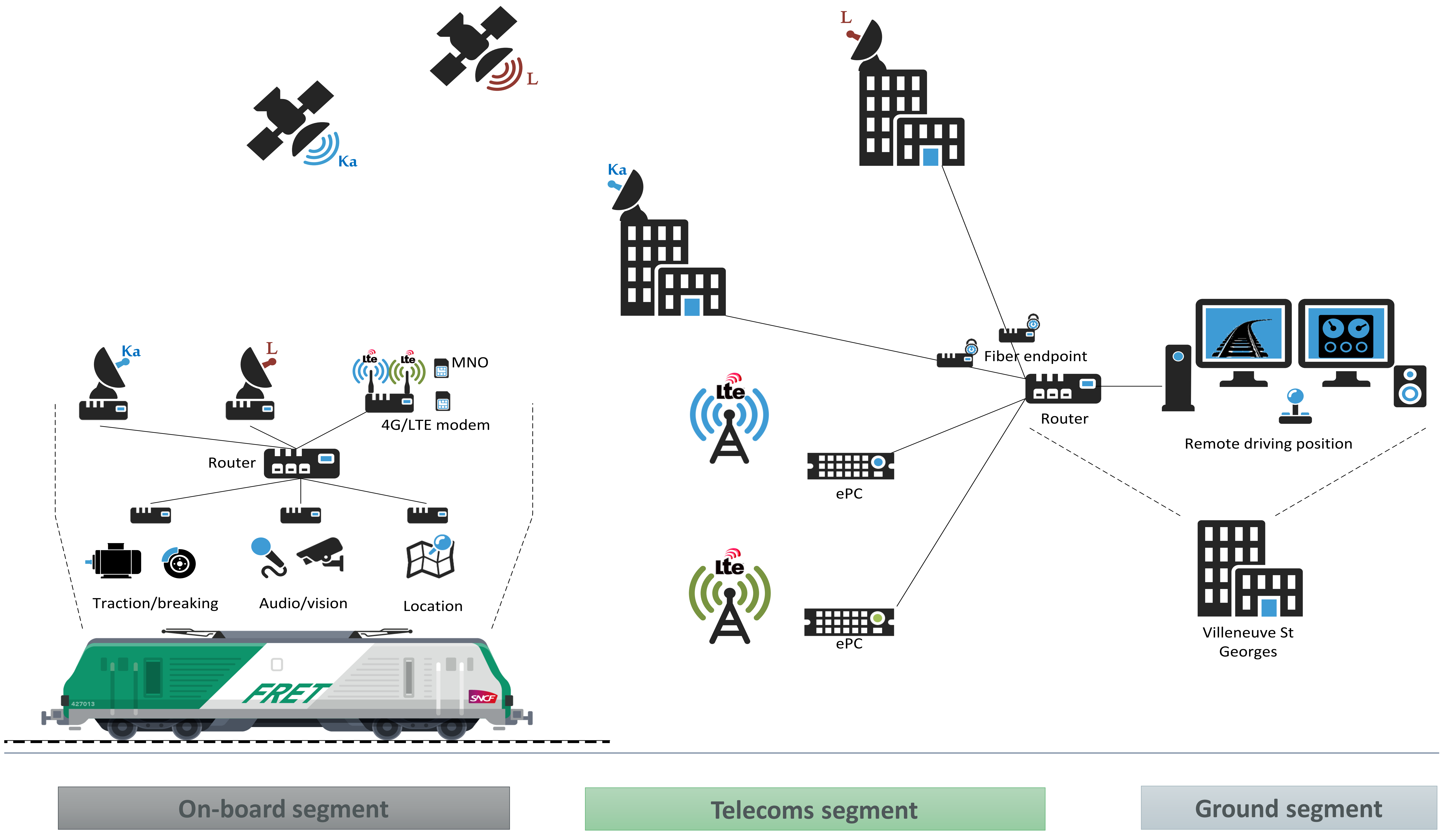
A simple approach based on **4 main functional** bearers between on-board (train) and ground (remote site) sub-systems

1. Commands and indicators (e.g. braking and traction information, speed, …)
2. Video with a codec adapted to match the railways needs (anti-flickering of signals, colors optimized,
3. Audio from the (in/out) cab to capture the mandatory noises in railways (detonators, collisions, whistles, …)
4. Localization (position, speed, time, acceleration)



*Telecoms links : includes hybridation fonction to the Adaptable Communications System (ACS) implemented by Thales

Prototype architecture



On-board Segment
Specific interface unit (commands/indicators)
Camera(s) and processing (adaptative codec)
Audio sensor in cabin
Localization interface

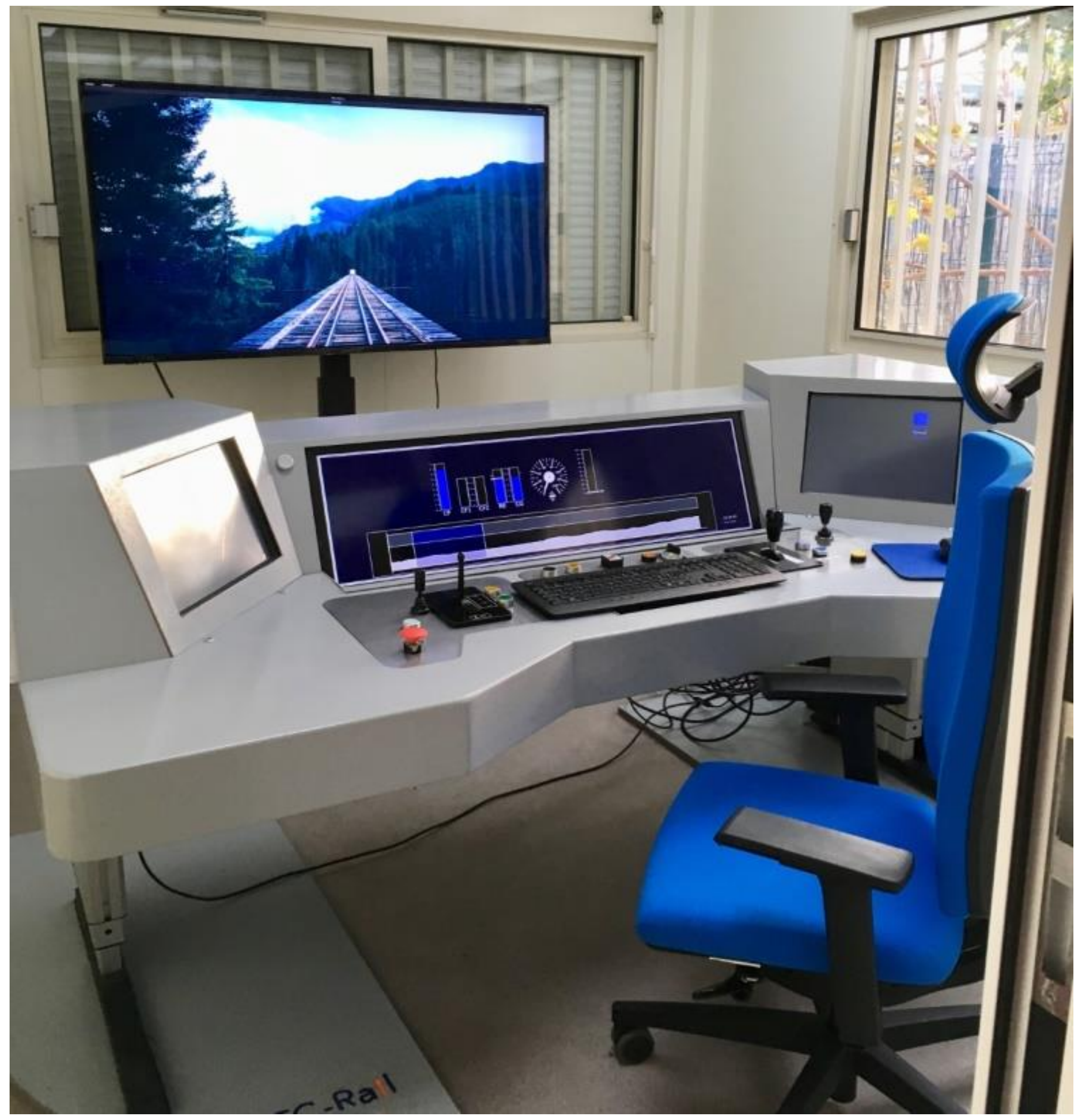
Telecoms Segment
Telecoms network infrastructure providing access to 4 different technologies
- private LTE at 2.6 GHz/TDD
- public LTE multi-operators
- SATCOM GEO/Ka
- SATCOM LEO/L)

Ground Segment
Remote driving panel and HMIs

Developments for the prototype

Remote driving panel (2019)

Remote driving panel (2021)



Specific Interface Unit

Telecommunications links (on-board)

Before processing

After processing

Video presentation

Conclusion

Ms Gemma Morral-Adell
SNCF Innovation and Project Directorate

Conclusions

SNCF approaches focus on developing prototypes with industries to ensure the deployment readiness

Our achievements:

- First prototype of remote driving on a train in different use cases:
    - at 70 km/h (with private/public 4G) in service line/urban area → almost 2 Mbps for the video uplink
    - at 10 km/h (with SATCOM L/LEO) in depot/urban area → 140 kbps in average for the video uplink
    - at 30 km/h (with public 4G) in rural area → variable bitrate around 500 kbps – 1 Mbps for the video uplink
- Firsts trials of prototypes of GoA2 over ERTMS for Freight and Passenger activities
- First prototype of signalisation and obstacle detection

Regarding Remote Driving challenges are still under study:

- The vision system must be 100% operational for any lateral signalisation color and technology
- Adapting the video link according to the telecoms performance link is required
- Satellite technologies need further analysis → SATCOM at Ka Band and GEO satellite is not possible for the remote driving use case
- Remote panel needs more user tests in order to collect the feedback of future remote drivers

“Delivering sustainable digital/automated service-oriented rail system to European citizens”

Ms Lea Paties

Programme Manager at the Shift2Rail Joint Udertaking

Mr Benoît Bienfait

Main Line ATO Design Authority at Alstom

Agenda

Introduction

- Grades of Automation (GoA) and work streams

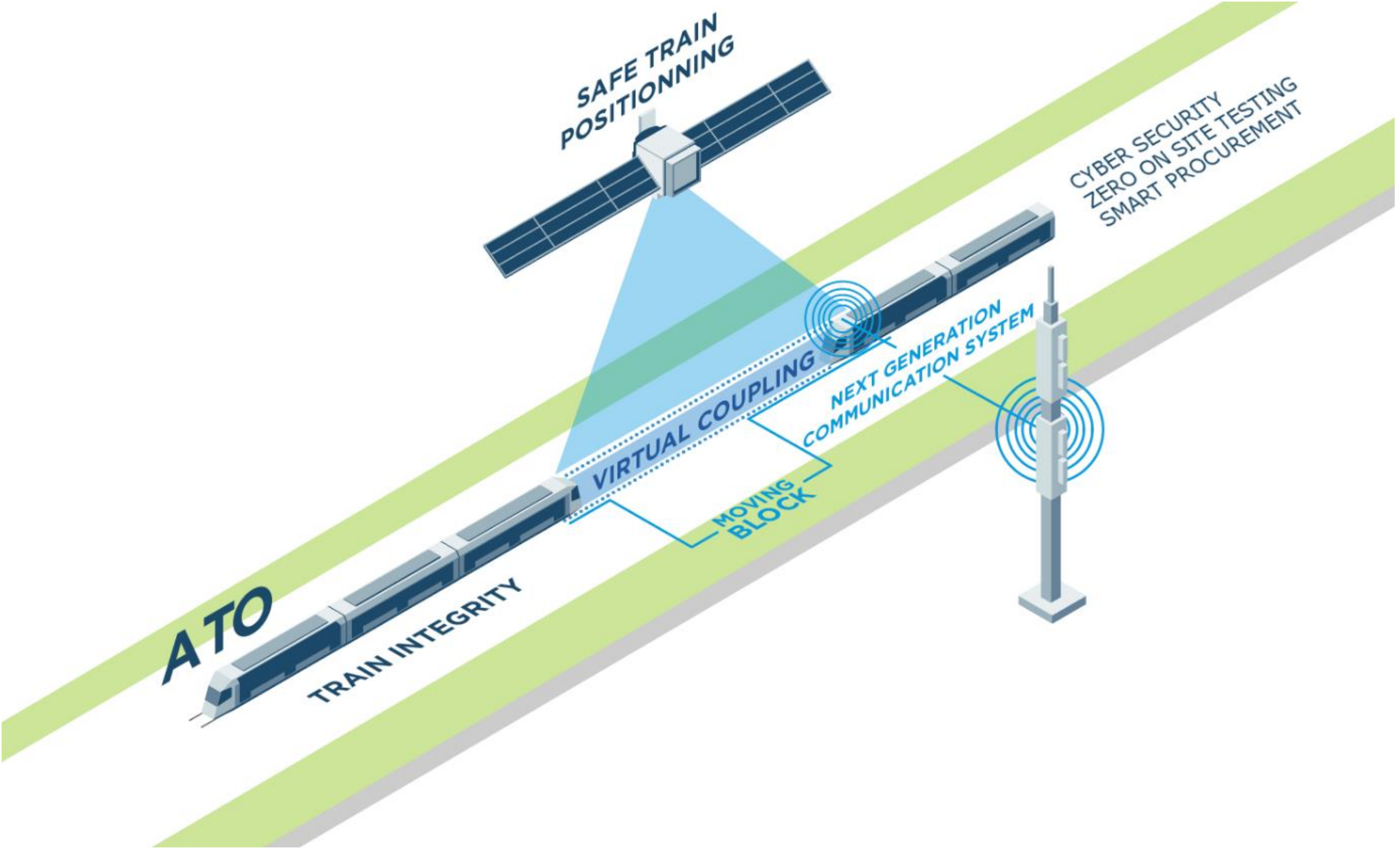
- GoA2
  - **Subsystems definition**
  - **GoA2 Documents**
  - **Reference Test Bench**
  - **Pilot tests**

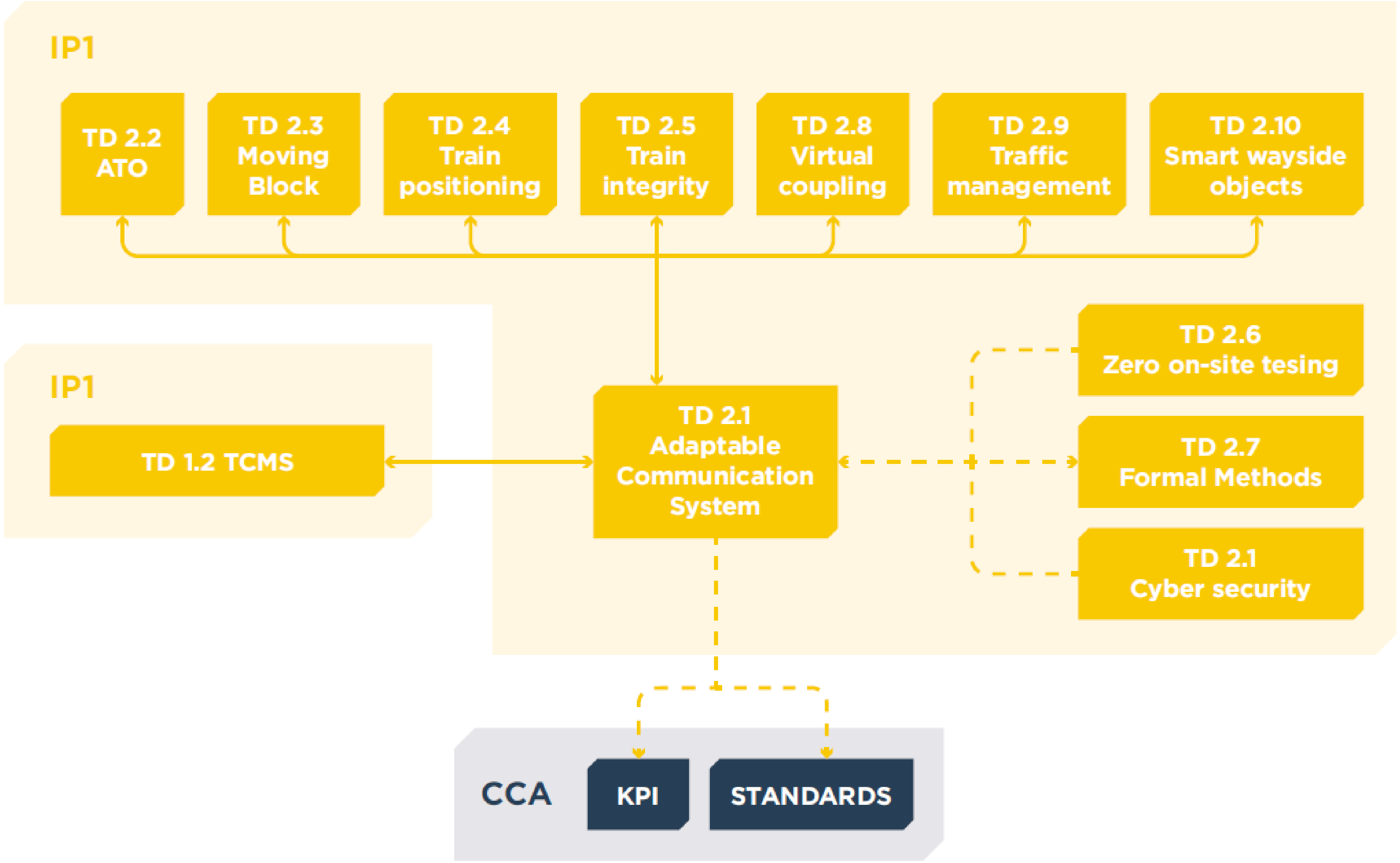
- GoA3/4
  - **Architecture**
  - **System Requirement Specification**
  - **Timeline**

Conclusion

Introduction

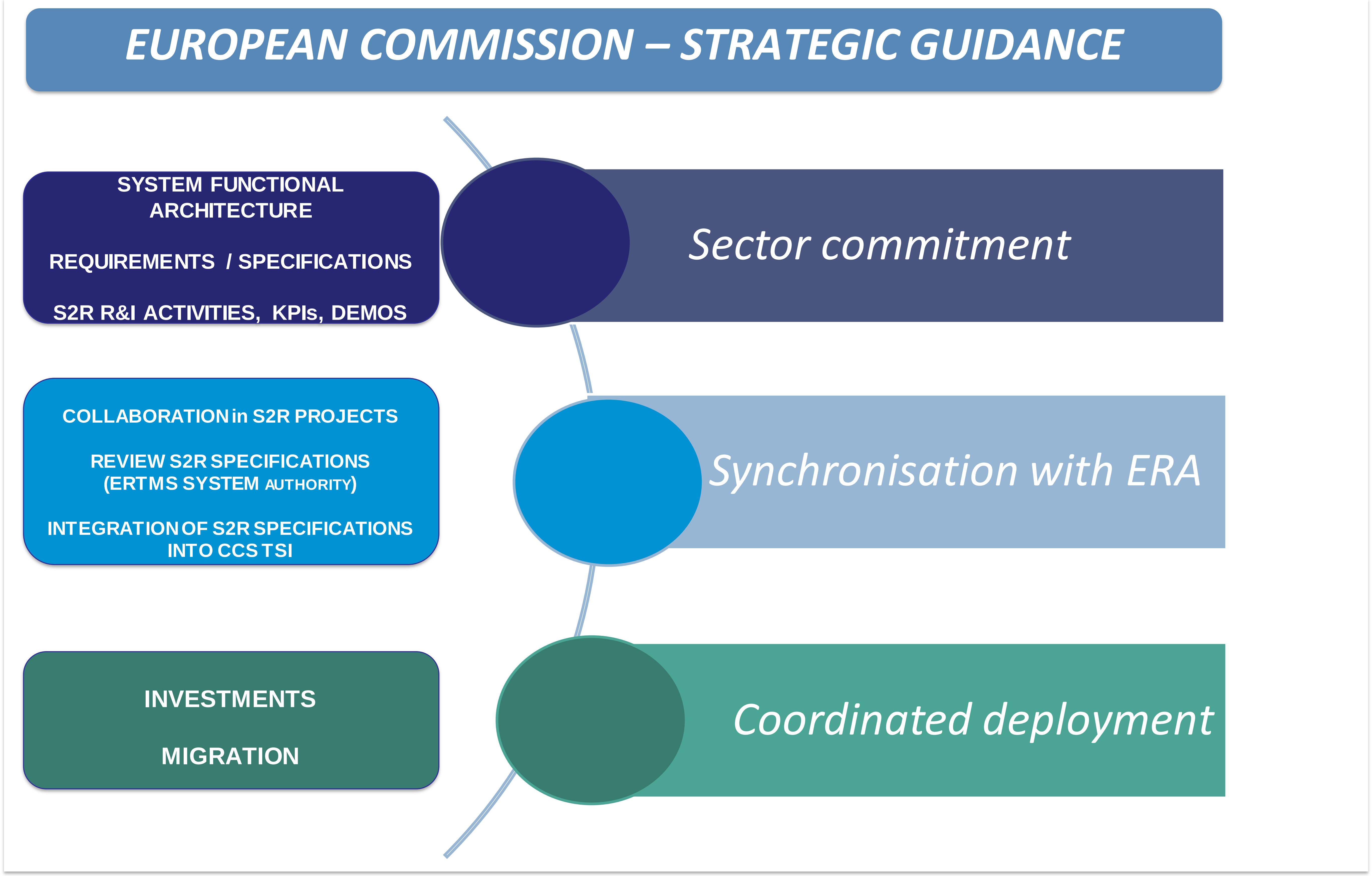
S2R Innovation Programme 2: Advanced Traffic Management and Control System





Introduction

S2R Innovation Programme 2



Key innovations

Moving Block based on ERTMS/ETCS specifications and opportunity to remove trackside fixed signalling systems.

