Railway Signalling in Practice

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Outline

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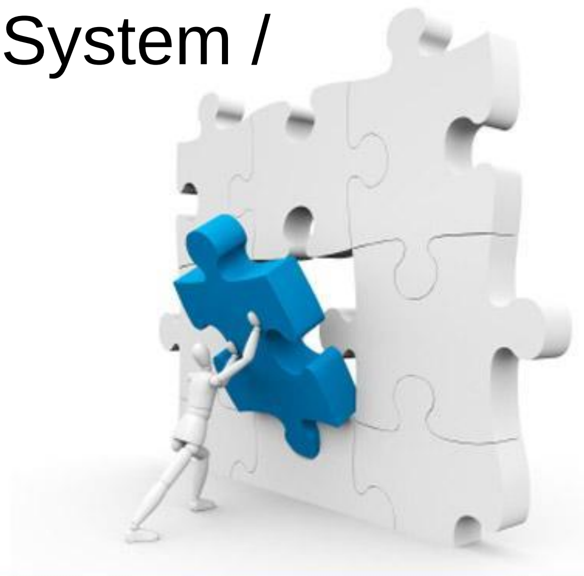


AUTOMATIC TRAIN CONTROL

Automatic Train Control

- Automatic Train Control (ATC): The system for automatically controlling train movement, enforcing train safety and directing train operations.

- *ATC must include*:
  - Automatic train protection (ATP)

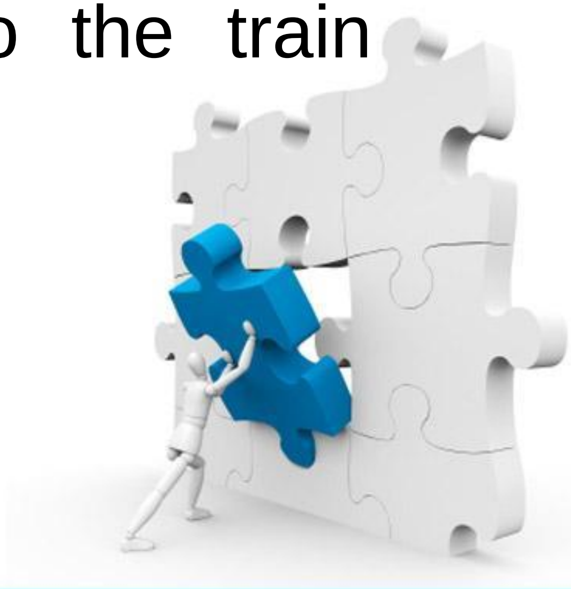
  and may include
  - Automatic train operation (ATO) *and/or*
  - Automatic train supervision (ATS).

Automatic Train Protection

- The subsystem within the automatic train control system which maintains fail-safe protection against collisions, excessive speed and other hazardous conditions through a combination of train detection, train separation and interlocking functions.

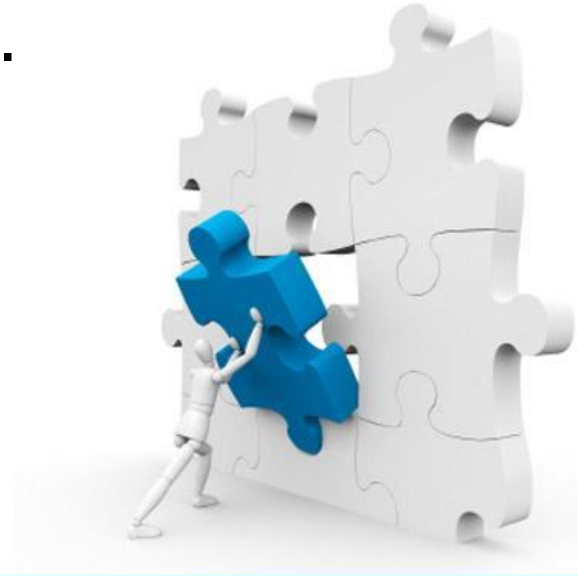
Automatic Train Operation

- The subsystem within the automatic train control system which performs any or all of the functions of speed regulation, programmed stopping, door control, performance level regulation or any other functions otherwise assigned to the train operator.

