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Railway Control with a Raspberry Pi

University of Strathclyde - Glasgow

22nd April 2017

Who are Siemens?

- Siemens is the largest manufacturing and electronics company in Europe
  - Siemens' UK operations were founded 174 years ago by Sir William Siemens, and we currently employ 14,000 people in the UK.

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Ingenuity for life

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Who are Siemens?

- Our goal is to improve quality of life through electrification, automation, and digitalisation.
  - e.g. State-of-the-art megnetic imaging technology;
    £160 million investment in wind turbine assembly;
    Removing 1m cars worth of CO2 through efficient drive technologies

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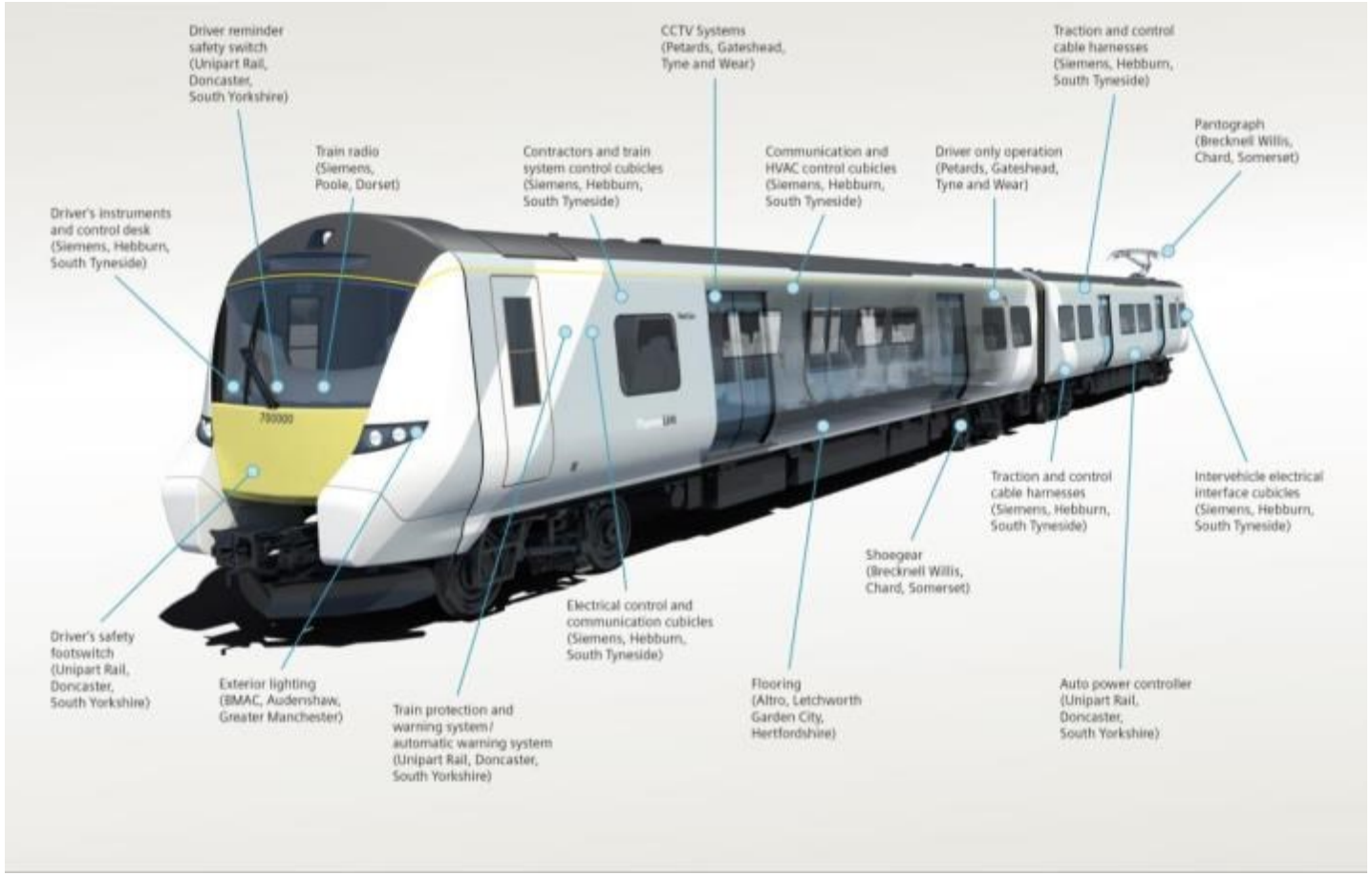
Ingenuity for life