Positioning systems applied to rail to remove physical balises and facilitating the application of moving block.

Advanced ATO for railway lines: GoA4 will reduce human error and increase service availability.

New and dynamic control of train management based on **Virtual Coupling** and **On-board intelligence**.

Automatic Train Operation (ATO)

Train level

Operating costs

- Energy gain: typically **up to 15%** in Intercity, **up to 45%** on Regional

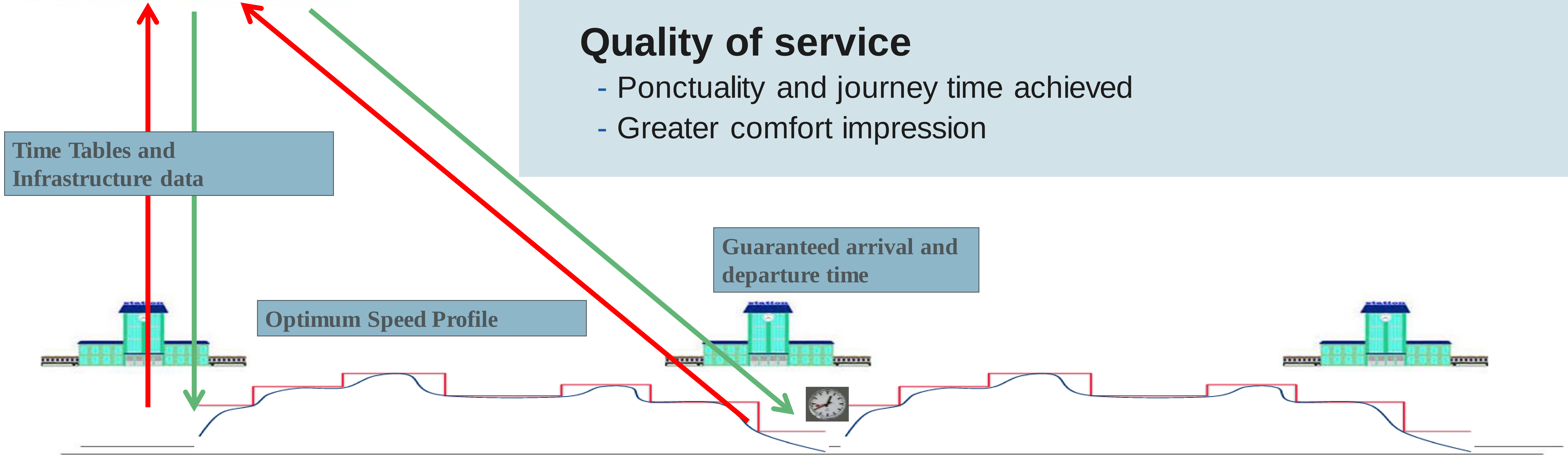
Network level

Capacity increase

- No provision for driver reaction time : -5 to 10s
- Reduced dispersion of driving styles, leading to reduced margin in timetable : typ. from 33 or 25% down to 15%
- Reduced operational headway : **typ -15% to 20%**

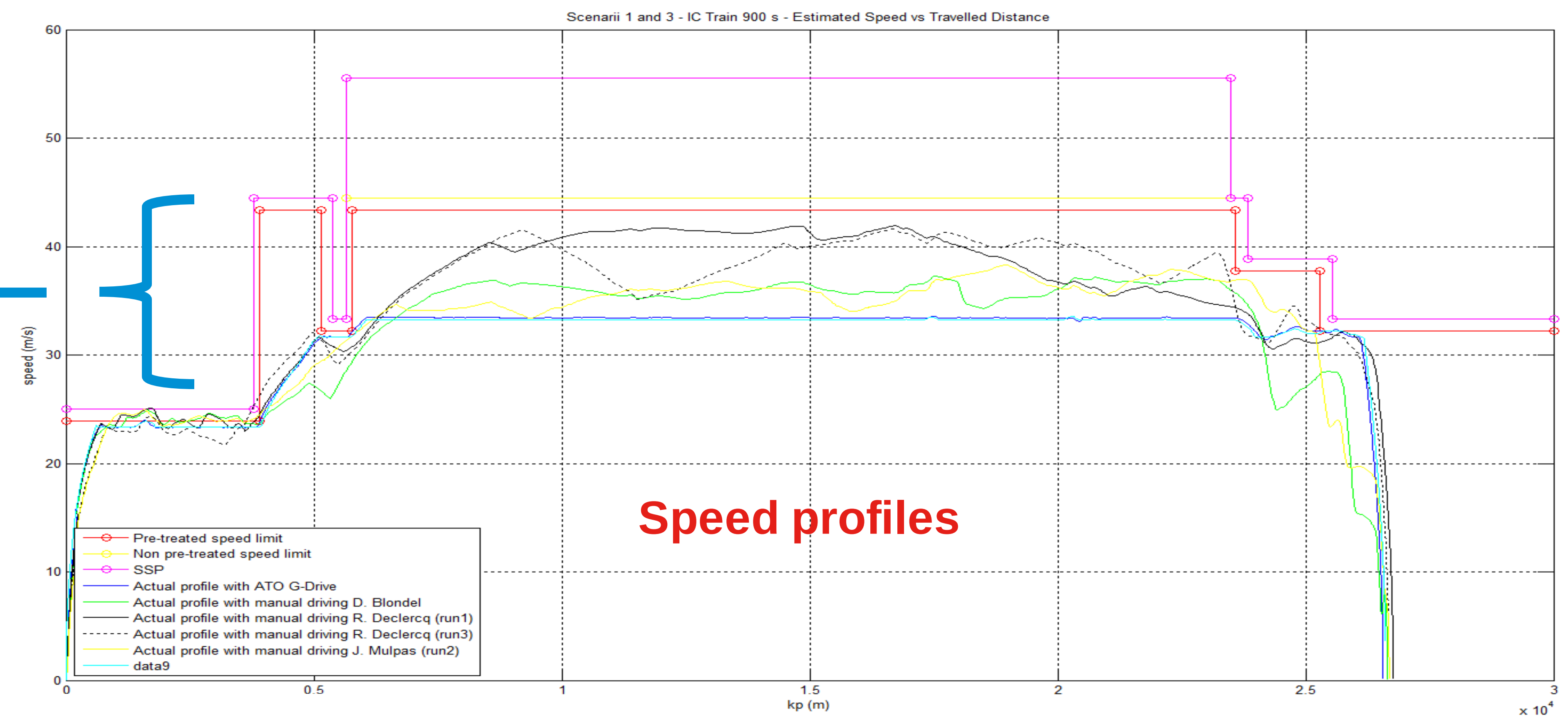
Quality of service

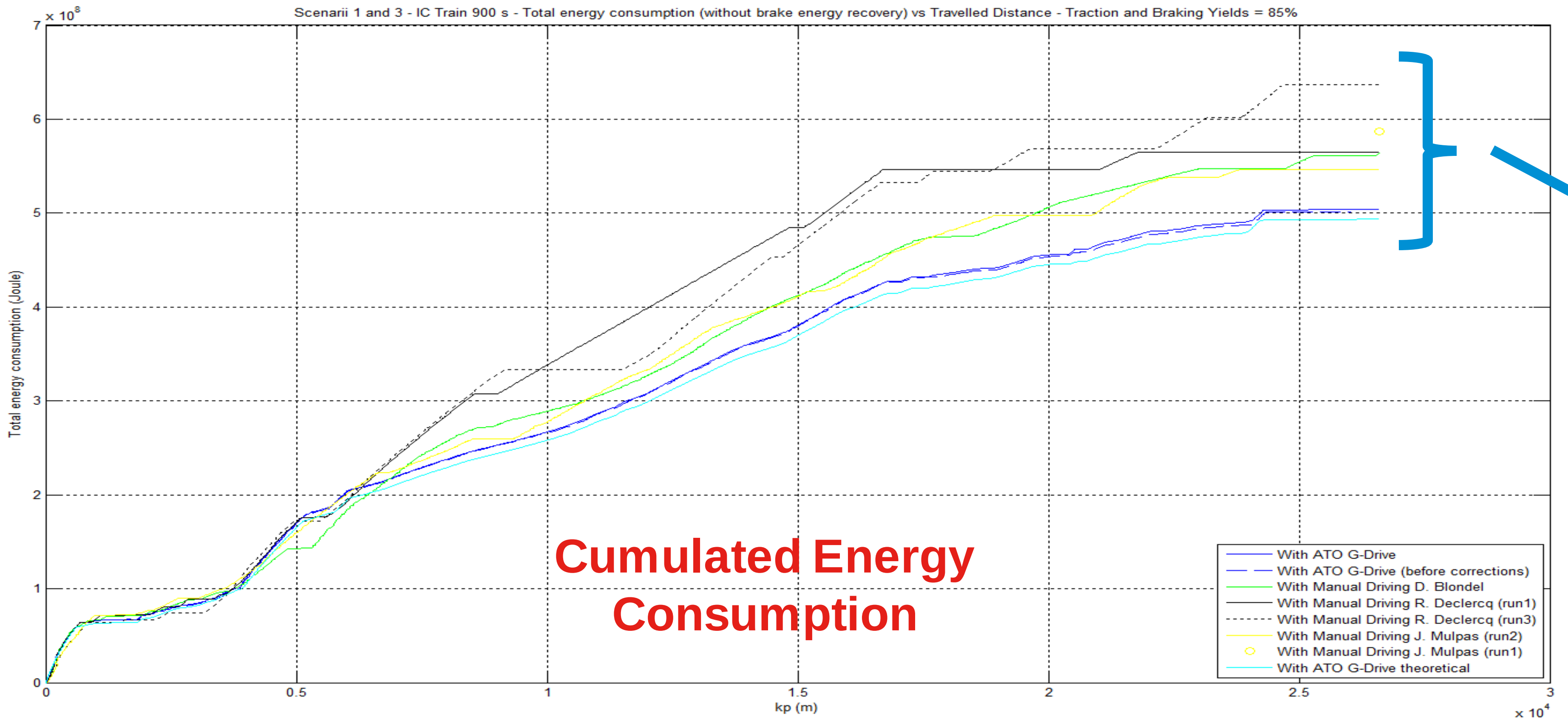
- Ponctuality and journey time achieved
- Greater comfort impression



Example of Energy Savings (Intercity trains)

Different driver behaviours on same journey…

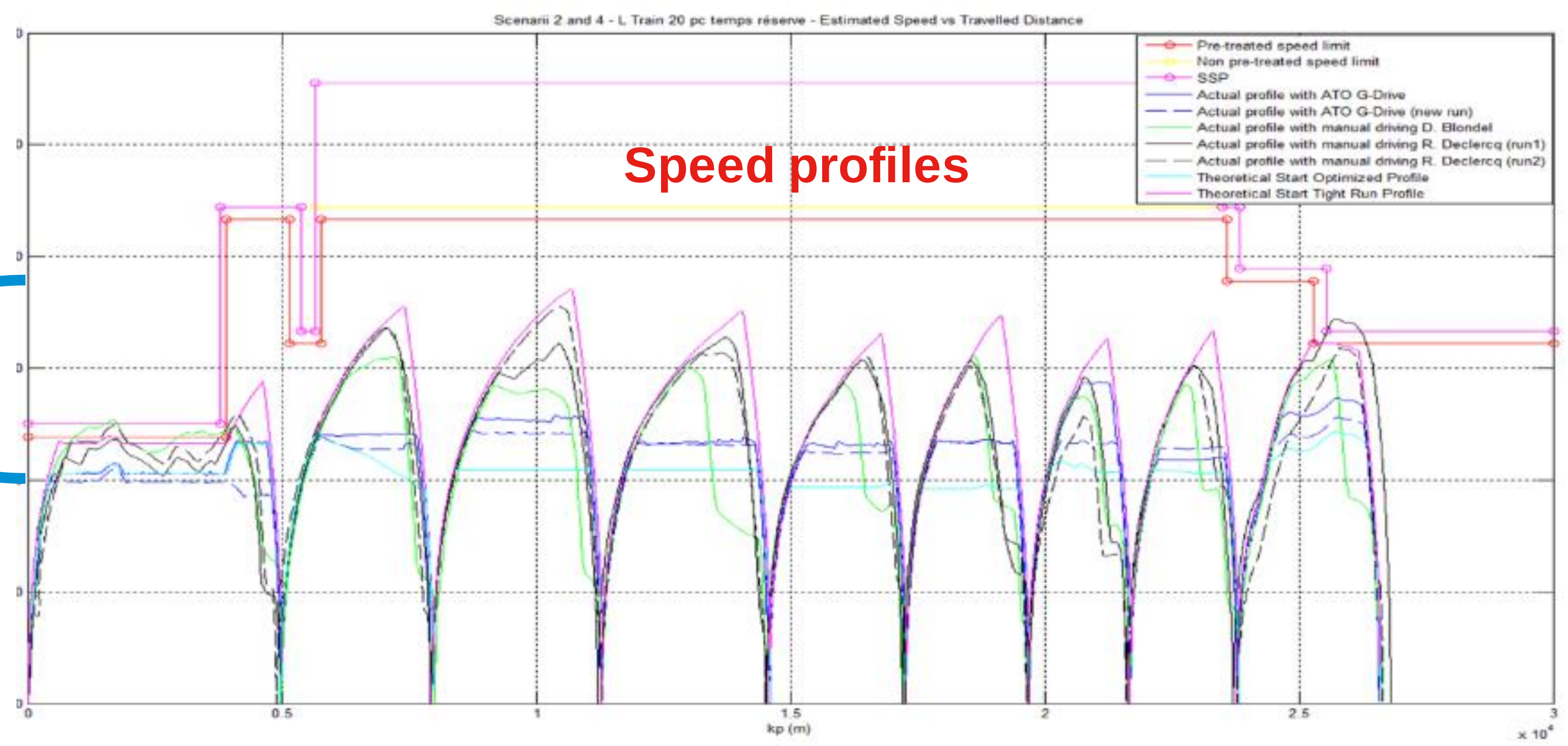


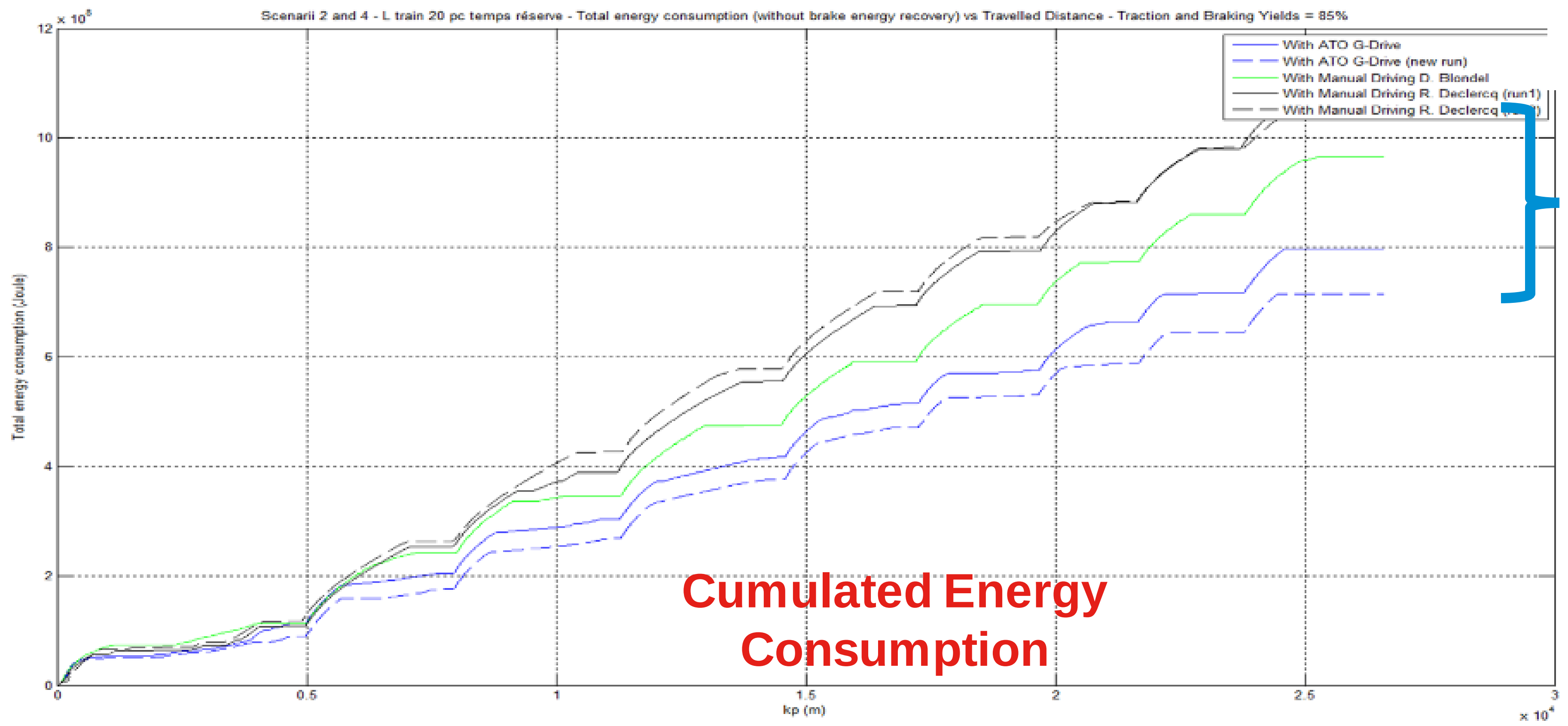


… lead to potential consumption of up to 15%

Example of Energy Savings (Local trains)

Different driver behaviours on same journey…





… lead to potential consumption of up to 42%

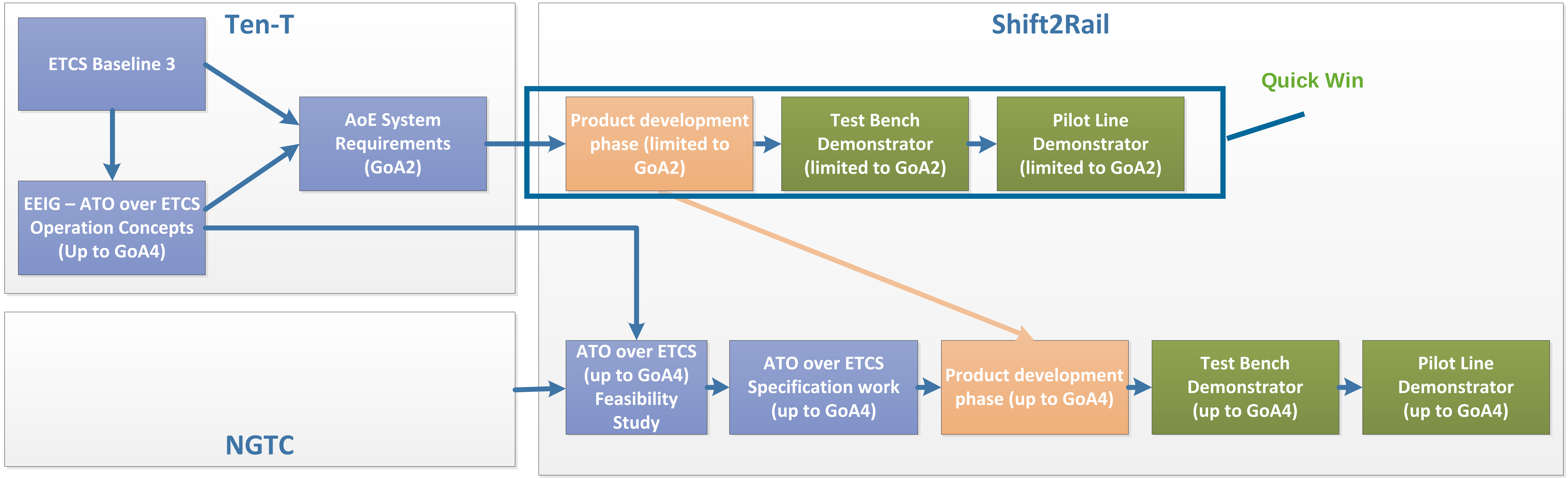
Grades of Automation (GoA)

Grade of Automation	Train Operation	Setting train in motion	Driving and stopping train	Door closure	Operation in event of disruption
GoA 1	ATP with Driver	Driver	Driver	Driver	Driver
GoA 2	ATP and ATO with Driver	Driver / Automatic	Automatic	Driver	Driver
GoA 3	Driverless (DTO)	Automatic	Automatic	Attendant / Automatic	Attendant
GoA 4	Unattended (UTO)	Automatic	Automatic	Automatic	Automatic