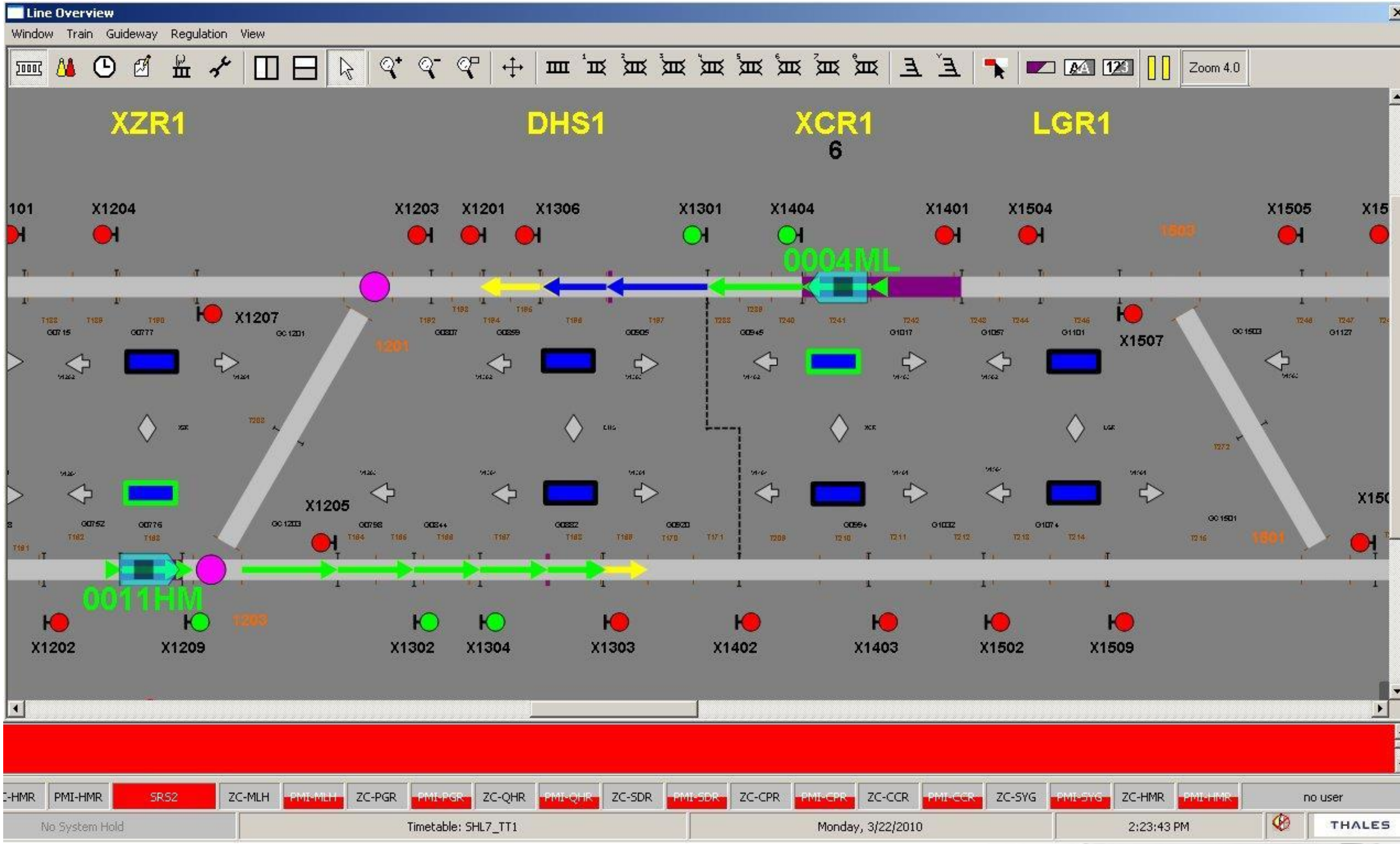


Automatic Train Supervision

- The subsystem within the automatic train control system which monitors train operation, adjusts the performance of individual trains to maintain schedules and provides data to adjust service to minimize the inconvenience otherwise caused by irregularities.



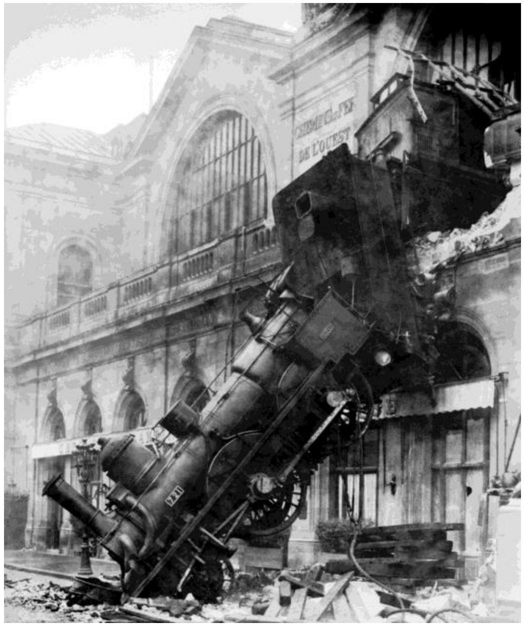
Automatic Train Supervision



Price of Failures in Railway

Obstruction Protection: the Price of Failure

- **Gare Montparnasse, 1895**
  - 1 dead, 2 injured
  - Buffer overrun due to
    - ➢ driver error
    - ➢ faulty brakes
- **Cannon St, 1991**
  - 2 dead, 524 injured
  - Buffer overrun due to driver error
- **Great Heck, 2002**
  - 10 dead, 82 injured
  - Collision with intruding road vehicle & knock-on collision with freight train, due to road vehicle driver negligence
- **Hoboken, N.J., 2016**
  - 1 dead, 114 injured
  - Train crashed at Hoboken Terminal station
  - No automatic brake system



Ensuring a Safe Speed: the Price of Failure

Waterfall (NSW), 2003

- 7 dead, 40 injured
- Derailment on curve due to excessive speed (driver heart attack, no guard intervention)

Morpeth (three times!)

- 1969: 6 dead, 46 injured
- 1984: 0 dead, 35 injured
- 1994: 0 dead, driver injured
- 3 x derailment on curve due to excessive speed

Nuneaton, 1975

- 6 dead, 67 injured
- Derailment on approach to station due to TSR warning board failure & driver error

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Safe Separation: the Price of Failure

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- **Harrow 1952**
- 112 dead, 88 hospitalised
- SPAD due to fog
- No redundancy – dependent on driver sighting only

Follow up action – Introduction of Automatic Warning System to Railway !

The Case for Automation of Safety Functions

In traditional systems, humans are on the critical path for each major safety function

Experience has shown that humans are not infallible

Conclusion:

Use technology to aid humans where

- reasonably practicable
- proven to bring benefit

As time has gone by, the definition of reasonably practicable has changed!

FIXED BLOCK SIGNALLING

Signals on Plain Line

- On plain track where separate tracks are provided for each direction of traffic, the only hazards are rear-end collision or train striking maintenance works or unexpected blockages

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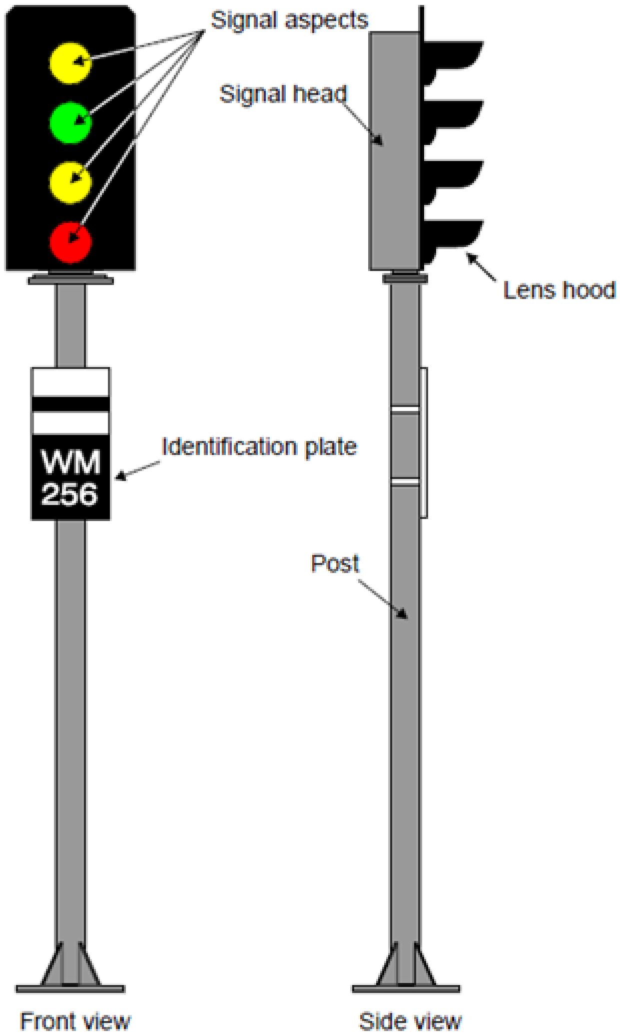
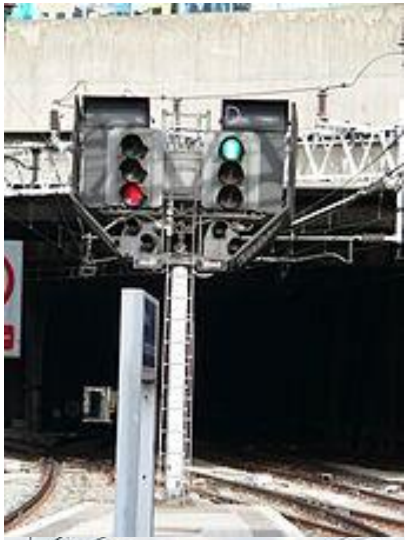
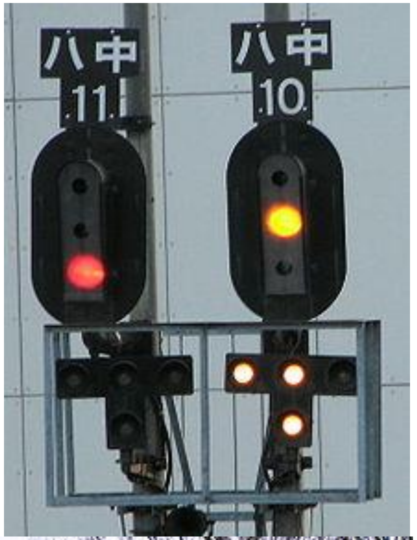
Headway