Who are Siemens?

- Siemens Mobility develop the rolling stock and signalling control systems that allow safe and sustainable growth of our public transport network.



What do we do?

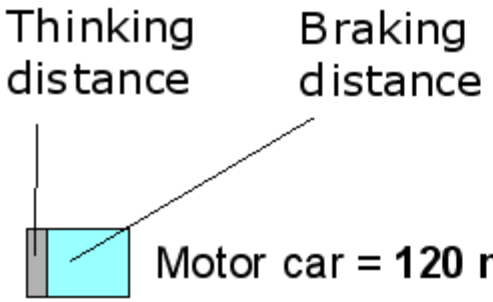
What do we do?


1 Hainault via Newbury Park
Calling at: Hainault.
1 min
4 Epping
6 mins
16 59:10
WITH MORE PROPERTIES
AN ANYWHERE ELSE
Way out
Northern line

What do we do?

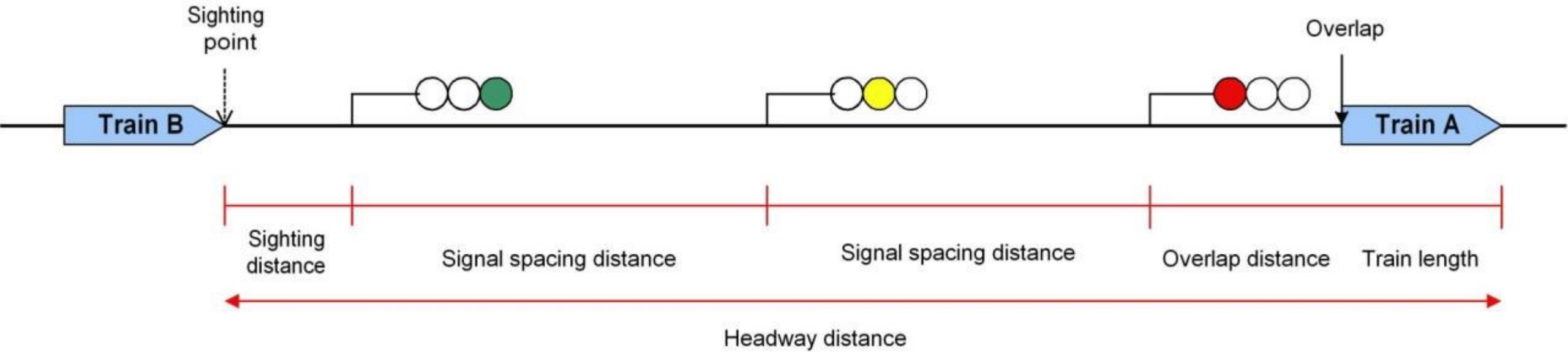
Motor car and train stopping distances compared

Total emergency stopping distances from **80 miles/hour** assuming dry conditions