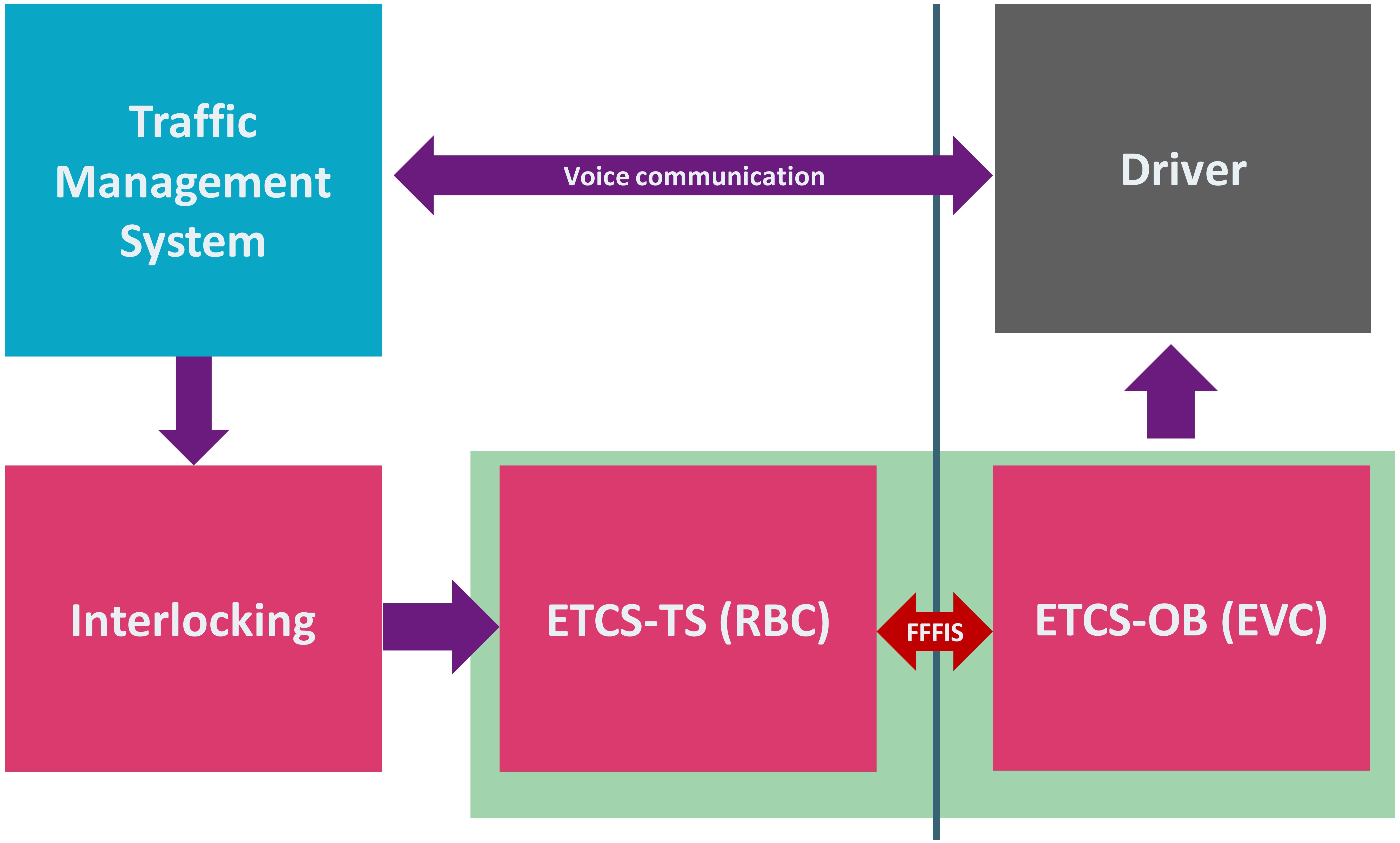
GoA1+
C-DAS over
ETCS

ATP: Automatic Train Protection
ATO: Automatic Train Operation
DTO: Driverless Train Operation
UTO: Unattended Train Operation

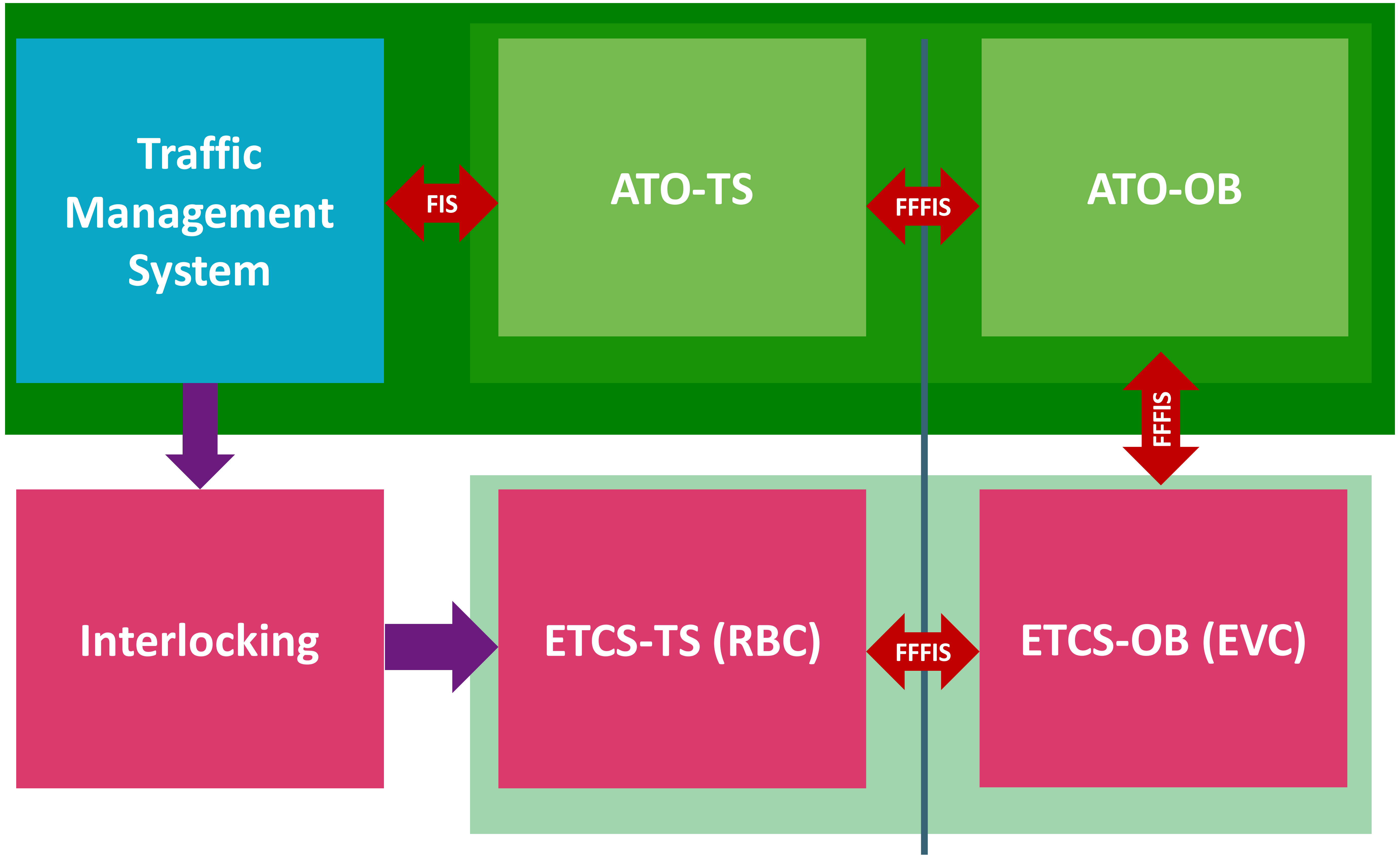
ATO over ETCS (AoE) in Shift2Rail



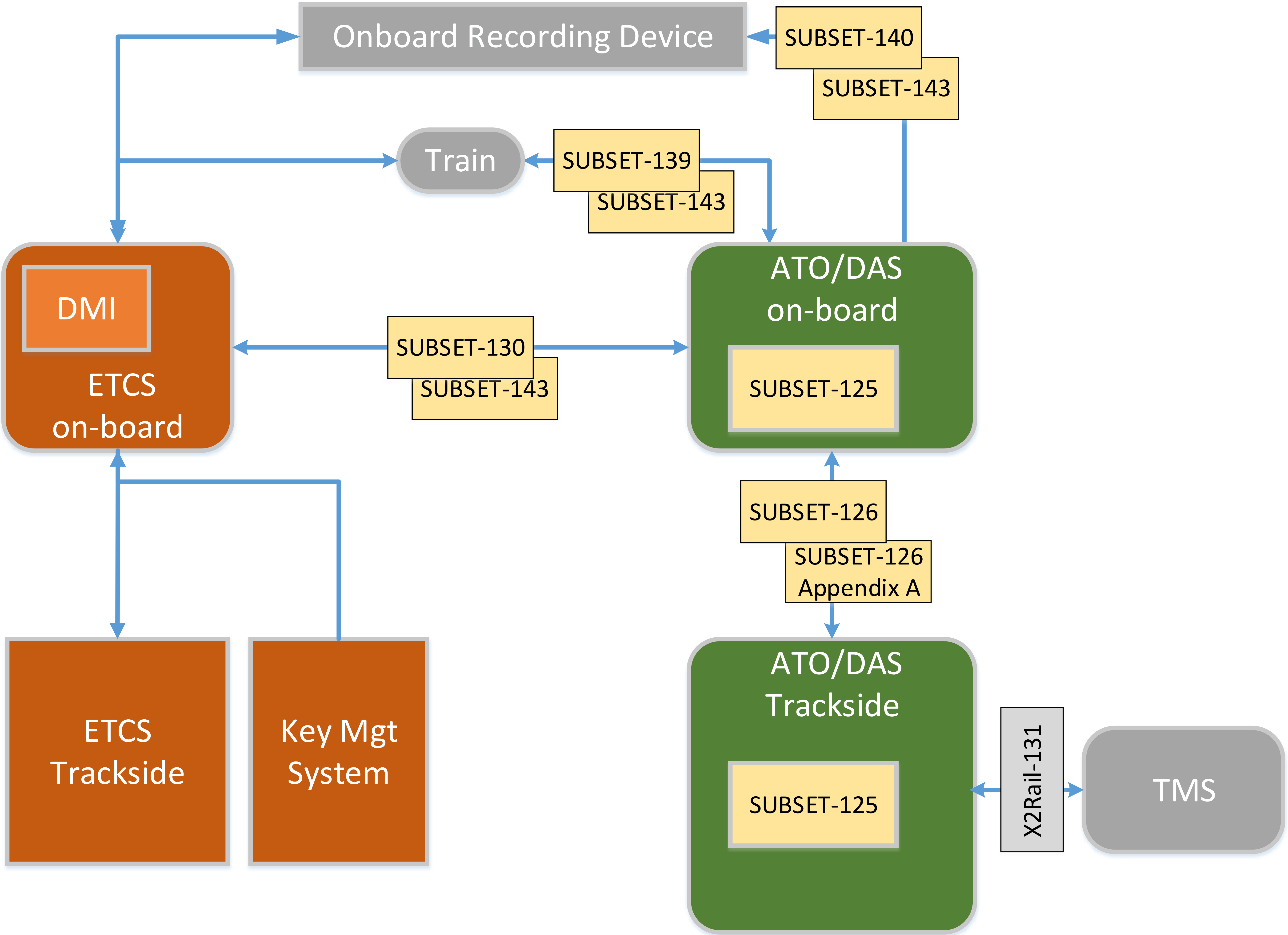
GoA1 Architecture



GoA2 Architecture



GoA2 interoperable specification

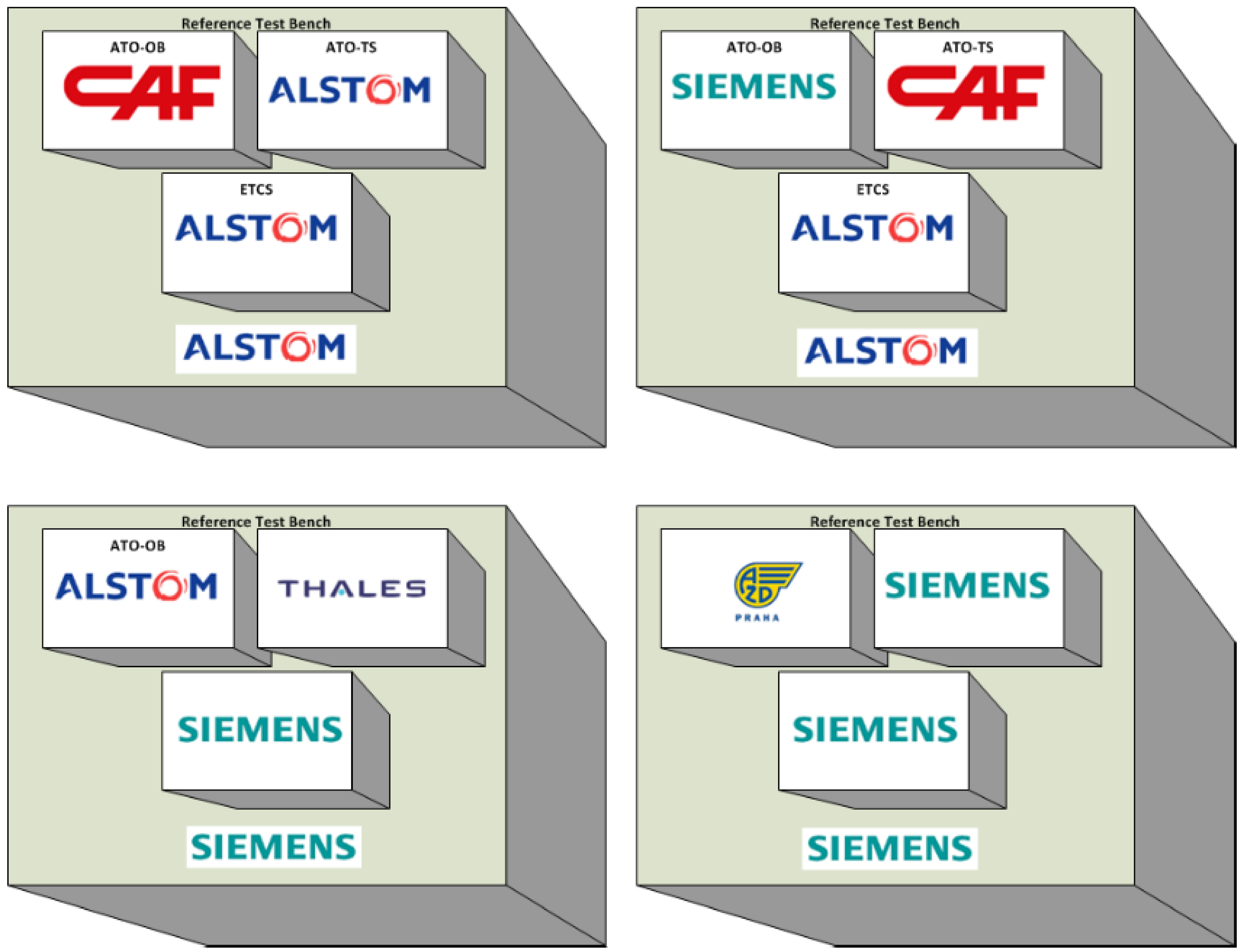


- Subset: Interface specification
- Suppliers defined
- ERA endorsed
- Publish in TSI 2022

Interoperability tests on Reference Test Benches

- Two Reference Test Benches (Belgium – Germany)
- Four different configurations
- Frozen Subset versions
- Tests performed in 12/18 and 1/19
- TEST SCENARIOS (21):
  - GoA1 to GoA2 transition on the move
  - Train stops at a stopping point
  - Train departs from a stopping point on time
  - Rerouting the train with JP Updates
  - Stopping Point Skip driver / TS

2018-19



GoA2 Pilot tests

The test activites have been performed in 2020 in two different pilot sites


S2R UK

- 1 Pilot train (Class 313; 3 cars 60m)
- 1 Pilot line (ENIF)
- ETCS-OB: ALSTOM
- ATO-OB: ALSTOM, AZD
- ATO-TS: SIEMENS, THALES
- ETCS Level 2
- Track train comm.: GSM-R GPRS

TARGETS:

- Interoperability
- EMU Operations
- Passenger Application
- Stopping point
- Rerouting

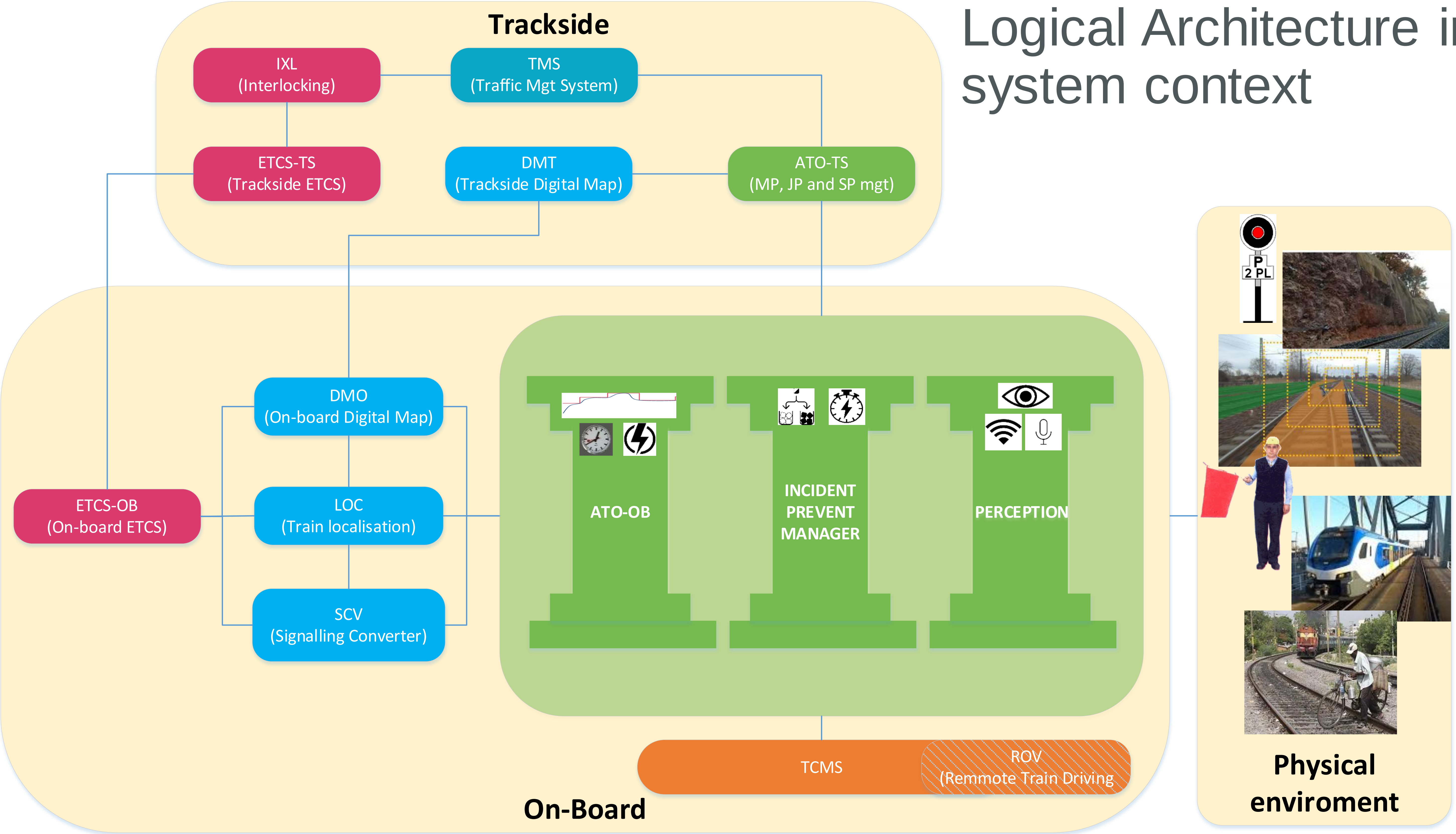

S2R Switzerland

- 1 Pilot train (loco Traxx AC1+14 freight cars)
- 1 Pilot line (Sion-Sierre)
- ETCS-OB: SIEMENS
- ATO-OB: ALSTOM, HITACHI, AZD, SIEMENS
- ATO-TS: SBB
- ETCS Level 2
- Baseline 2.3.0d
- Track train comm.: LTE public network

TARGETS:

- Interoperability
- Loco Operations
- Freight Application
- Commercial operation impacts
- Signalling stop