- Headway is a measurement of train frequency at a given point of track. We imagine a railway route to be a long pipeline through which trains are being pushed as frequently as possible, ignoring the effect of junctions and stations.

Colour Light Signals

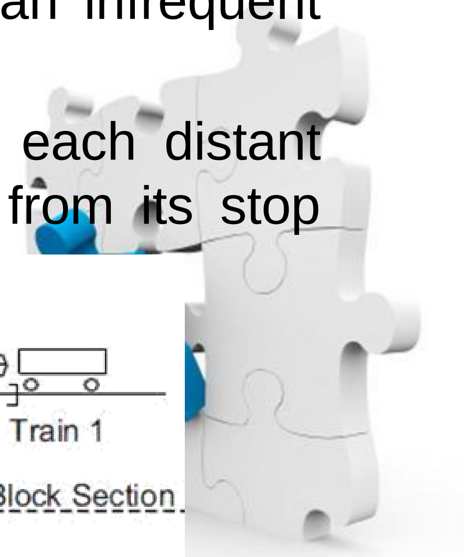






Two Aspect Signalling

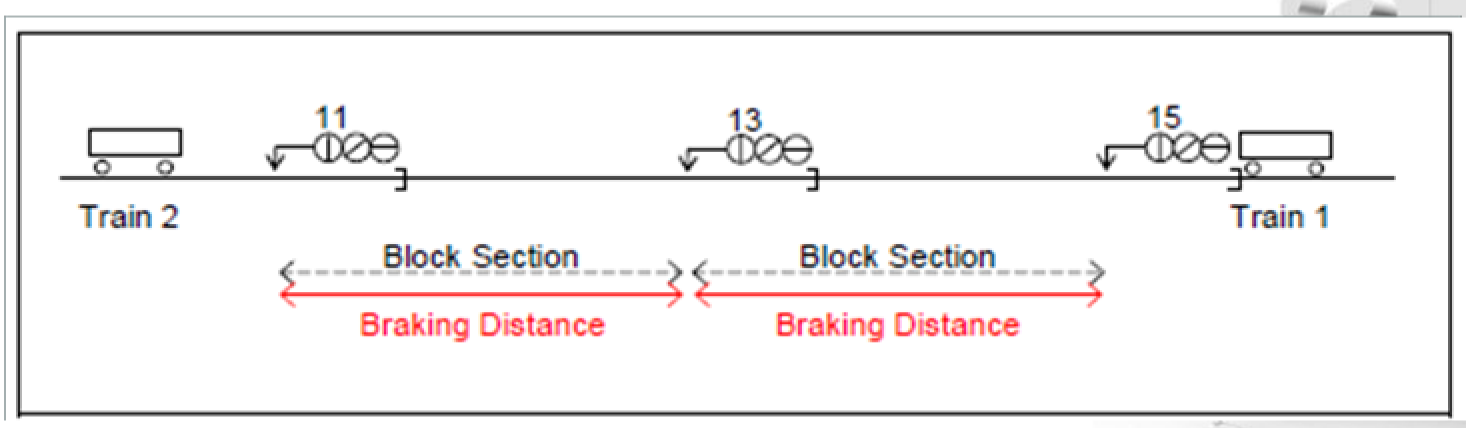
- In two aspect signalling, a red/green stop signal controls the entrance to each relatively long block section. To give a driver correct warning of the need to stop at a stop signal, a yellow/green distant signal is placed at braking distance on the approach to each stop signal.
- All three signal aspects are used, but each signal is only capable of showing two of them.
- Two aspect signalling is best suited where there is an infrequent train service.
- The block section can be very long if required, but each distant signal is still placed at the correct braking distance from its stop signal.



Three Aspect Signalling

- In three aspect signalling, all signals are identical. Each signal is a stop signal in its own right and also acts as a distant signal for the next signal beyond.