ATO (up to GoA4) Architecture



Logical Architecture in railways system context

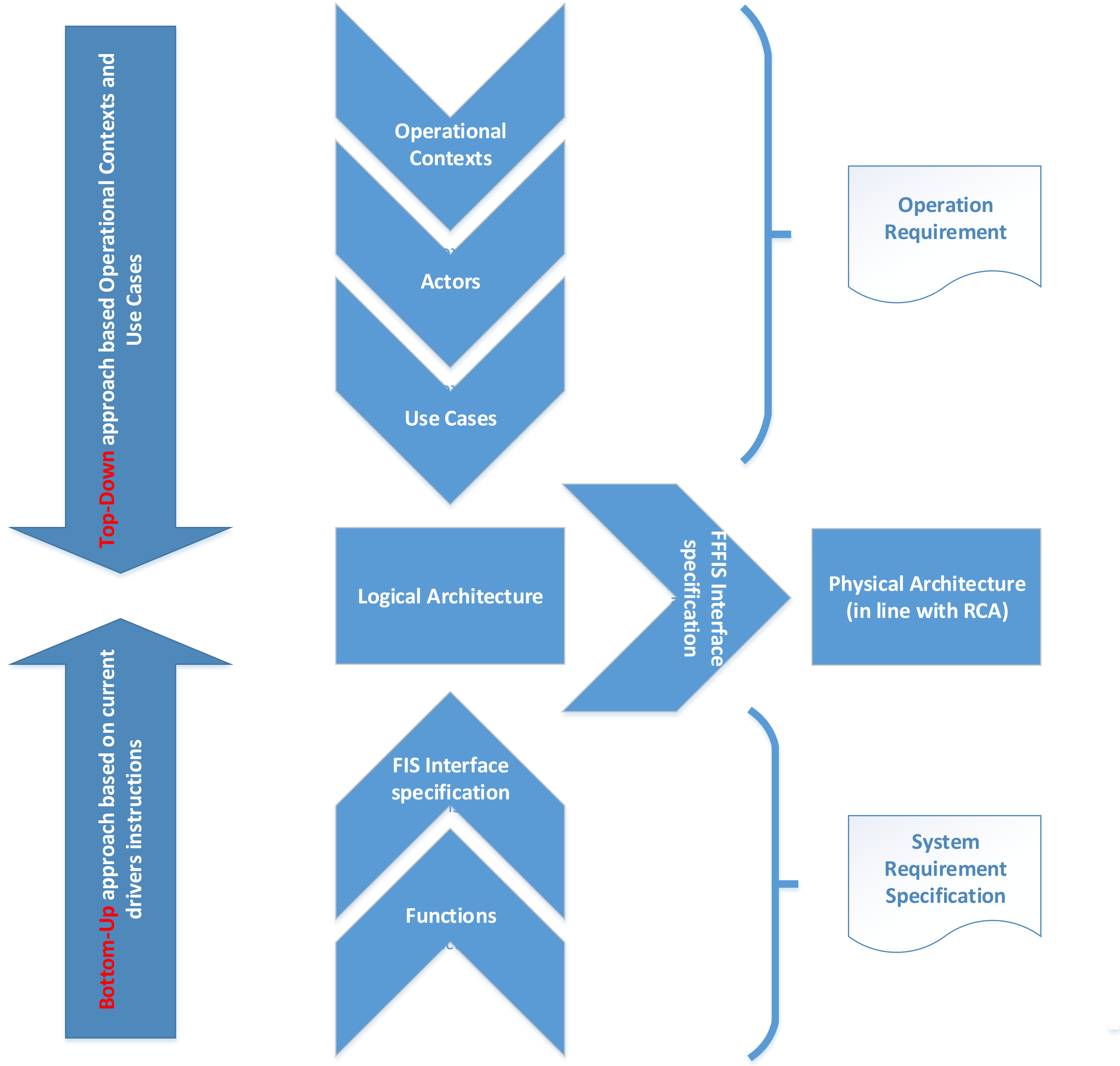
ATO system border

adjacent systems and human actors

interfaces with the ATO system

allocation of functions

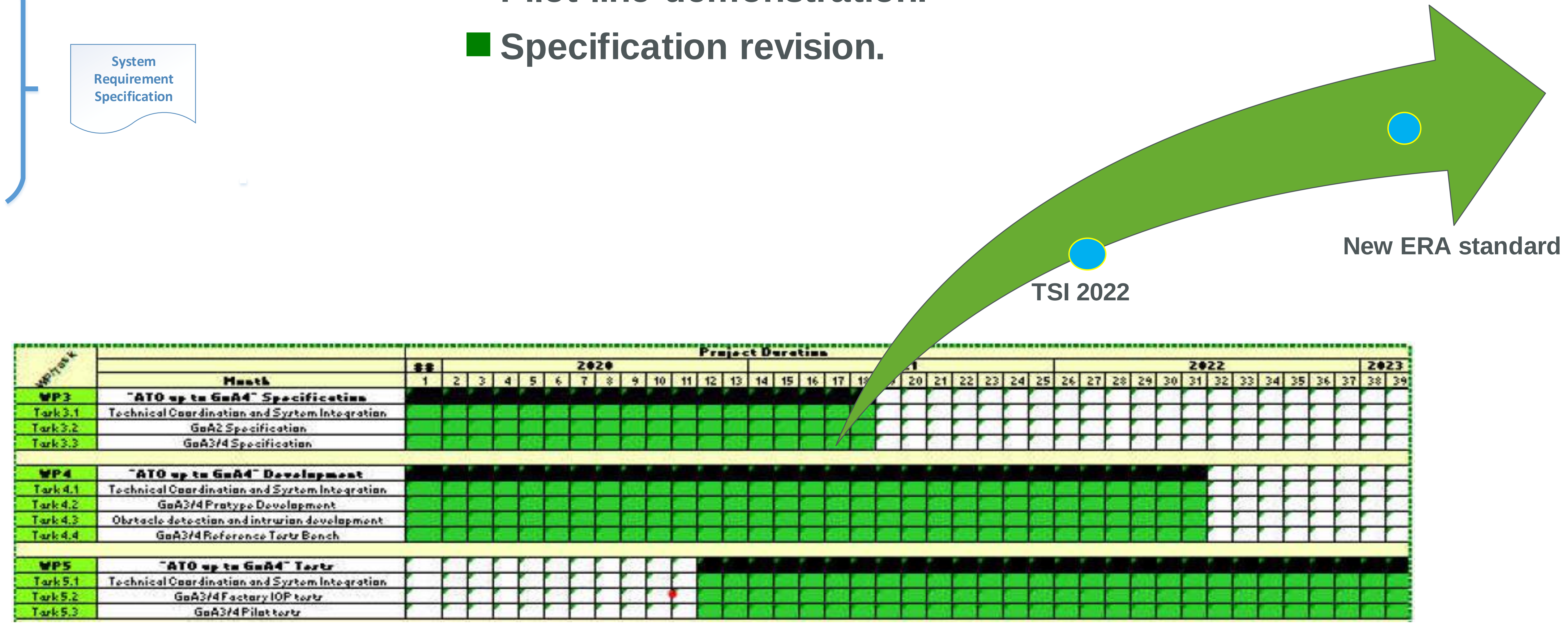
ATO (up to GoA4) Timeline



The first stable set of document are foreseen in May 2021, these specifications are the reference for prototypes development and safety analysis.

Next steps are:

- Risk assessment and safety analysis
- Laboratory test.
- Pilot line demonstration.
- Specification revision.



Conclusions

ATO over ETCS is a reality for GoA2
- Mature solution
- Full interoperability has been demonstrated
- Pilot tests have demonstrated the deployment of GoA2 on existing trains
- Interoperable specification for ATO over ETCS in GoA2 will be part of TSI 2022

Objectives identified at the beginning are achieved
- Performances
- Energy consumption
- Comfort

GoA3/4
- Users requirement harmonisation is on-going (new system)
- Interoperable specification for ATO over ETCS up to GoA4 will be ready for end 2021
- Involvement of The Agency (ERA) will start in 2022

Next steps
- TSI 2022 for GoA2
- Pilot tests for AoE up to GoA4 in January 2023

International Railway Research Board

INTERNATIONAL UNION OF RAILWAYS

10 minutes Coffee-Break

International Railway Research Board

INTERNATIONAL UNION OF RAILWAYS

“Challenges, opportunities and perspectives of rail automation and autonomation in the Russian Federation. Experience of the RZD Holding”

Mr Pavel Popov

Deputy Director General, JSC NIIAS, RZD Holding, Russian Federation

Developing autonomous trains in Russia

2015

Start of project

2017

Start of shunting locomotive testing

2019

Start of the first commuter train GoA3 testing

2020

Start of the second commuter train GoA3+ testing

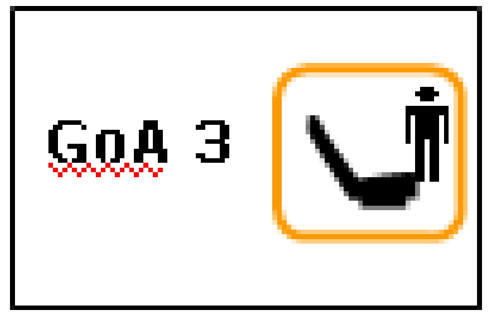
2021

Start of commuter train GoA3+ operation

2022

Start of commuter train GoA4 testing

Main challenges for GoA3 trains



- *The driver may not be in the cab for GoA3.*
- *So the on-board system must detect obstacles.*

Seeing, perceiving and acting – on par with humans or better – are the main challenges to the implementation of autonomous trains.

- What objects to be detected and at what distance?
- How to prove that train perception works correctly?
- How to test train perception?
- How do lighting conditions affect obstacle detection?
- How do visibility conditions affect obstacle detection?
- How does reflectivity of objects affect obstacle detection?
- Where should obstacles be detected?

What are the requirements for perception?

It is necessary to establish the requirements for machine vision, better than the capabilities of the driver, taking into account the level of technology development.

What are the driver's detection capabilities?

- Perception-Reaction time (PRT)?
- Detection range?
- The effect of fatigue
- Influence of weather conditions

Perception-reaction time of human driver

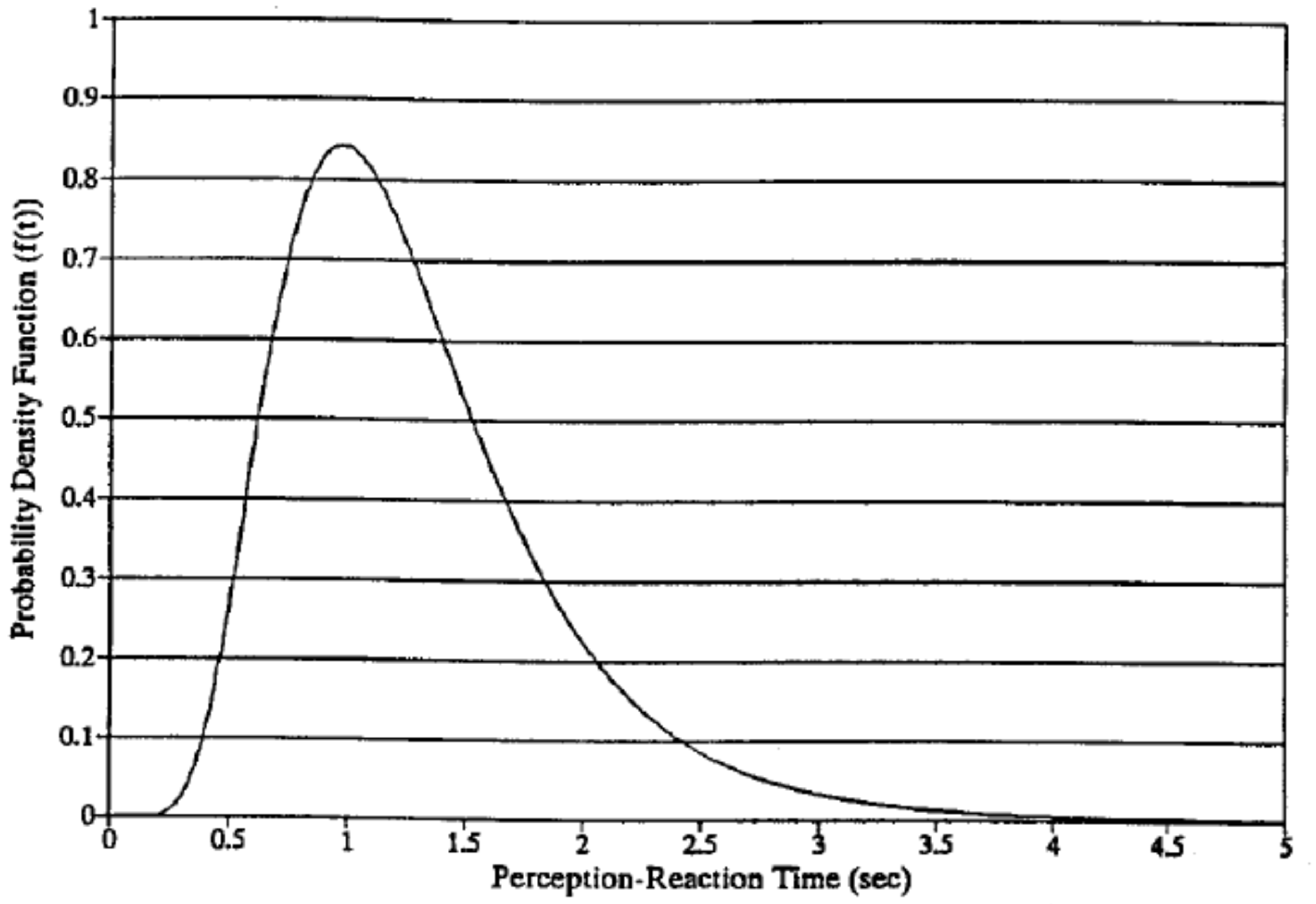


Figure 3.2
Lognormal Distribution of Perception-Reaction Time.

Component	Time (sec)	Cumulative Time (sec)
1) Perception		
Latency	0.31	0.31
Eye Movement	0.09	0.4
Fixation	0.2	1
Recognition	0.5	1.5
2) Initiating Brake Application	1.24	2.74

Hooper-McGee Chaining Model of Perception-Response Time

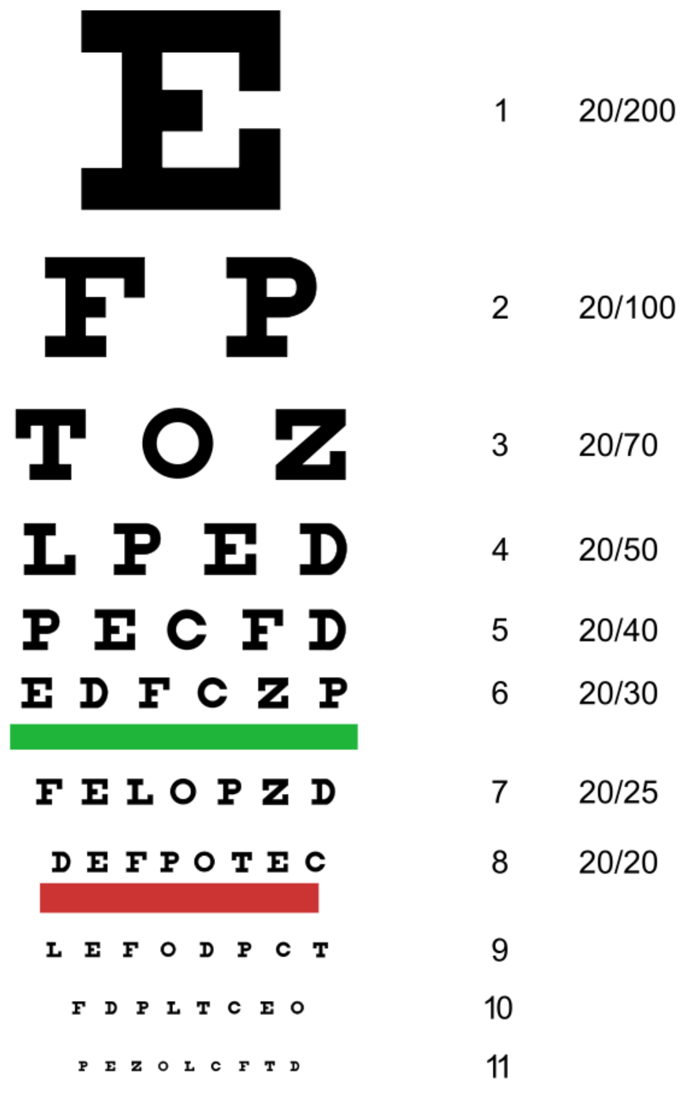
	"Surprise"	"Expected"
Mean	1.31 (sec)	0.54
Standard Dev	0.61	0.1
λ	0.17 (no unit)	-0.63 (no unit)
ξ	0.44 (no unit)	0.18 (no unit)
50th percentile	1.18	0.53
85th percentile	1.87	0.64
95th percentile	2.45	0.72
99th percentile	3.31	0.82

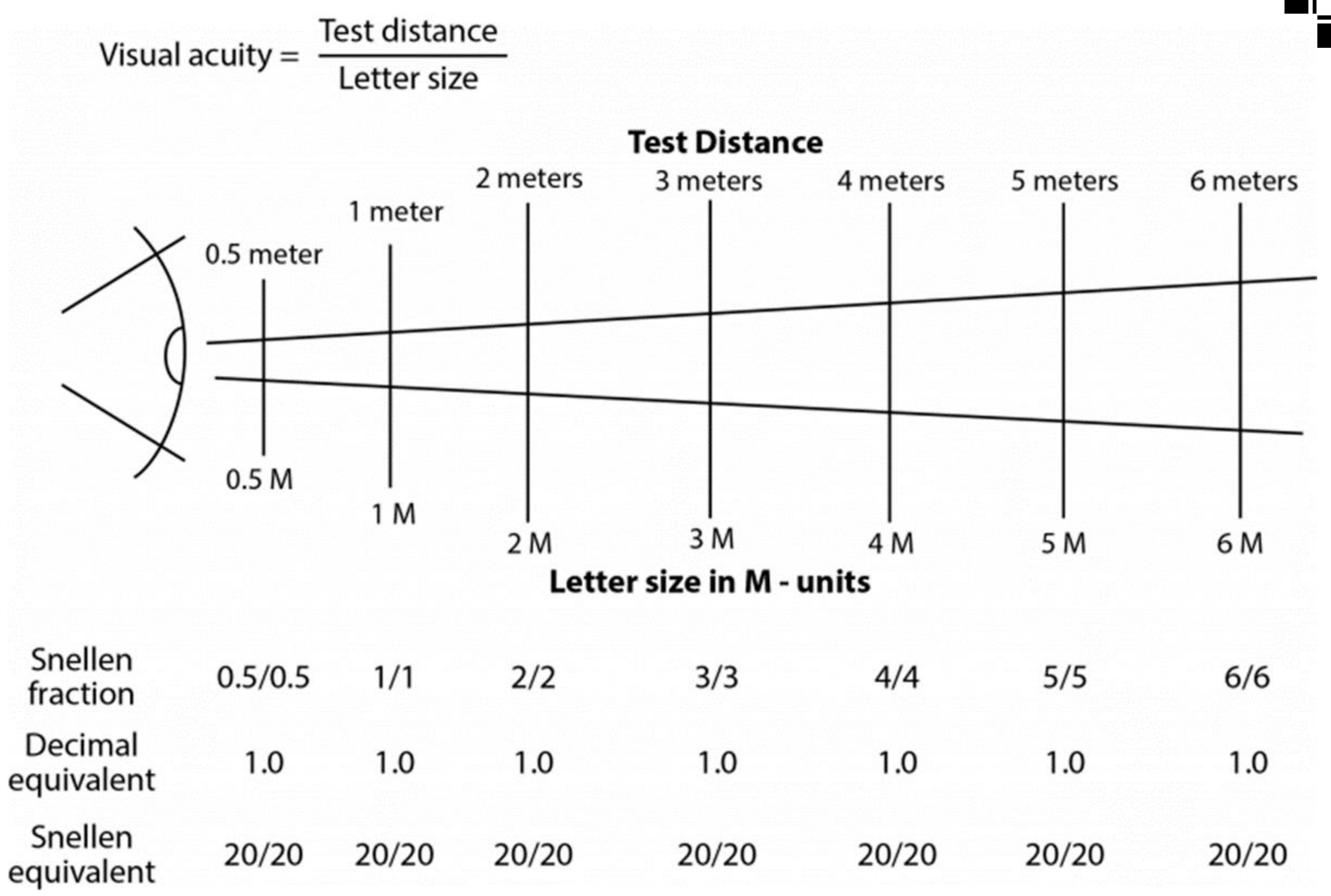
Brake Perception-Reaction Time

Human vision described by visual acuity

Visual acuity is a measure of the spatial resolution of the visual processing system.

A typical Shellen chart that is frequently used for visual acuity testing.





Visual Acuity and Letter Sizes

Snellen Acuity	Visual angle of letter or symbol		Legibility Index
SI (English)	'of arc	radians	m/cm
6/3 (20/10)	2.5	0.00073	13.7
6/6 (20/20)	5	0.00145	6.9
6/9 (20/30)	7.5	0.00218	4.6
6/12 (20/40)	10	0.00291	3.4
6/15 (20/50)	12.5	0.00364	2.7
6/18 (20/60)	15	0.00436	2.3

The exact formula for calculating visual angle is

$$\measuredangle = 2 \arctan\left(\frac{L}{2D}\right)$$

where, L = diameter of the target (letter or symbol)
D = distance from eye to target in the same units

The formula for calculating detection range is:

$$D = \frac{L}{2 * tg\, ^{\alpha}/_{2}}$$

Obstacle and Hazard Detection by human driver

Table below summarizes the detection findings of an object detection study on a roadway.

Object	Mean	Tolerance, 95th confidence		
		STD	95th	99th
1" x 4" Board, 24" x 1"*	2.47	1.21	5.22	6.26
Black toy dog, 6" x 6"	1.81	0.37	2.61	2.91
White toy dog, 6" x 6"	2.13	0.87	4.10	4.84
Tire tread, 8" x 18"	2.15	0.38	2.95	3.26
Tree Branch, 18" x 12"	4.91	1.27	7.63	8.67
Hay bale, 48" x 18"	4.50	1.28	7.22	8.26
All Targets	3.10	0.57	4.30	4.76

****frontal viewing plan dimensions***

Source: Picha D. "Determination of Driver Capability in the Detection and Recognition of an Object."

Human detection

This is a simple example of calculations for the detection distance of a person with normal vision (20/20).

Obstacle	Max size, m	Detection distance, m daylight	Detection distance, m nightlight
Adult	1,7	1172	584
Child	1,2	827	412
Cattle	2	1337	687
Small animals	0,5	344	172
Car	4	2759	1374
Bicycle	2	1337	687
Static obstacle 0,7*0,7m	0,7	483	240
Static obstacle 0,3*0,3m	0,3	207	103

“Since visual acuity declines by as much as two snellen lines after nightfall, to be detected such targets with similar contrast would have to subtend somewhere around 2.5 times the visual angle that they would at detection under daylight conditions.”

Visibility conditions

Visibility condition	Parameter, meters	Examples
Normal	visibility> 2000	Light precipitation or better
Poor	200< visibility<2000	Light fog, snow, heavy haze
Very poor	visibility < 200	Heavy fog, heavy snow

Visibility is a parameter that is possible to measure!

The requirements for detecting obstacles are set, taking into account the visibility conditions.

Visibility measuring device

Lighting conditions

Lighting condition	Lighting, lux
Daylight	5000 - 100000
Overcast day	1000 – 5000
Twilight	1 -1000
Night	0,001 – 0,1

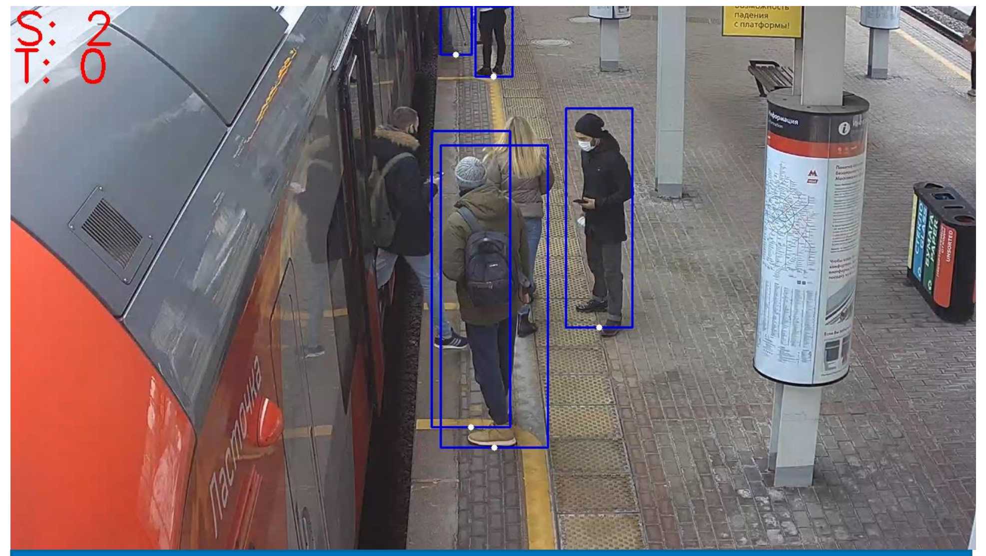
The bright glare of the sun or the combination of artificial lighting from different sources at night and at dusk, the presence of shadows significantly complicate the detection of obstacles.

The level of lighting has to take into account in algorithms for the detection and during tests.

Obstacle classification for railway

№	Class	Subclass	Status or description	Threat to an obstacle	Threat to a vehicle
1	Pedestrians	Adults	Standing, moving, sitting, lying	Yes	No
		Kids	Standing, moving, sitting, lying		
2	Animals	Big animals (examples: cow, horse, moose)	Standing, moving, sitting, lying	Yes	Partially (at high speed)
		Medium and small animals (examples: goat, dog, cat)	Standing, moving, sitting, lying	Yes	No
3	Train units	Locomotives, train cars, maintenance vehicles and etc.	Standing, moving	Yes	Yes
4	Road vehicles	Cars, trucks	Standing, moving	Yes	Yes
		Motorcycles, bicycles		Yes	No
5	Static obstacles	Big (cross section area in the plane perpendicular to the rails is more than 0.5 m^2)	Violation of the clearance gauge : building construction, fallen tree, tilted posts and other constructions	No	Yes
		Medium (cross section area in the plane perpendicular to the rails from 0.1 to 0,5 m^2)	Boxes, shrubs, parts of building constructions	No	Partially
		Small (cross section area less than 0,1 m^2)	Brake shoe	No	Yes
			Stones, rail tools and mechanisms	No	Partially
			Various items (boxes, wood boards and etc.)	No	No
6	The defects of infrastructure	Sun kink, a drawdown of the track, broken rails		No	Yes
		breakage, sagging of catenary		No	Yes
7	Natural phenomenon	Flooding of tracks, undermining of tracks		No	Yes
		Fire		No	Yes
		Snowdrift		No	Partially
		Landslide, mudflow		No	Yes

System architecture



Embarkation and disembarkation control

Digital communication LTE-1800

Remote control center

Remote drivers

Dispatchers

Stationary obstacle detection system

Maintenance

Trains GoA4

Autonomy is not only about trains, but also about the appropriate infrastructure!

Our GoA3 trains for tests

Commuter GoA3 trains for tests (2 modifications)

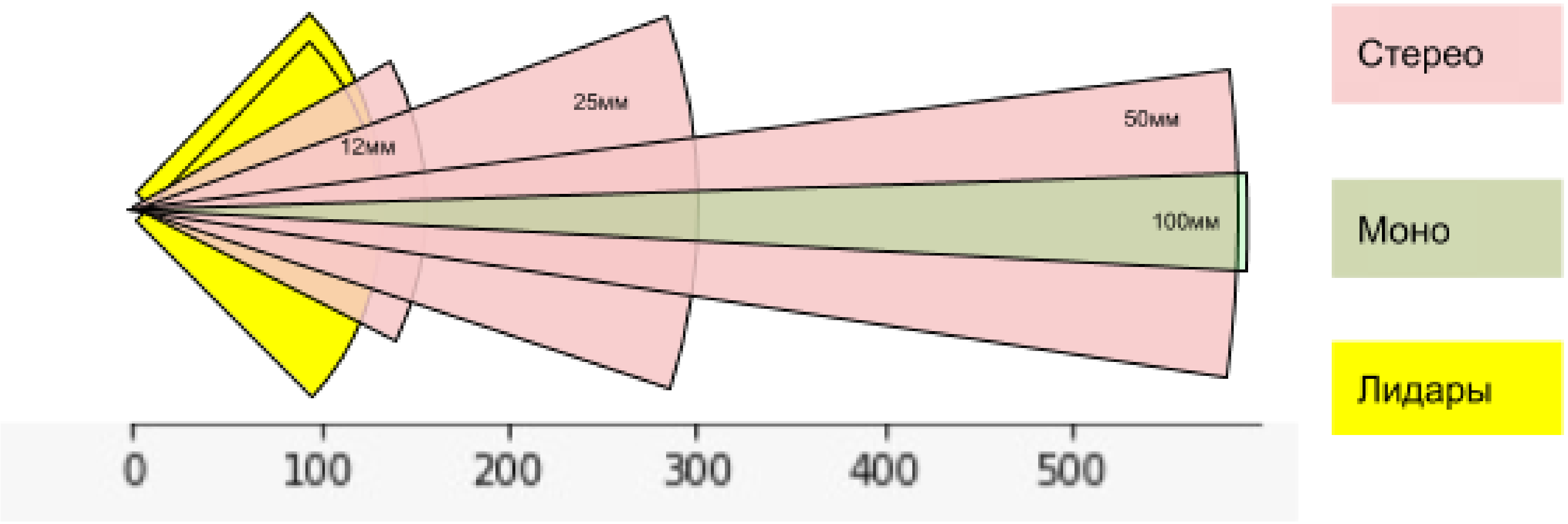
The first GoA3 train

IR camera

8-cameras behind frontal glass

Lidars

Lastochka ES2G- №113



The second GoA3 train for tests

Lastochka ES2G №136

- Advanced set of optical cameras;
- Lidars with cleaning system;
- Advanced Localization system;
- IR cameras with cleaning system;
- Cameras for pantograph and catenary control
- Majority processing of sensors.

Pantograph and catenary control

Examples of perception processing

Railway datasets

Type of climate	Time of day	Shape of track	Ego Motion	Rail conditions
Fine, Cloudy, Rainy, Sleet, Snow, Hail, Fog	Morning Daytime Evening Night	Straight Curve Downhill Uphill	Accelerating Decelerating Constant speed Stopping	Dry Wet Water trough …

«Autonomous vehicle technology typically involves some type of machine learning, especially for object detection and classification» (SOTIF)

- ➢ Should there be a shared open railway dataset?
- ➢ How to check the correctness and completeness of the dataset?
- ➢ How to label a dataset? Should be a general rules for labeling?

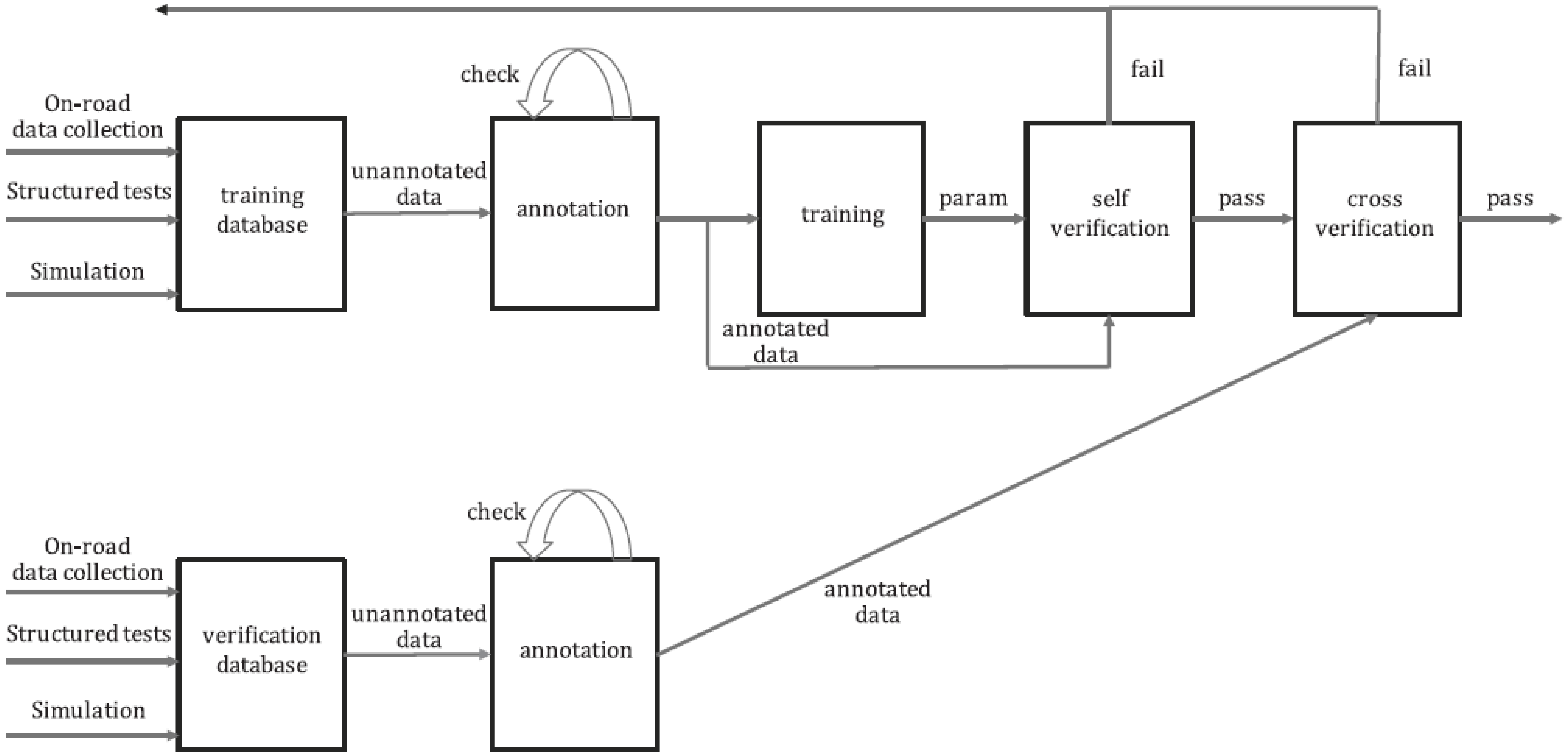
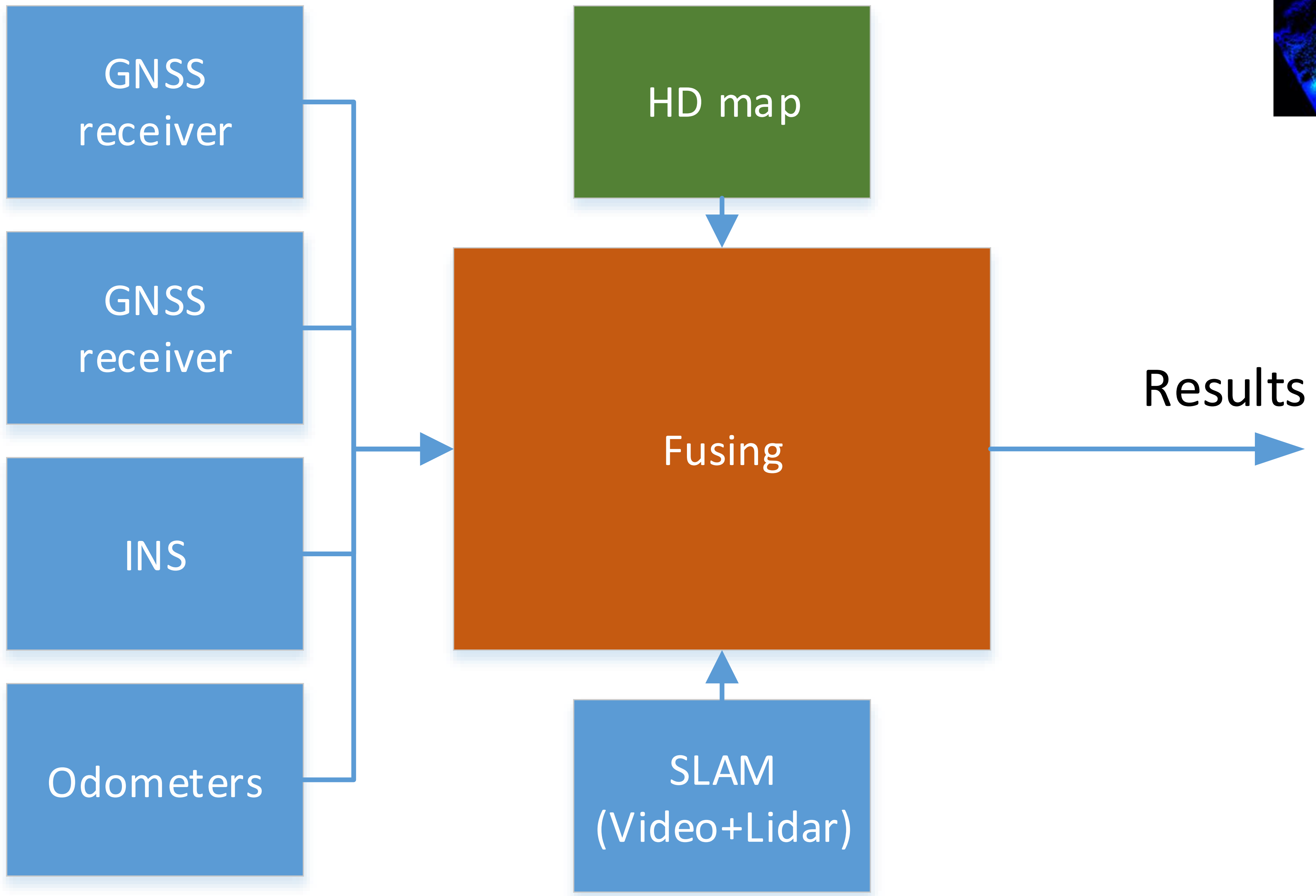


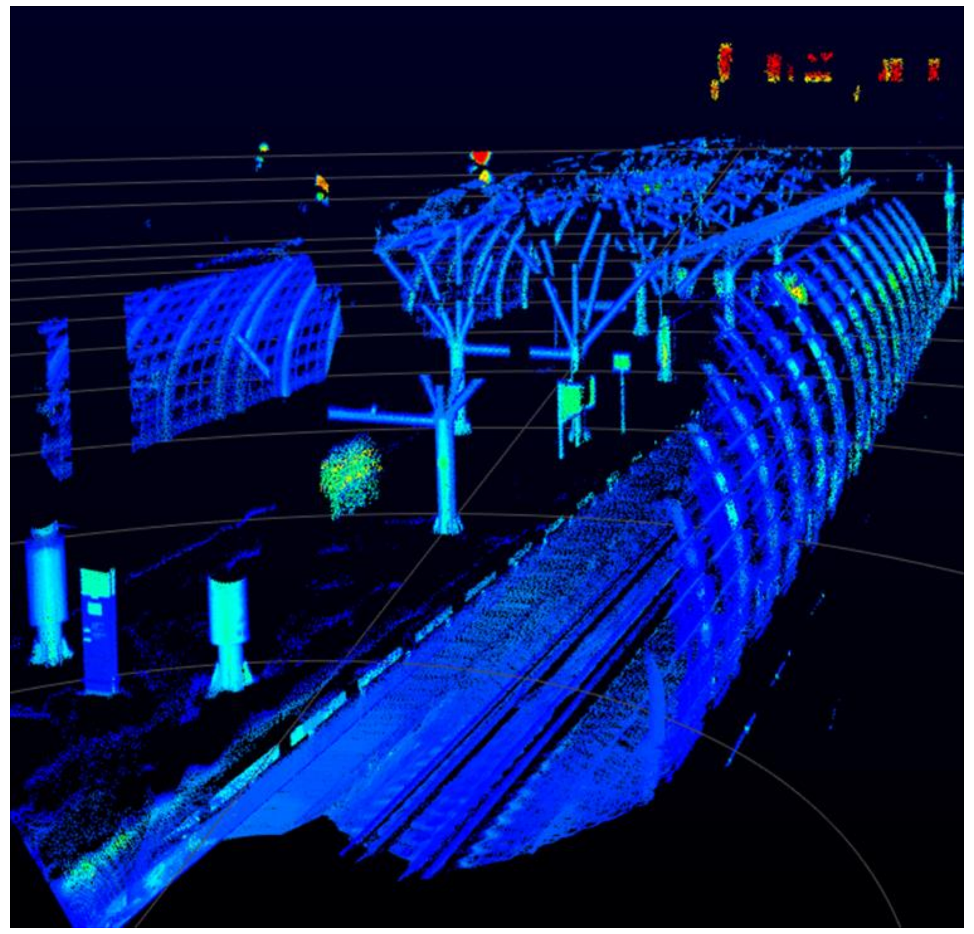
Figure G.1 — Off-line machine learning process flow

Where is the track? What obstacles are to be detected?

Localization and high-definition maps

- Satellite compass based on two GNSS receivers
- Inertial navigation system (INS)
- Odometers
- SLAM
- HD map





Lidar data. 1-10 cm

Orthophoto. 10-15 cm

Remote control and driving

Why?