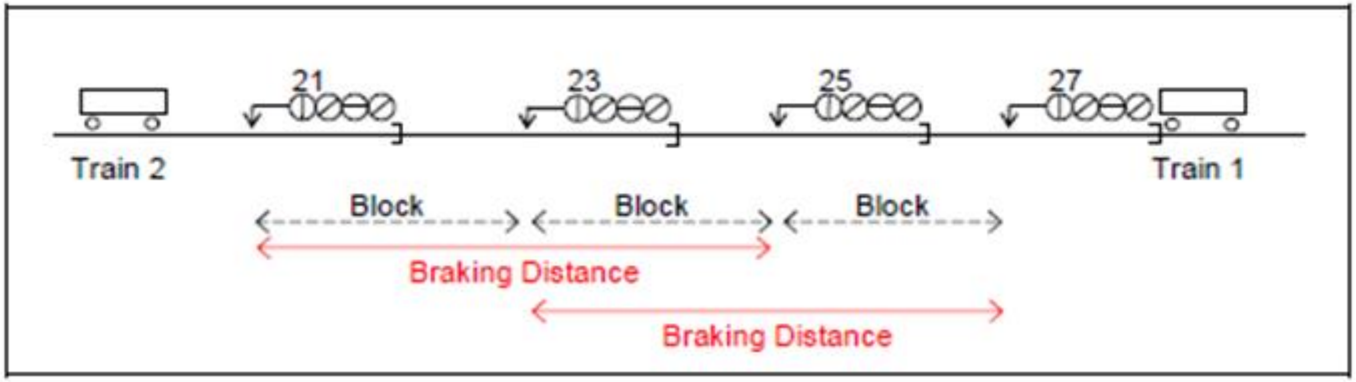
- Three aspect signalling is suitable for moderately frequent train services. Each train is able to safely follow a preceding train more closely than with two aspect signalling



Four Aspect Signalling

- In 4 aspect signalling, all signals are identical stop signals. Each signal is capable of displaying a single yellow aspect in respect of the next stop signal, and a double yellow aspect as the “first caution” in respect of the next but one stop signal.

- Four aspect signalling is suitable for very frequent train services. Each train is able to safely follow a preceding train more closely than with three aspect signalling.

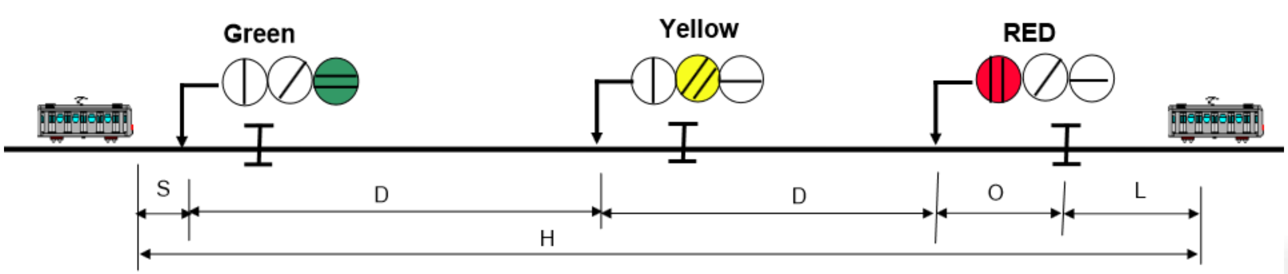


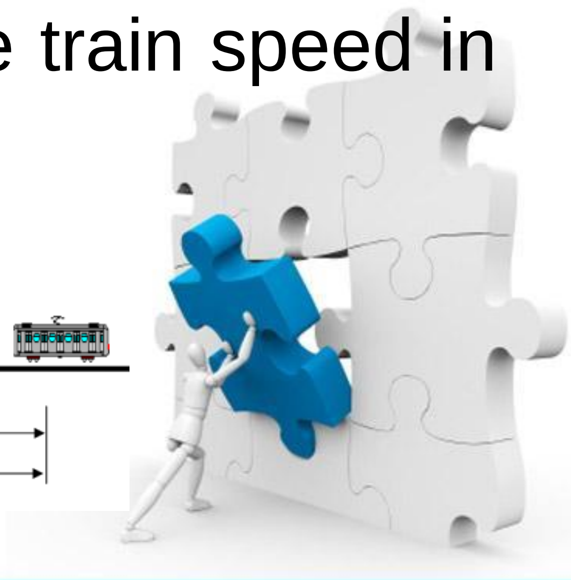
Mainly for Mainline Services

DISTANCE TO GO SIGNALLING

Distance-to-go

- Overlap provides a safety margin should a train overrun a signal at Stop. Overlap therefore utilizes valuable track segments.
- Distance-to-go feature in the ATP system removes the overlap.
- The on board ATP supervises the train speed in accordance to the braking curve.