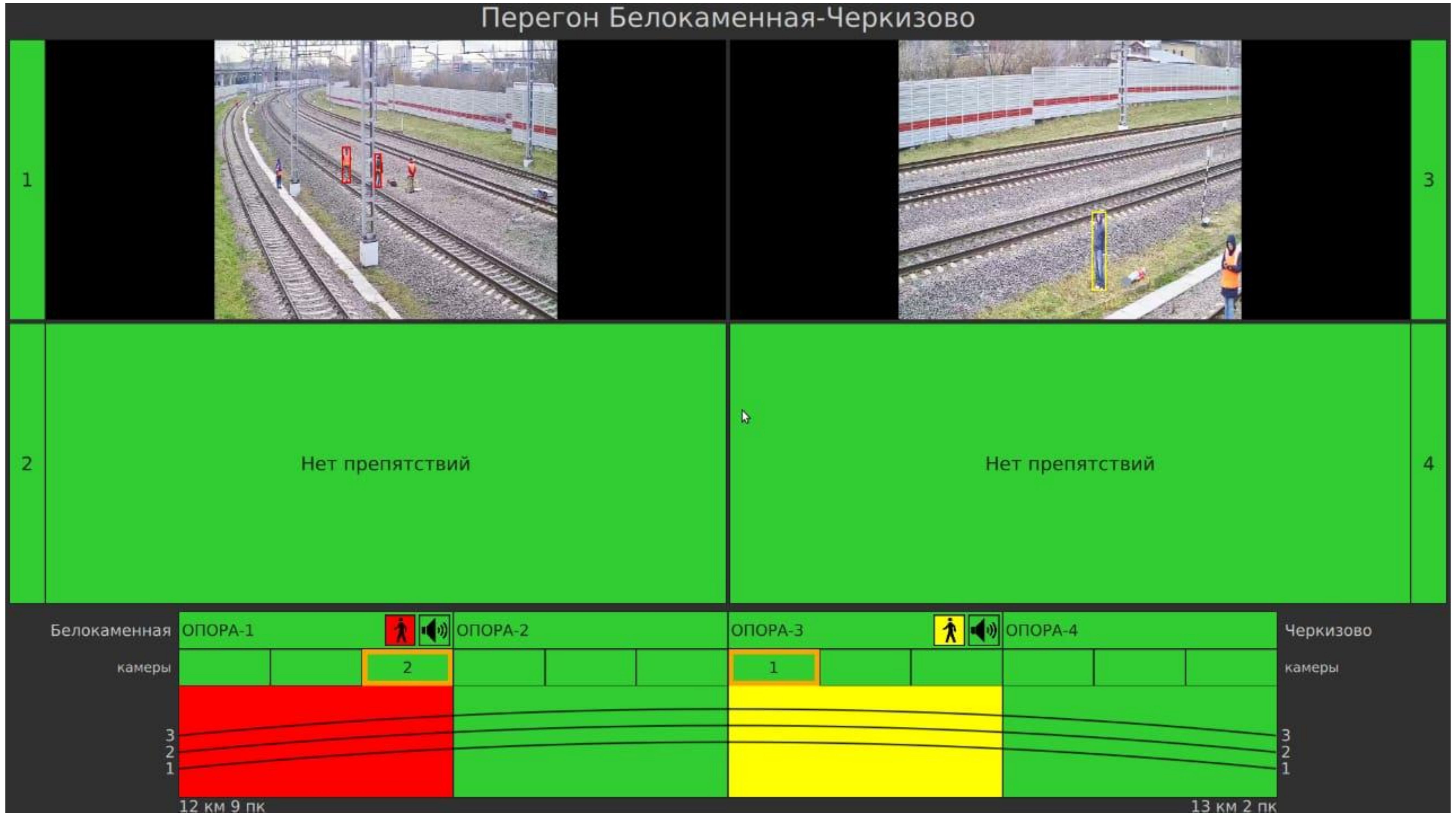
- Communication with passengers
- Control when obstacles are detected
- Cancellation of the braking in case of false positives
- Actions in case of emergency situations (smoking, fire, fight in the car and so on)
- Remote driving, when it's necessary (for example, equipment failure)

The operator controls up to 10 trains and drives one train remotely, if necessary

Technical challenges:

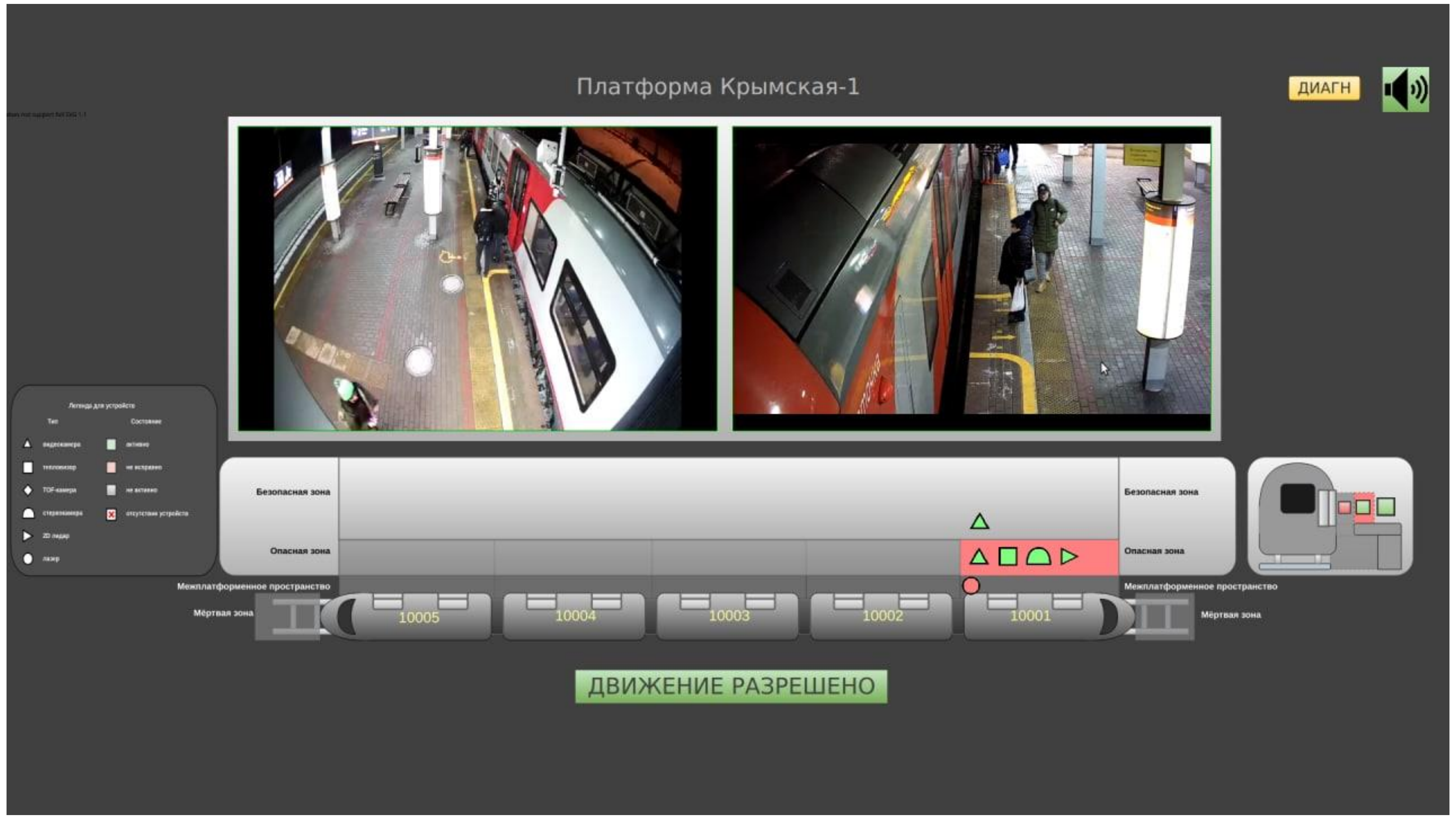
- Low latency and high bandwidth of digital communication
- reducing the latency of the video stream (coding and encoding of video streaming)
- Trade-off between fps and resolution of image

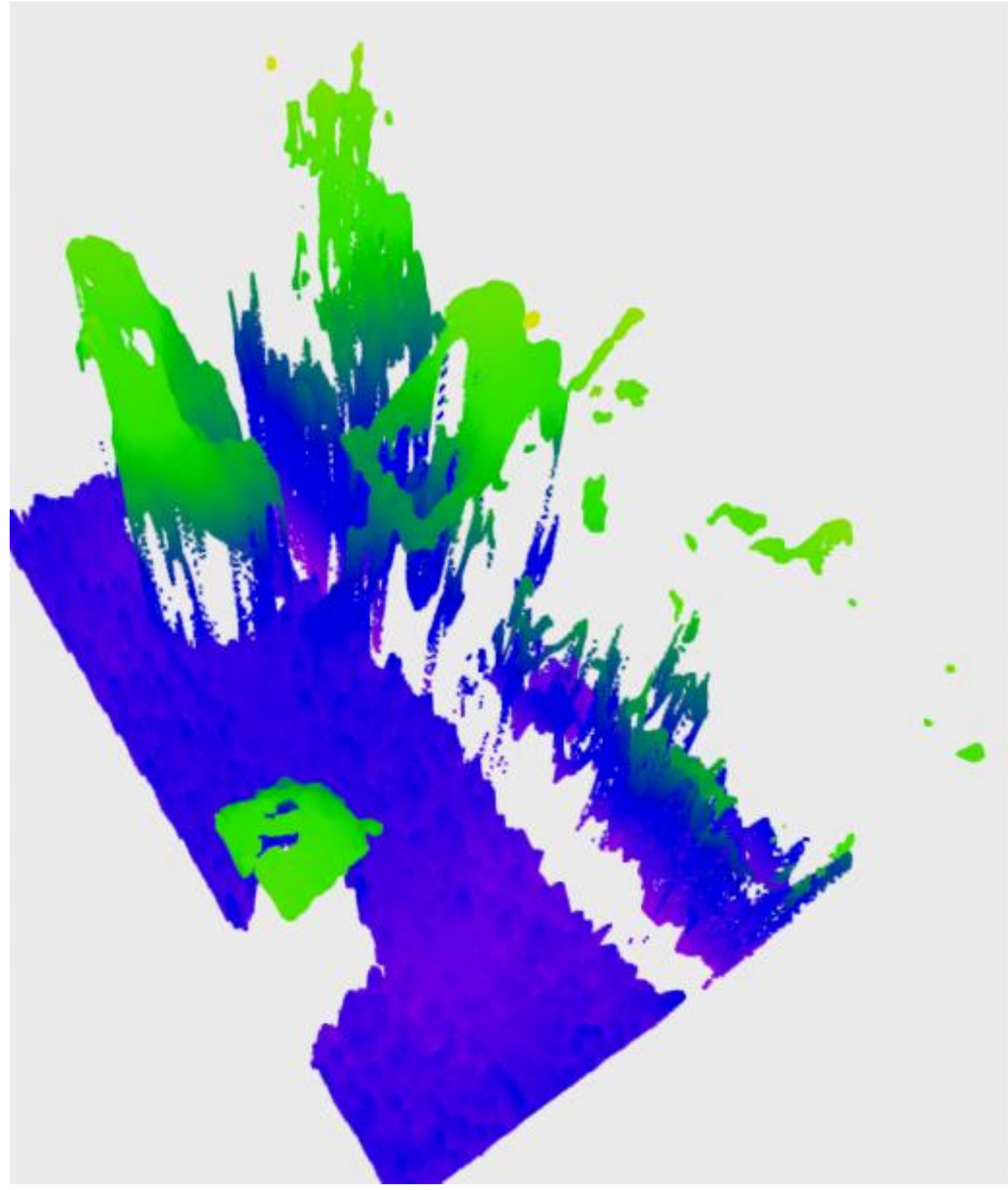
Stationary obstacle detection system for areas with limited visibility (curves, tunnels)

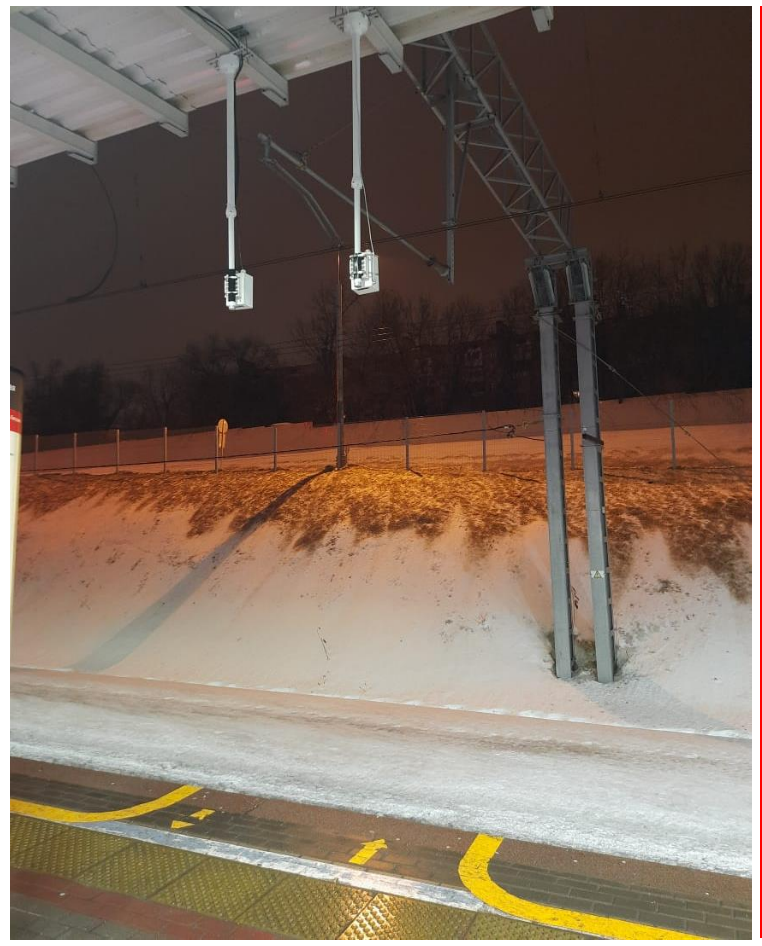


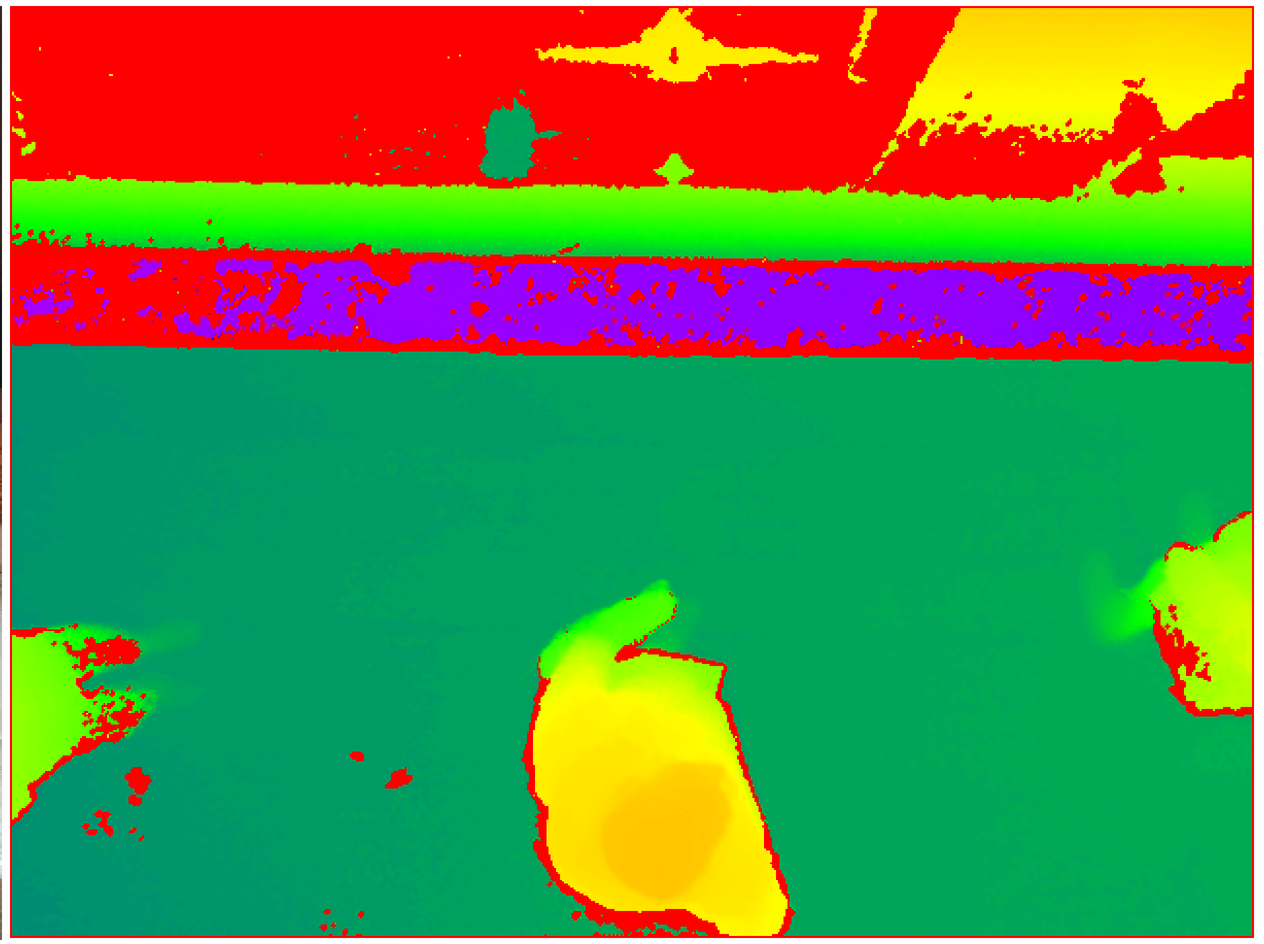
Detecting obstacles on the track, setting temporary speed restrictions and sound notification

Supervision of passenger boarding and detraining



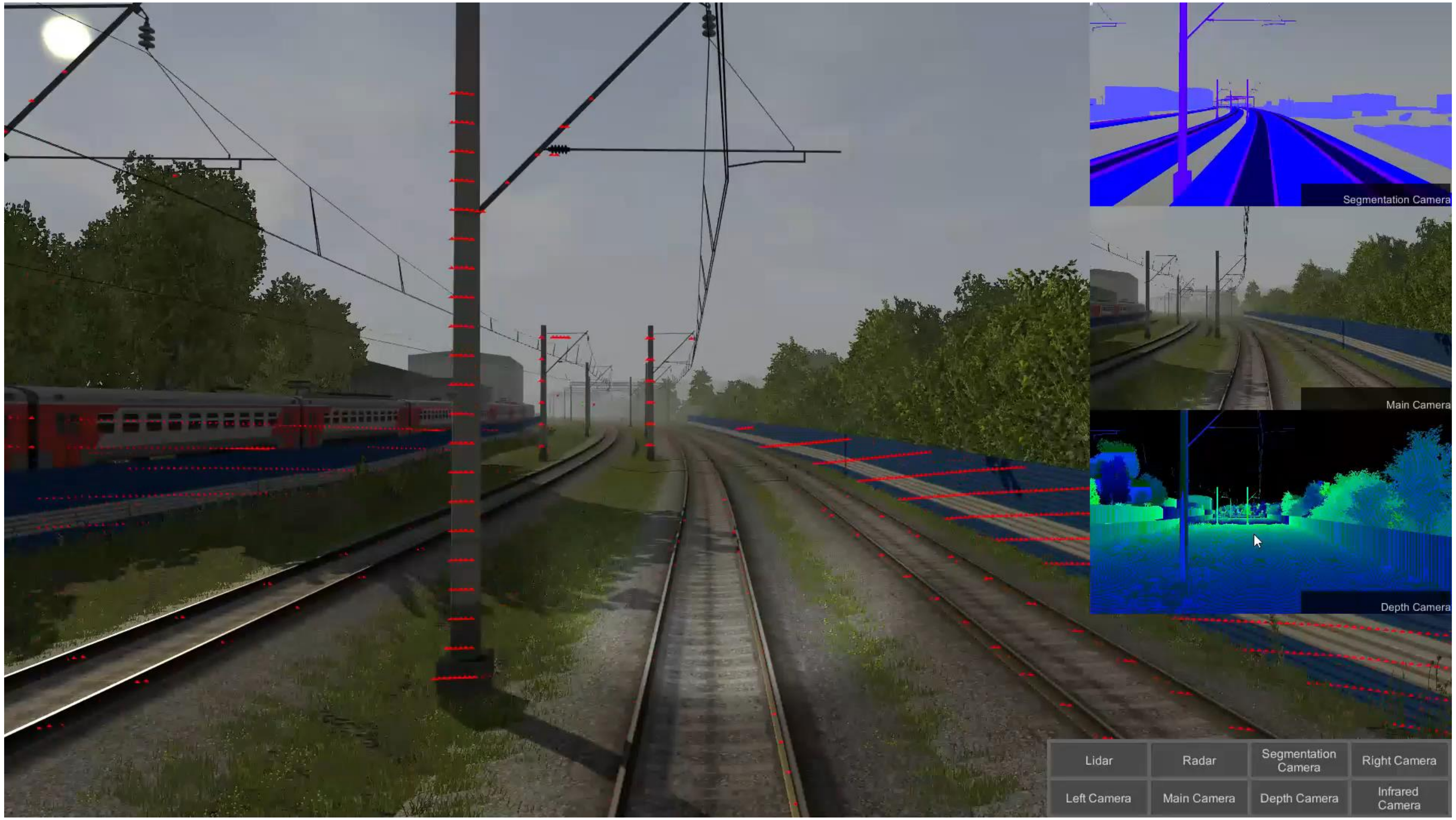






Requirements for the detection: pinching people or parts of them, people falling between the train and the platform, people or obstacles on the track, deviant behavior on the platform

Simulator



Problems to be solved through the simulator:

1. Testing of data processing algorithms for different sensors
2. Testing system behavior in hazardous situations

Easily test rare and difficult conditions: rainstorms, snowstorms, and sharp glare at different times of the day and night, with different rail surfaces and surroundings.

DUMMIES

WHAT DUMMIES IS IT NECESSARY TO USE FOR THE TESTS?

Figure 5-1: Euro NCAP Pedestrian and Bicyclist and bike Targets (EPTa, EPTc and EBT)

WHAT ARE THE REQUIREMENTS FOR DUMMIES?

Onsite tests

TEST EQUIPMENT

- Luxmeter;

- Visibility sensor;

- Reflectometer (optional);
- Set of dummies.

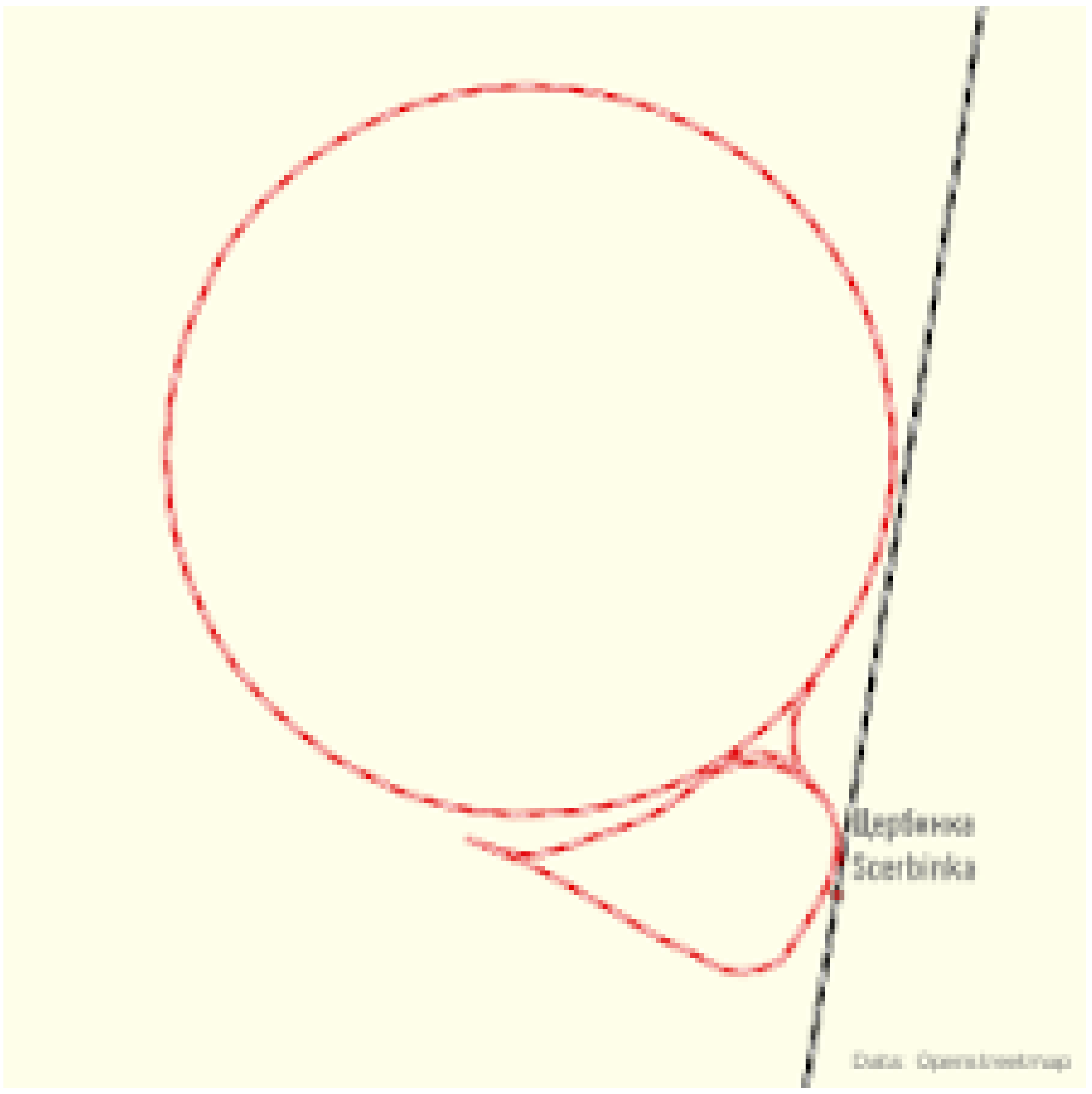
TEST SCENARIOS

Formalized description of test scenarios and conditions for their implementation

ASAM

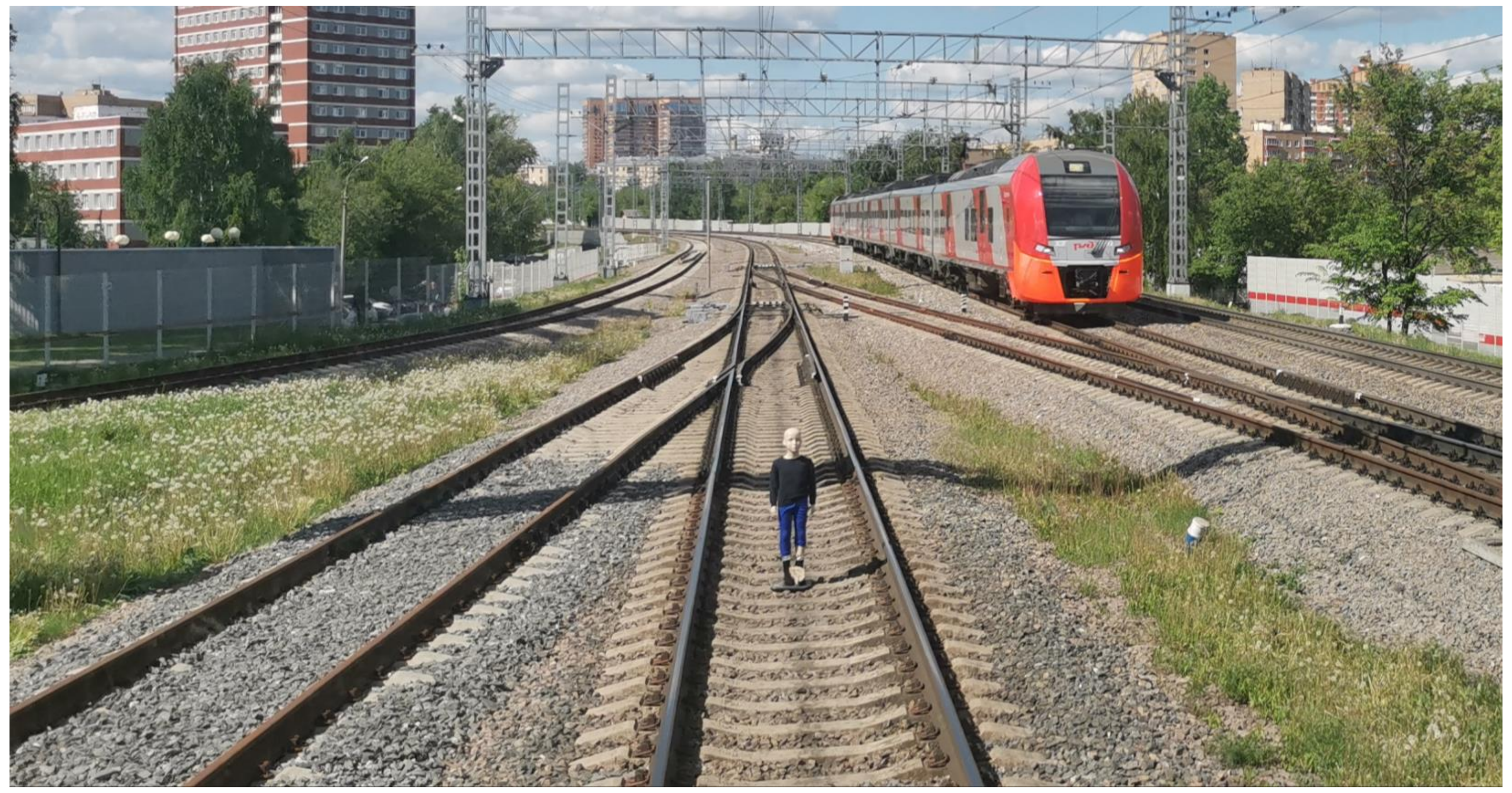
OpenSCENARIO: Version 2.0.0 Concepts

TEST RING



Scherbinka

Our onsite tests



Our onsite tests






My e-mail:
p.popov@vniias.ru

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“Challenges, opportunities and perspectives of rail automation and autonomation. Experience of the AAR”

Mr Gary Fry

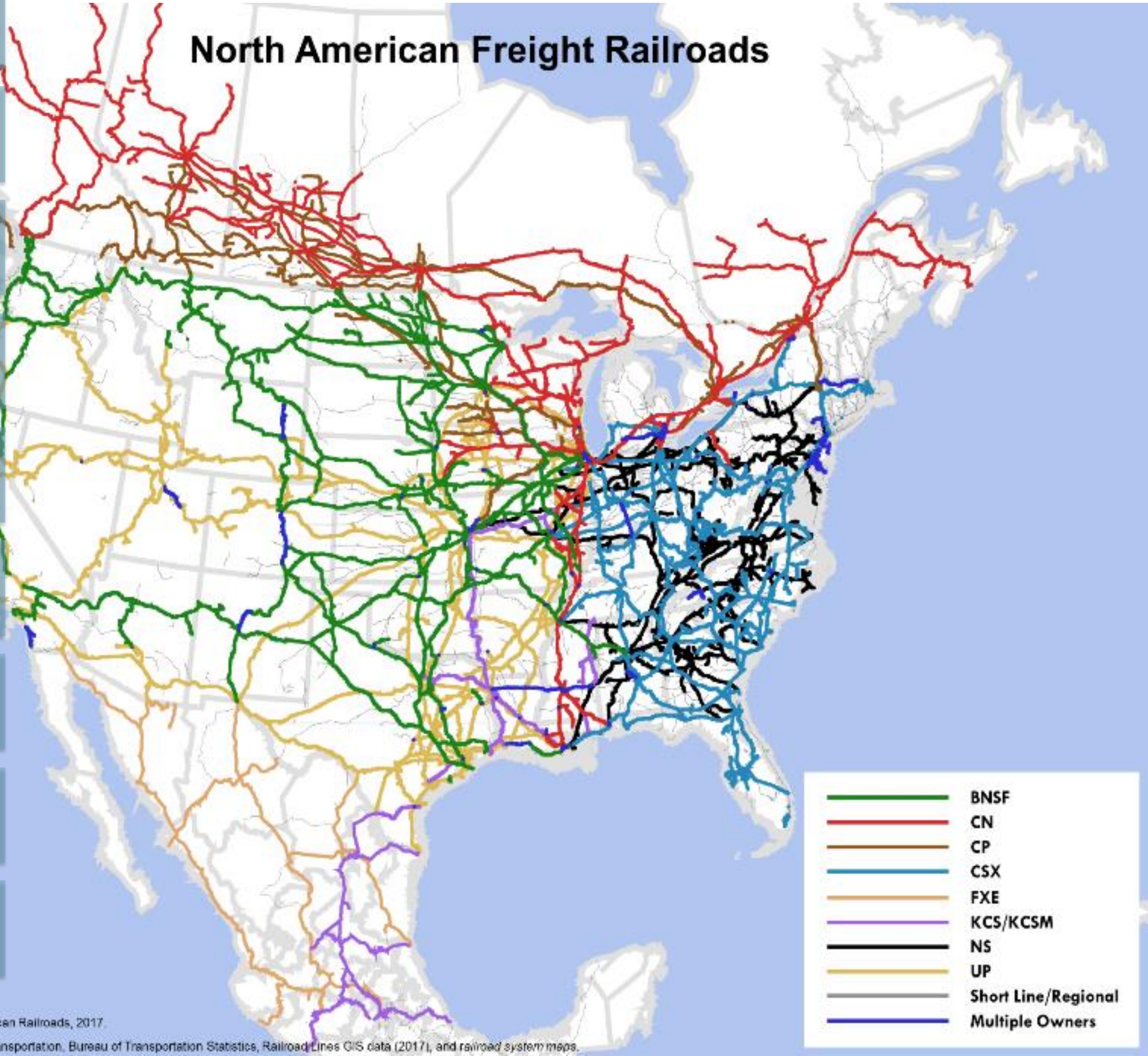
Vice-President for Research and Development, AAR, Transportation and Technology Center

Mr Thomas Nast

Principal Investigator II, TTCI

North American Freight Railroads

- 650 separate railroads; 7 Class I
- 1.6 million freight wagons
- 290,000 kilometers of track
- 167,000 employees
- 32.5-tonne axle loads allowed
- 1.47 billion tonnes of freight annually
- 32 million passengers annually
- 30,000 locomotives
- $70 billion USD annual revenue



AAR Strategic Research Initiatives Program

- **SRI Vision**:

The SRI vision for North America's railways is a future without train derailments or train accidents.

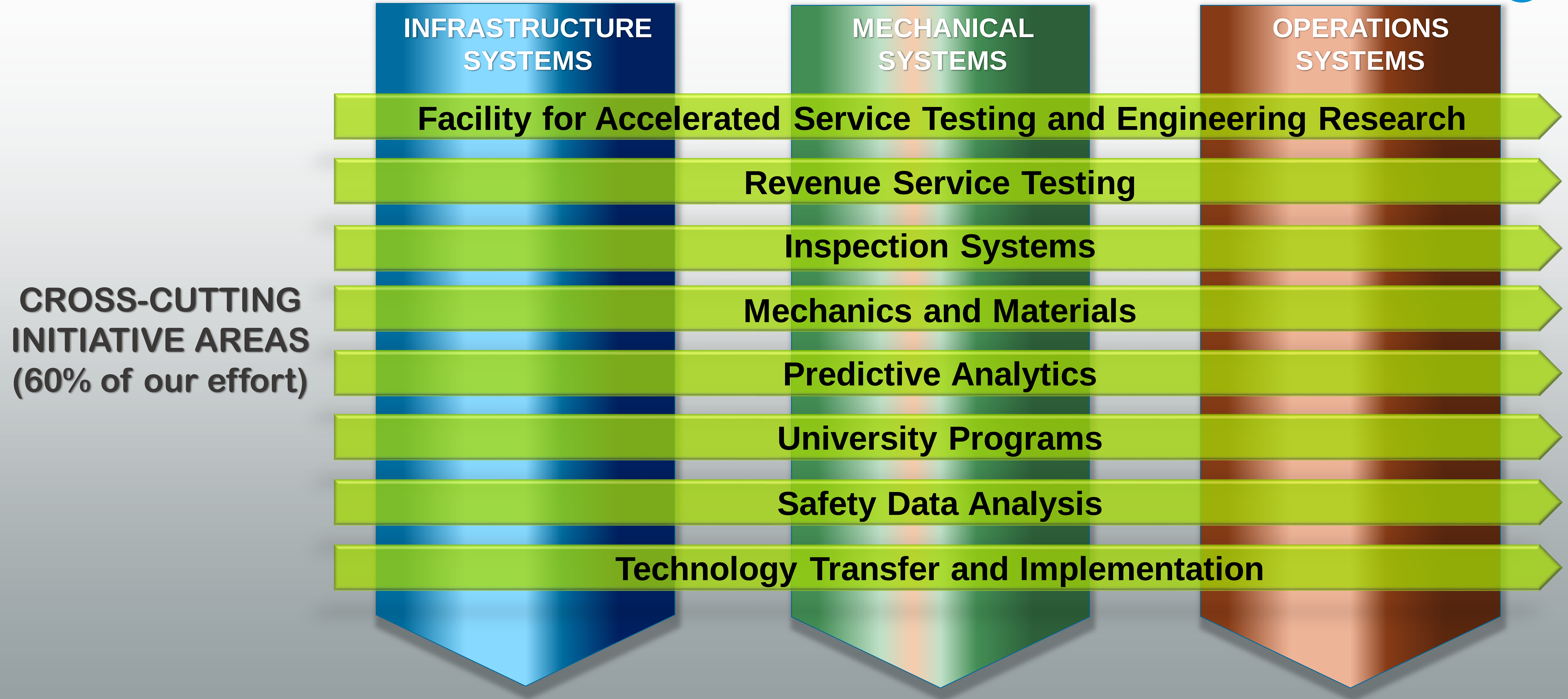
- **SRI Mission**:

The SRI mission for North America's railways is to create and transfer knowledge, to innovate, to support functional and technological development, and to support *IMPLEMENTATION*.

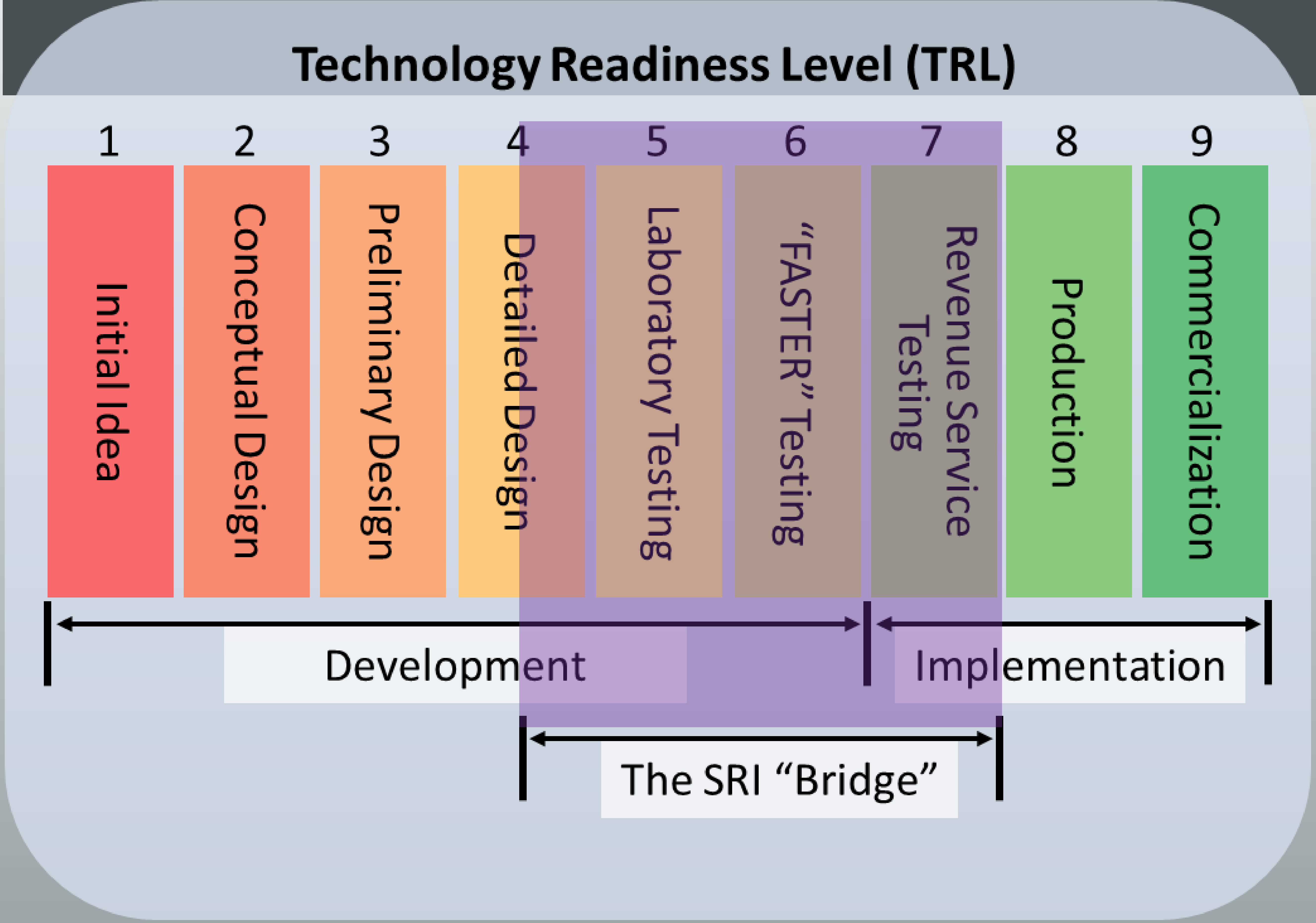
Enhance Safety	Eliminate track and equipment-related derailments
Enhance Reliability	Eliminate line-of-road failures
Enhance Efficiency	Increase productivity and reduce costs

SRI Objectives

SRI Subject Matter Structure



SRI Technology Transfer and Implementation



- **Technology Transfer**—Plan, manage, and support knowledge exchange to discover new technology and to strengthen new technology development.
- **Technology Implementation**—Support revenue service implementation of new technology, including ongoing monitoring and measurements.
- **Regulatory Support**—Perform data collection and analyses in support of waivers, pilot programs, and improved rule-making.

International Railway Research Board

INTERNATIONAL UNION OF RAILWAYS

North American Freight Rail Automated Train Operation

Concept and Industry Efforts

Mr Gary Fry

Vice-President for Research and Development, AAR, Transportation and Technology Center

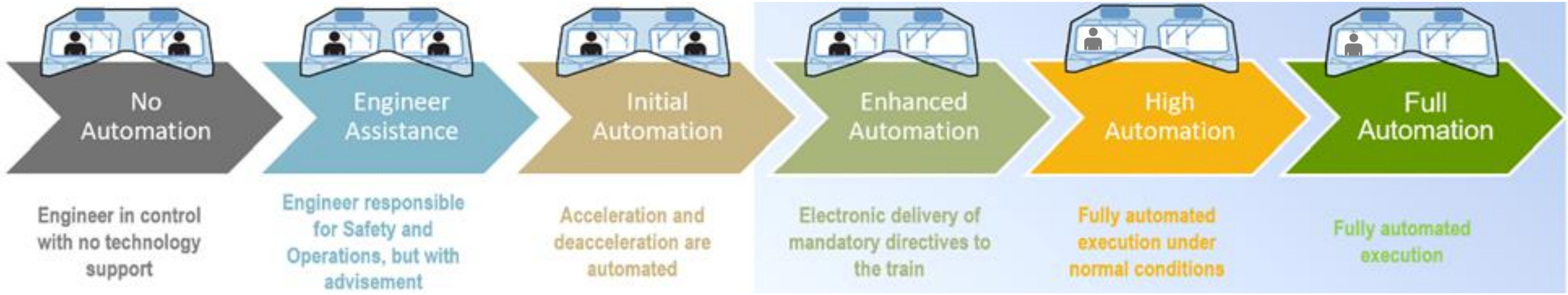
Mr Thomas Nast

Principal Investigator II, TTCI

IRRB Webinar Autonomous Technologies in Rail – Anticipating Expectations, June 9 2021

What is Automated Train Operation (ATO)?