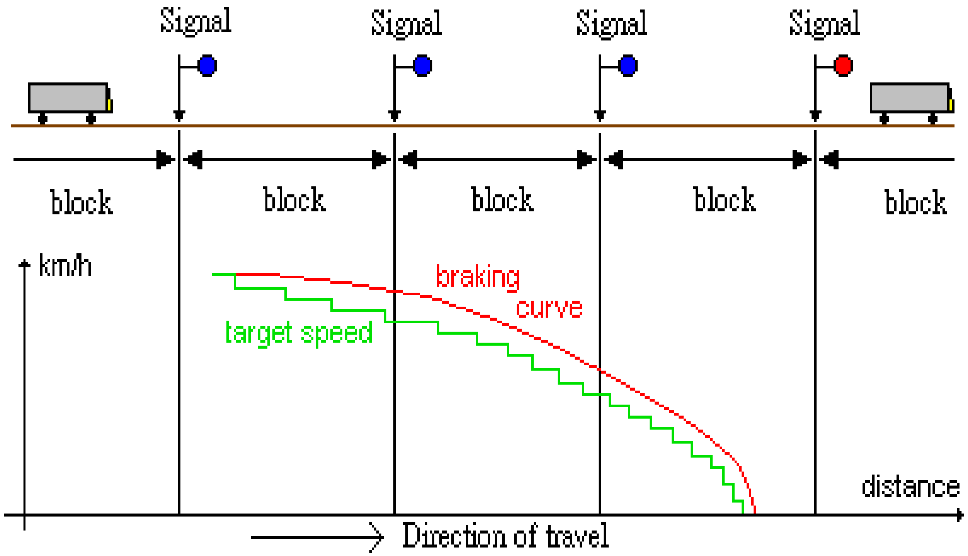




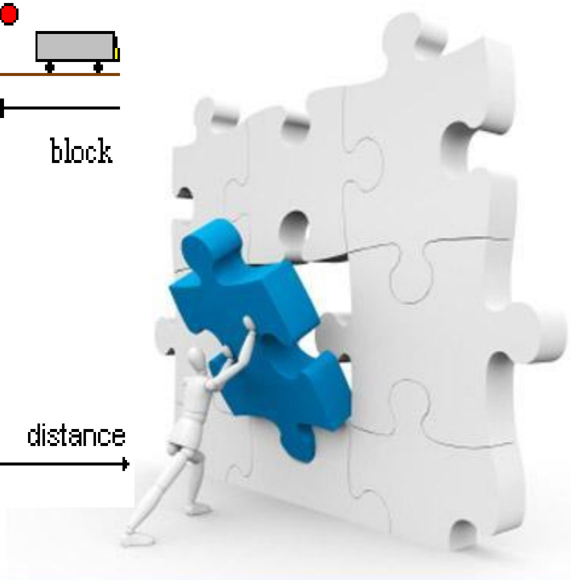
Distance-to-go

The Beacon used in HK

The wires shown are the loops used in HK



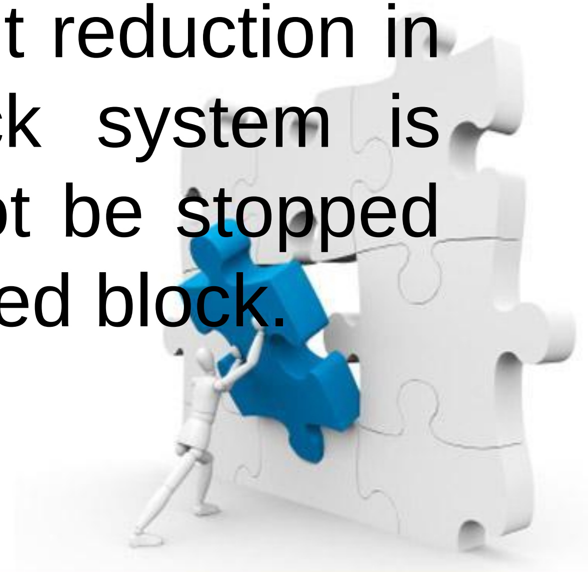
The braking curve of Distance-to-go



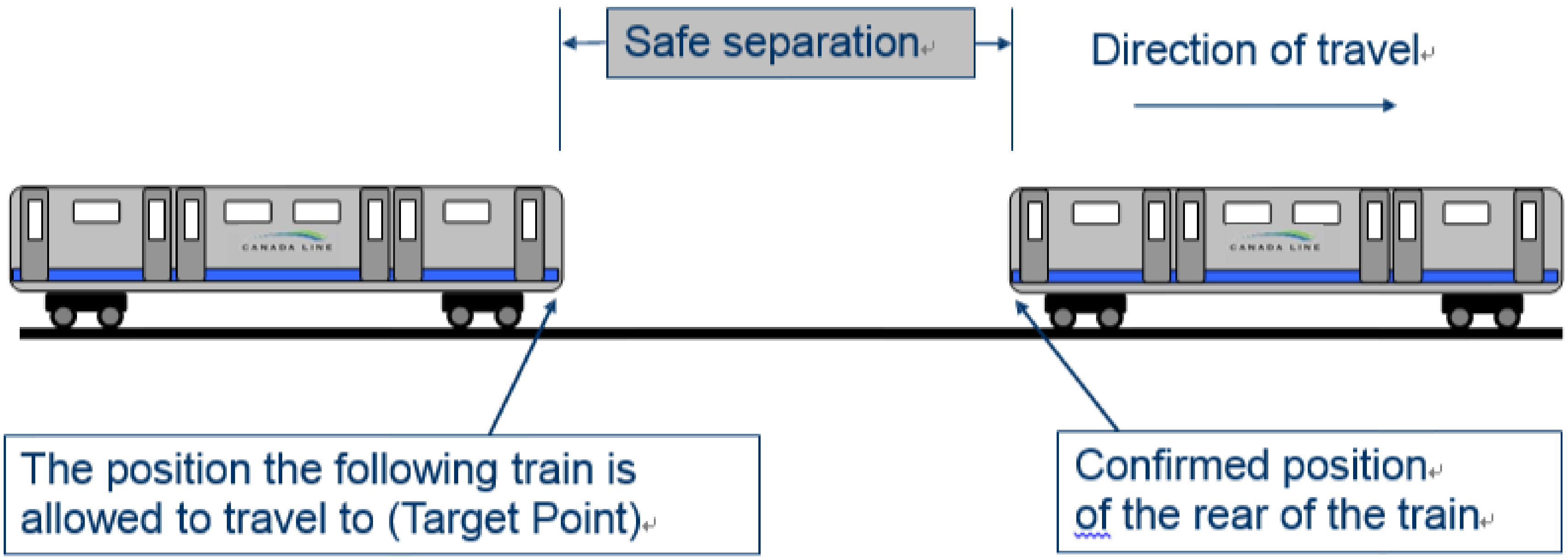
MOVING BLOCK SIGNALLING

Moving Block Principles

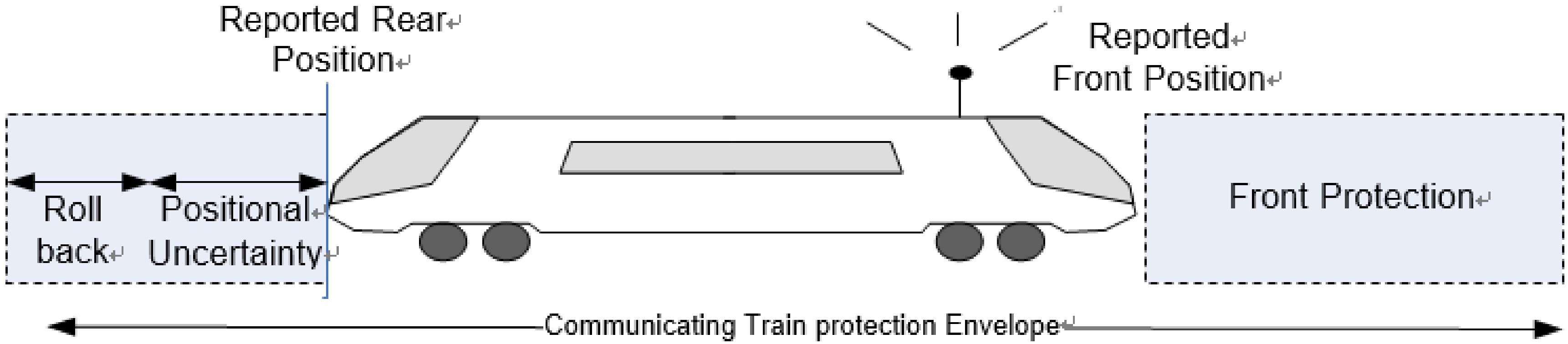
- Moving block principle – the safe separation behind the preceding train is dynamically calculated based on the maximum operating speeds, braking curves and locations of the trains on the track.
- In many applications, a significant reduction in headway relative to fixed block system is possible, since the train need not be stopped at the entrance to an occupied fixed block.