Within the North American Freight Rail Industry concept, ATO is the fusion of multiple existing and emerging railway systems to automate train operation functions.

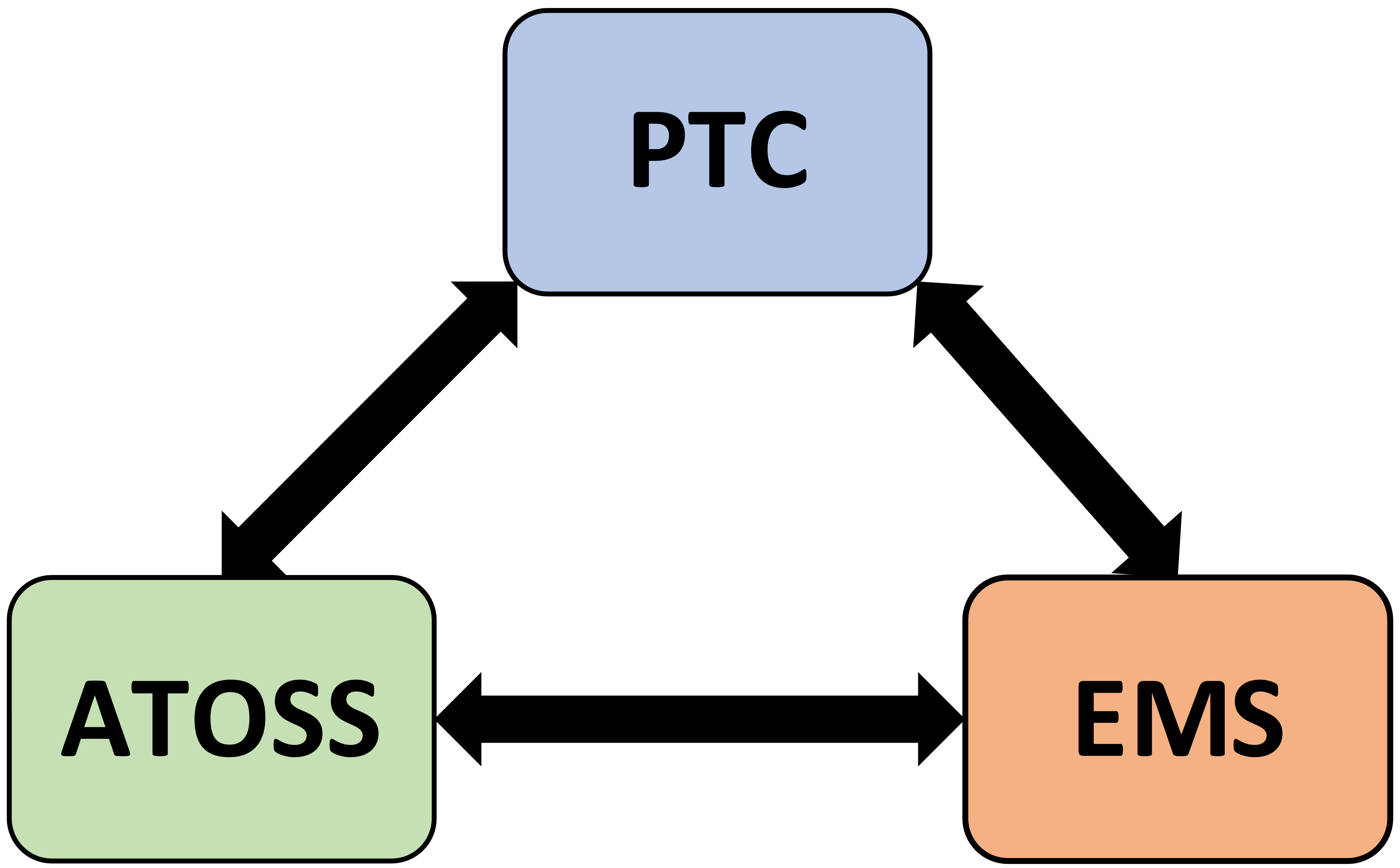


Train automation level is driven by capability of constituent systems

Objectives of ATO in the North American Freight Rail Industry

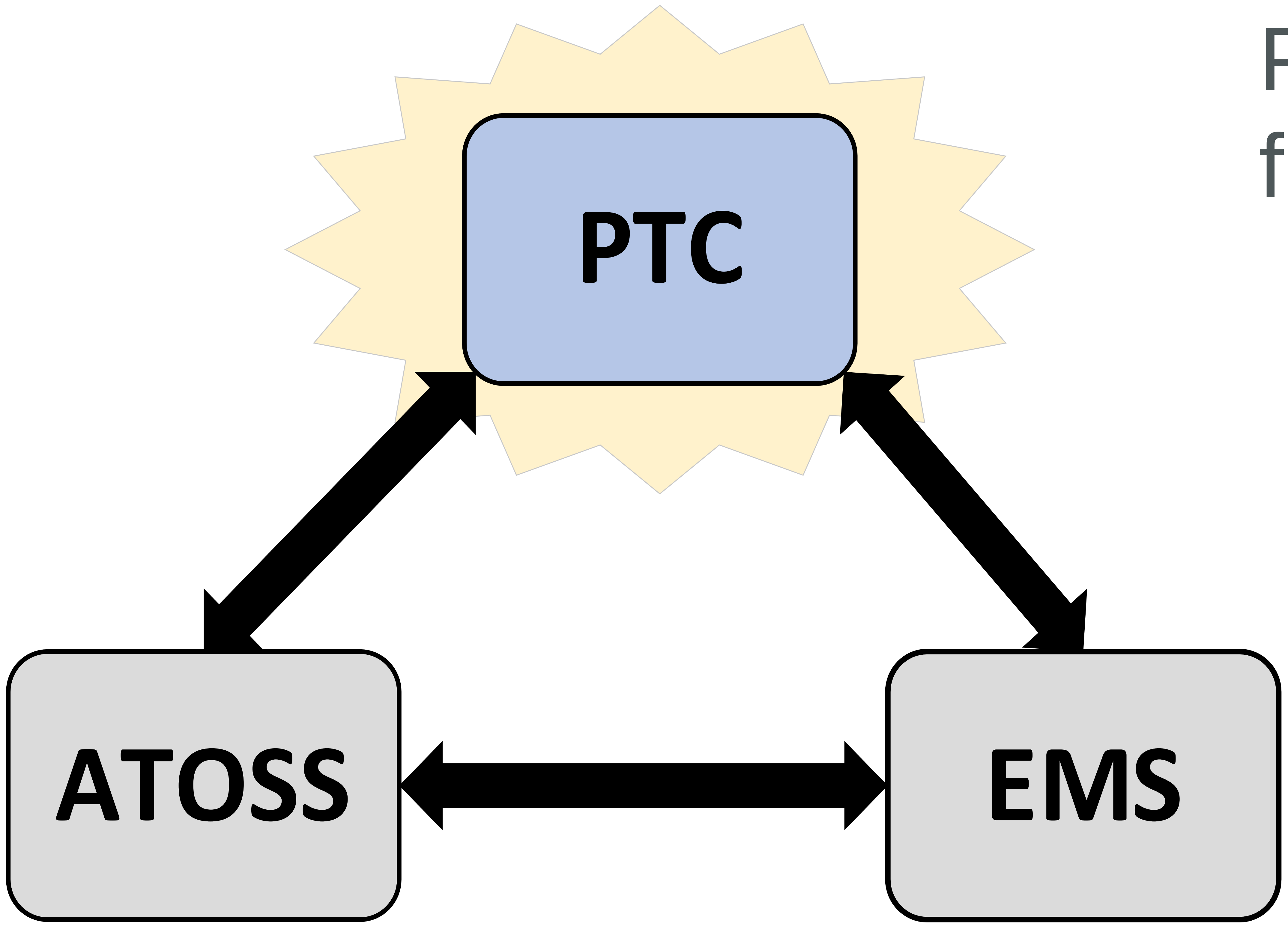
- Improve railroad efficiency by increasing consistency of train operation
- Satisfy industry safety targets
- Promote and maintain industry interoperability

Interoperable Constituent Systems within the North American Freight Rail ATO Concept



- Train automation functions are provided by the independent function and interaction of:
  - Positive Train Control (PTC)
  - Energy Management System (EMS)
  - ATO Support Systems (ATOSS)
- Primary system interaction between systems occurs on the locomotive
- Cross monitoring between systems promotes system safety

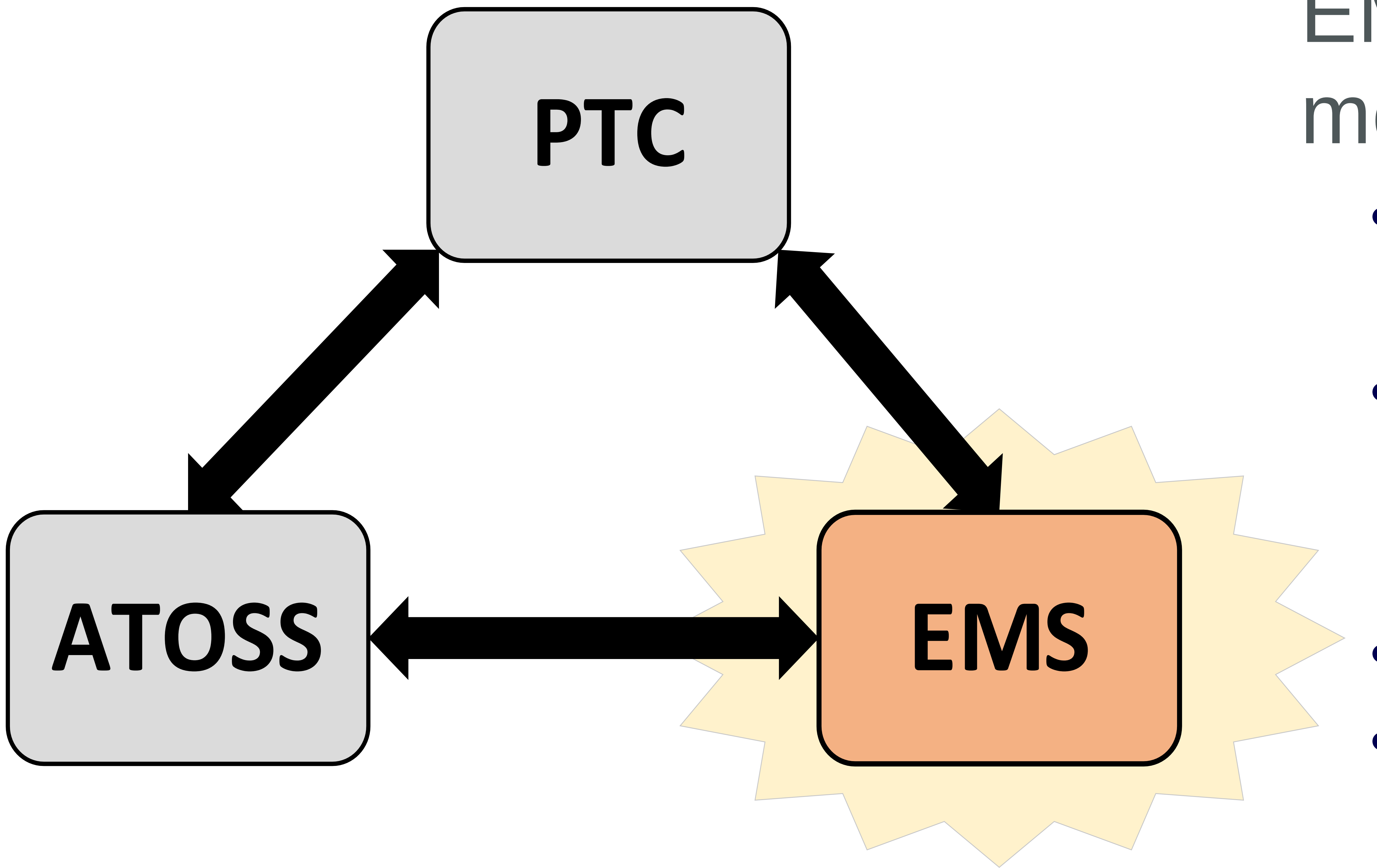
Role of PTC within the North American Freight Rail ATO Concept



PTC is responsible for train control functions, for example:

- Enforcement of movement authority limits
- Enforcement of civil speed restrictions
- Enforcement of temporary speed restrictions
- Enforcement of work zone limits
- Enforcement of critical alerts
- Prevent train movement through a switch in an unsafe position
- Conveyance of mandatory directives and critical alerts to trains

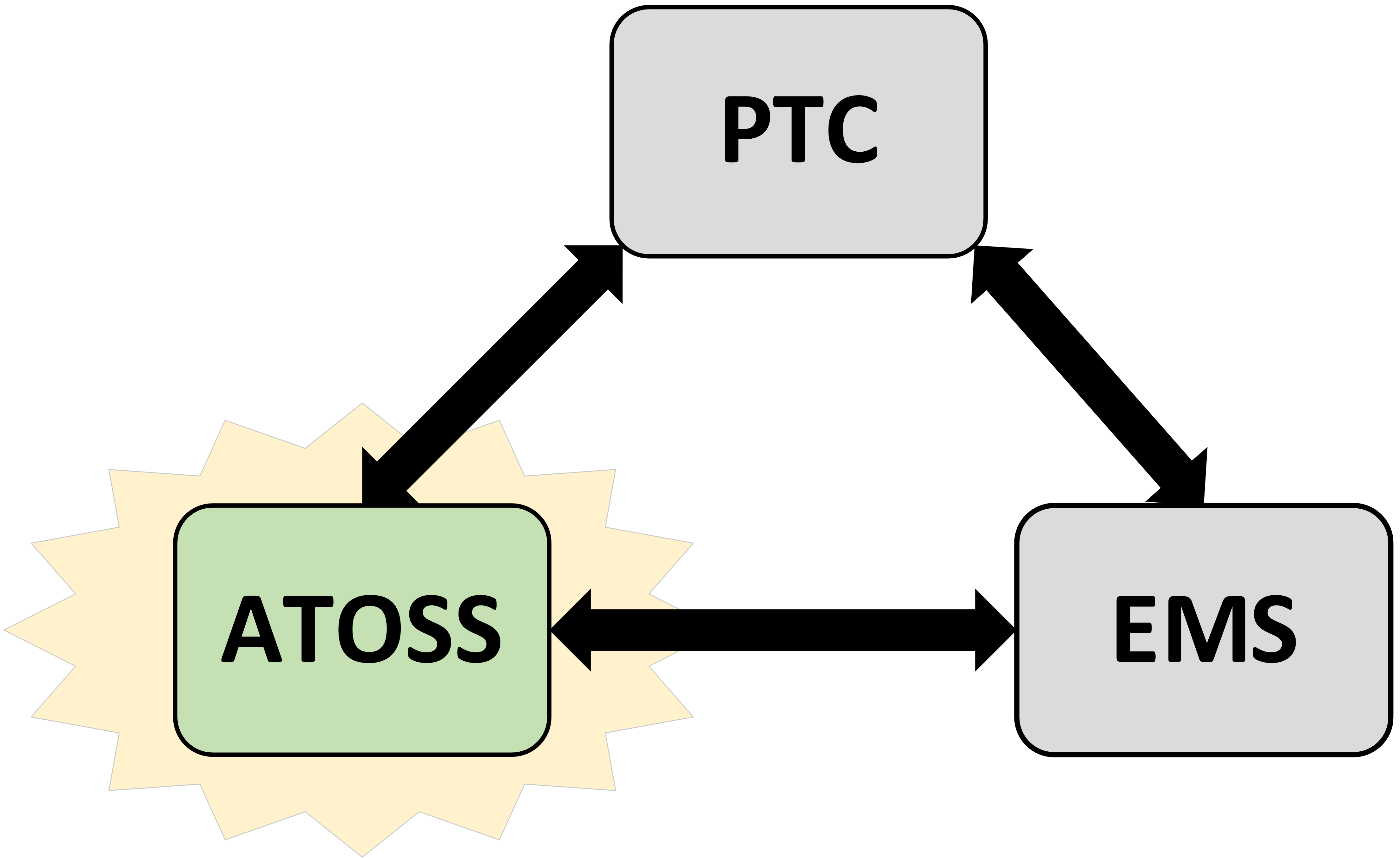
Role of EMS within the North American Freight Rail ATO Concept



EMS is responsible for train motion control, for example:

- Accelerate train from stop to designated speeds
- Maintain train speed within limits defined by mandatory directives and railroad-defined parameters
- Stop train at designated locations
- Interaction with train propulsion control systems
- Interaction with train brake systems

Role of ATOSS within the North American Freight Rail ATO Concept



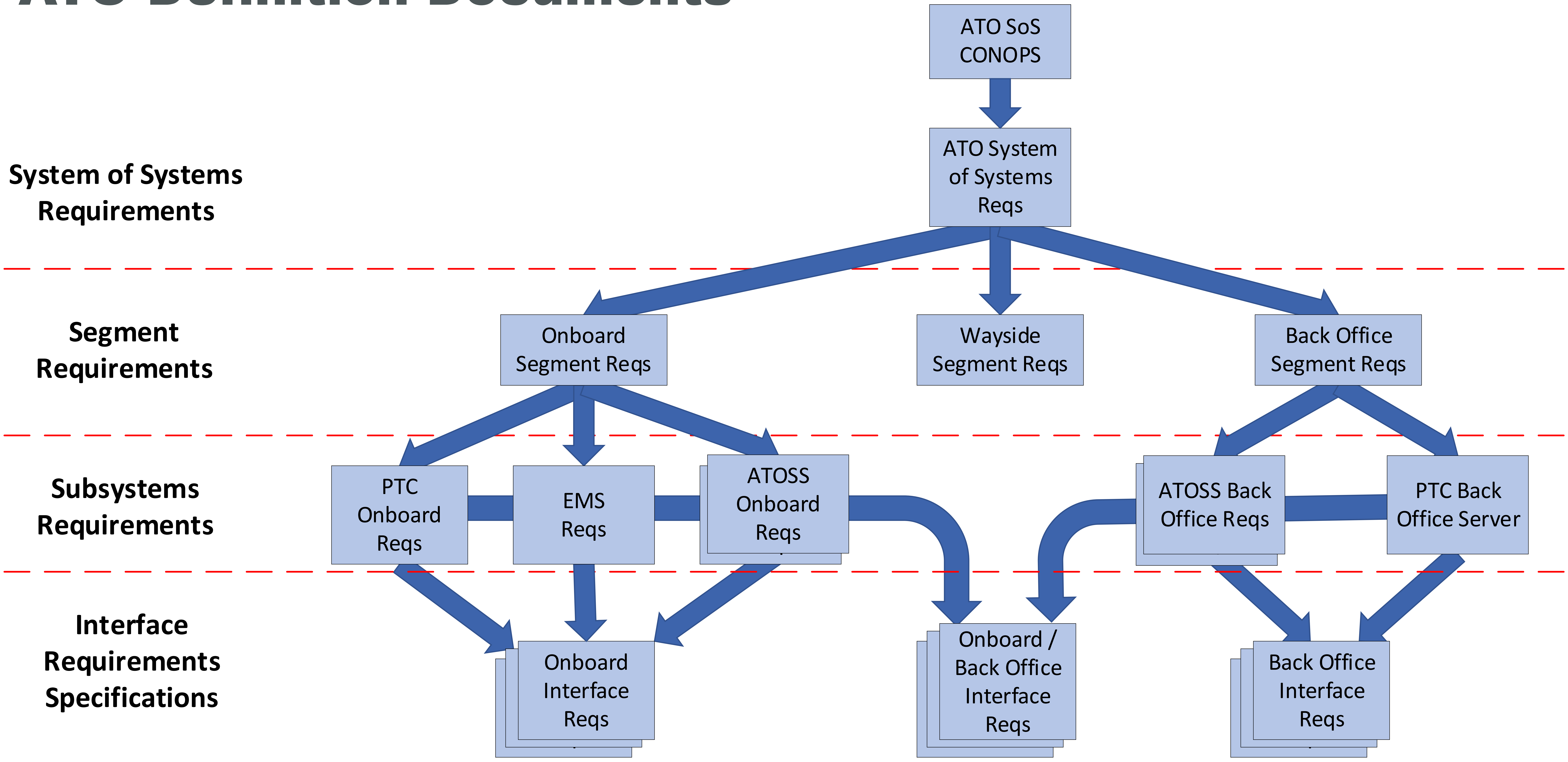
ATOSS are responsible for detecting hazards, for example:

- Obstructions to train motion
- People and vehicles in track wayside
- Severe track damage
- Failed crossing protection systems

North American Freight Rail Industry ATO Development

- Efforts funded by the Association of American Railroads Strategic Research Initiative Program and the United States Federal Railroad Administration Office of Research, Development, and Technology
- Current focus on interoperable specification development:
  - System of systems requirements
  - Constituent system requirements
  - Interface requirements
  - ATO safety program
  - Hazard detection system specification development

North American Freight Rail ATO Definition Documents



Panel discussion

Dr Boris Lapidus
Honorary IRRB Chairman, Chair of the Joint Scientific Council of JSC “Russian railways”

Mr Christian Chavanel
Director of UIC Railway System Department

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Closing remarks

Mr Vladimir Andreev

UIC IRRB Chairman – Head of the Technical policy Department, JSC « Russian railways » (RZD)

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Thank you for your attention.