Moving Block Principles



Moving Block Principles



Advantages of Moving Block

- Allows more trains to safely occupy the same amount of track, hence more trains can be used to provide a service
- Better headway control
- Greater failure management handling
- Greater operational flexibility
- Bidirectional operation

Moving Block Signalling System

- Signalling system requires a lot of dynamic and static information in order to calculate the most updated target point for each train in real time.
  - Train positions
  - Train lengths
  - Train velocities
  - Travel directions
  - Propulsion rates
  - Brake rates
  - Wheel diameters
  - Speed restriction areas
  - Occupied tracks
  - Point positions

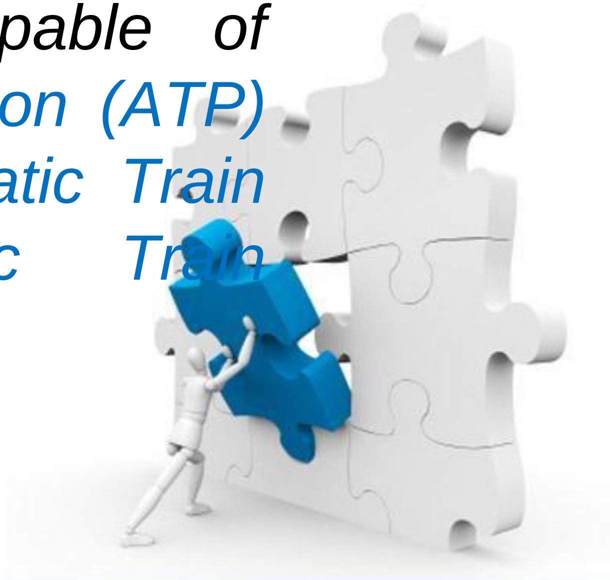
COMMUNICATION BASED TRAIN CONTROL

CBTC

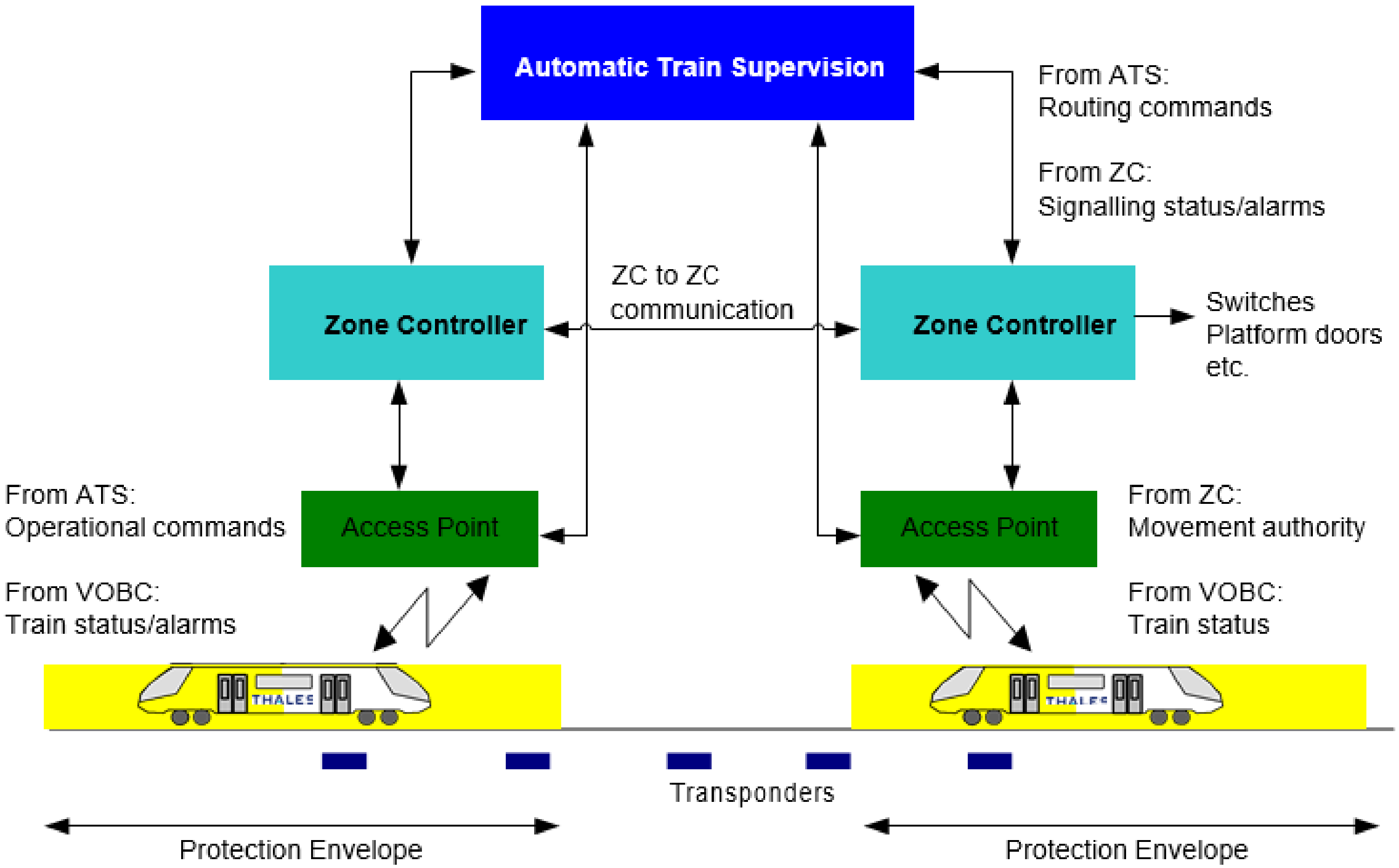
- Communications-Based Train Control (CBTC) is a railway signalling system that makes use of the telecommunications between the train and track equipment for the traffic management and infrastructure control.
- By means of the CBTC systems, the exact position of a train is obtained more accurately than with the traditional signalling system.
- This results in a **more efficient** and **safer way to manage the railway traffic**.
- Railway systems are able to **improve headways while maintaining or even improving safety**.

CBTC

- As Defined in the IEEE 1474 standard, CBTC system is a *"continuous automatic train control system utilizing high resolution train location determination, independent of track circuits; continuous, high-capacity, bi-directional train-to-wayside data communications; and train-borne and wayside processors capable of implementing Automatic Train Protection (ATP) functions, as well as optional Automatic Train Operation (ATO) and Automatic Train Supervision (ATS) functions."*

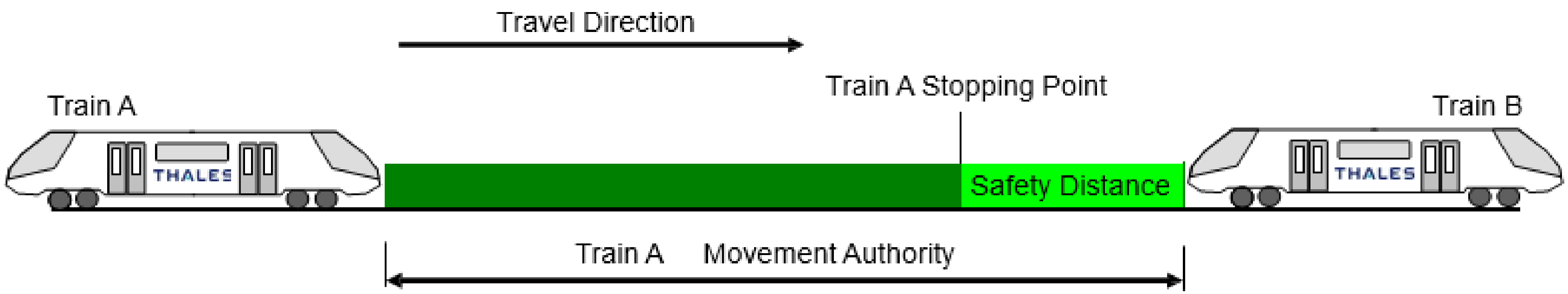


CBTC functional diagram

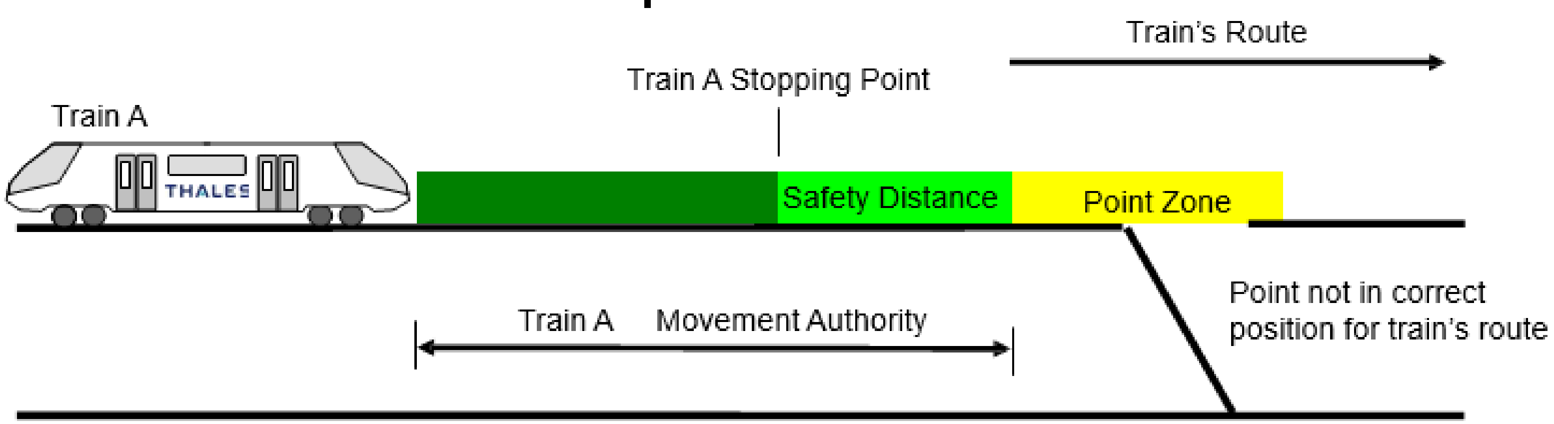


CBTC provides

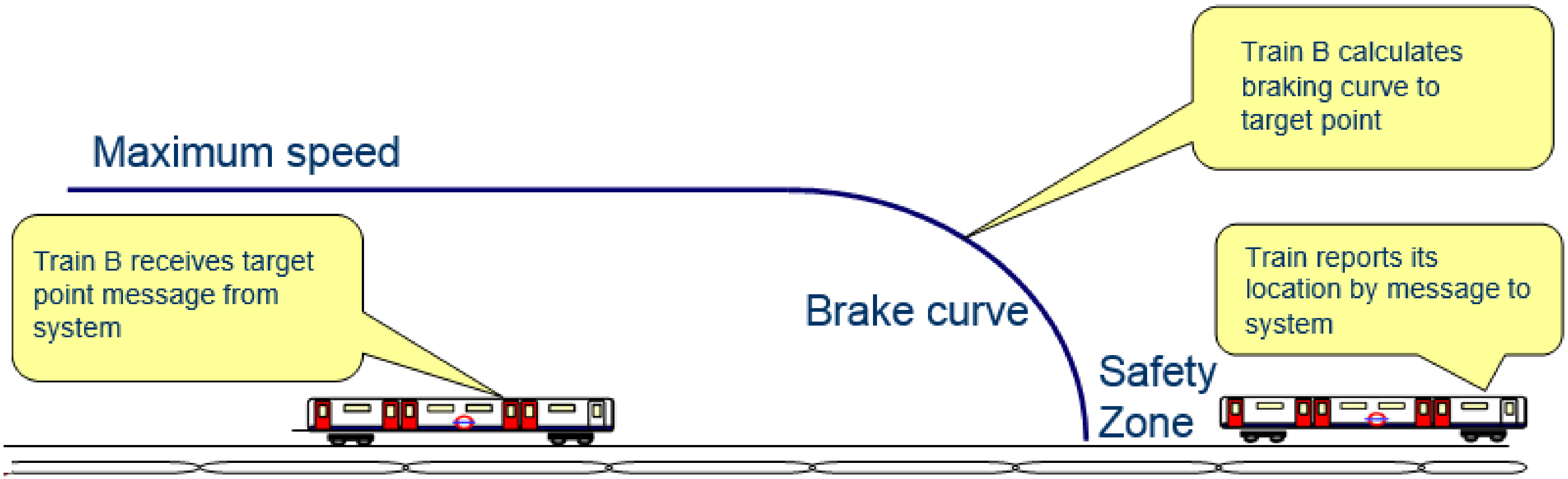
- Safe train separation



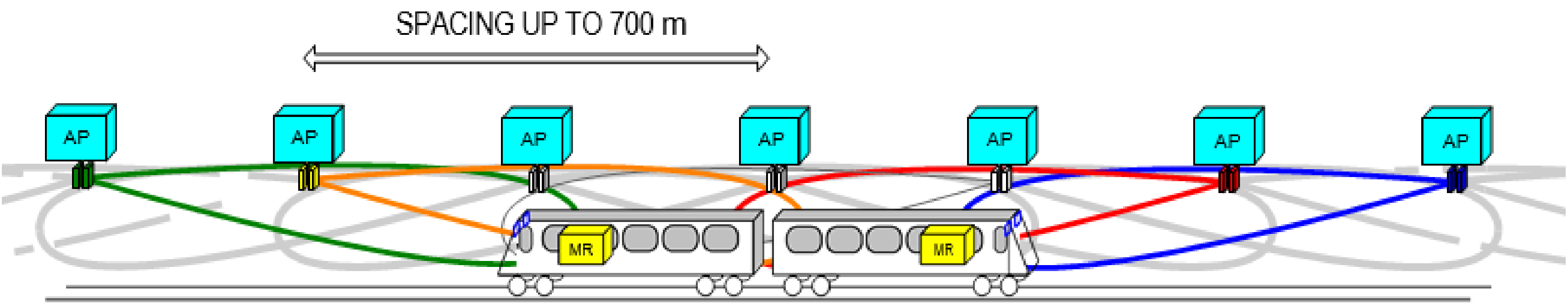
- Safe movement of points



Braking curve and Target Point



Data Communication System



EUROPEAN RAIL TRAFFIC MANAGEMENT SYSTEM / EUROPEAN TRAIN CONTROL SYSTEM

ERTMS

European Rail Traffic Management System

ETCS + GSM-R = ERTMS

ETCS

Provide permitted speed and movement authority to train and continous surveillance of permitted speed and braking distance

Founded 1991 by EC, UIC and signalling industry

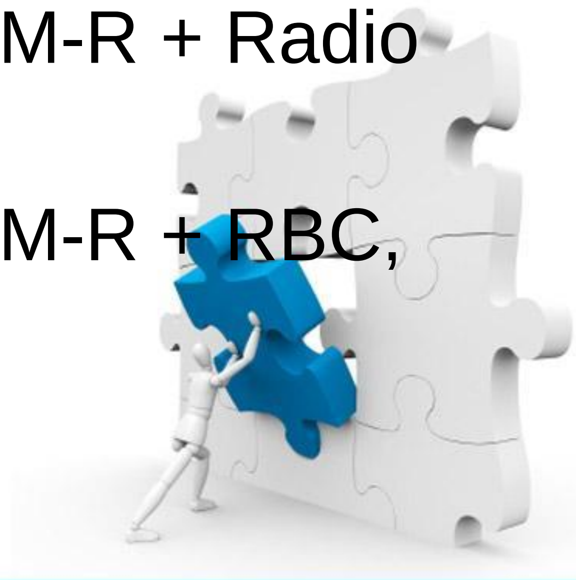
GSM-R

Provide track-train bi-directional voice and data communication, especially used in the communication between trainborne ETCS and wayside RBC/radio infill.

Founded 1993 by EC, UIC and telecom industry

Level of ETCS

- ETCS – Level 0 (ETCS vehicle used on a non-ETCS route)
- ETCS – Level 1 (Eurobalise + infill (Euroloop, radio or extra balises))
- ETCS – Level 2 (Eurobalise + GSM-R + Radio Block Centre, fixed block)
- ETCS – Level 3 (Eurobalise + GSM-R + RBC, moving block)



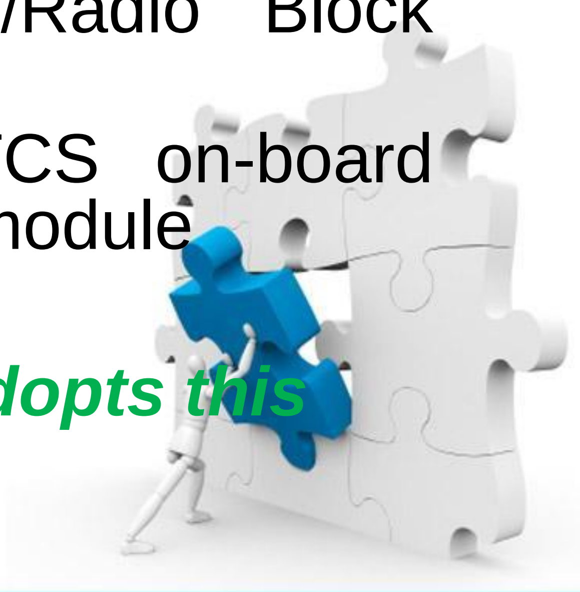
CHINESE TRAIN CONTROL SYSTEM

CTCS

- CTCS is a train control system used on railway lines in China.
- CTCS is similar to the ETCS.
- Two subsystems: ground subsystem and on-board subsystem.
- Ground subsystem includes transponder, track circuit, wireless communication network (GSM-R), and Train Control Centre (TCT)/Radio Block Centre (RBC).
- On-board subsystem includes CTCS on-board devices and on-board radio system module

.

High Speed Rail in Hong Kong adopts this standard



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Definition of CTCS

- **CTCS – Level 0** (Track Circuit + Cab Signalling + ATS) – legacy system non CTCS equipment
- **CTCS – Level 1** (Track Circuit + Cab Signalling + ATS)
- **CTCS – Level 2** (Track Circuit + Balise + ATP)
- **CTCS – Level 3** (Balise + GSM-R + ATP)
- **CTCS – Level 4** (Balise + GSM-R + ATP, moving block)

CTCS Level	Train Integrity	Data Transmission Method	Line side Signals	Track Detection Device	Radio Block Centre
	On-board Equipment		Wayside Equipment		
1	×	Beacons	√	√	×
2	×	Balises	×	√	×
3	×	Balises + Radio	×	√	√
4	√	Balises + Radio	×	×	√

SIGNALLING SYSTEM FOR HIGH SPEED RAILWAY

Signalling Systems for High Speed Railway

- An adoption of ATP is mandatory for High Speed Railway because:
  - At high speed, the driver does not have sufficient time to read, interpret, and react to signal aspects
  - Much longer stopping distance beyond driver sighting

- Cab signalling is required

Signalling Systems for High Speed Railway

Region	System	Year of Design	Brake mode	Communication channel
Japan	ATC	1964-1997	Multiple-level speed control	SSB-AF Analog track circuit
Italy	SCMT/BACC	1985		Audio track circuit
France	TVM300	1981-1989	Multiple-level speed control	UM 71
Germany	LZB	1991-2002	Target distance control	Loop cable
France	TVM430	2001	Multiple-level speed control	UM71 / UM2000
Belgium	ADVANTICK	2002		
Japan	DS-ATC	2002	Target distance	Digital track circuit control

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Thank You!

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