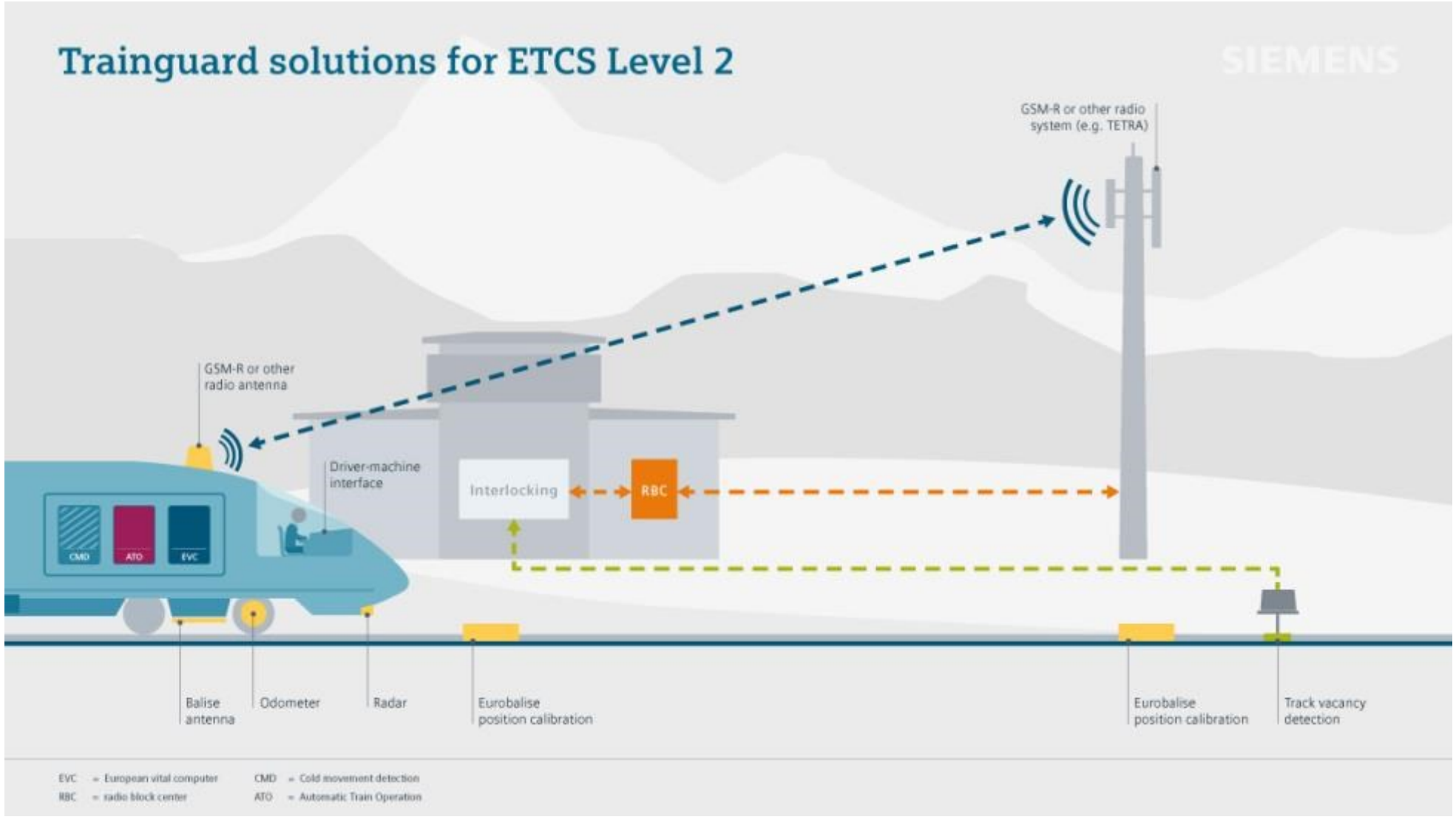


@ 80 miles/hour,
braking distance for train
= 16.7 x braking distance for car

What do we do?


Sighting point
Overlap
Train B
Train A
Sighting distance
Signal spacing distance
Signal spacing distance
Overlap distance
Train length
Headway distance

What do we do?


Trainguard solutions for ETCS Level 2
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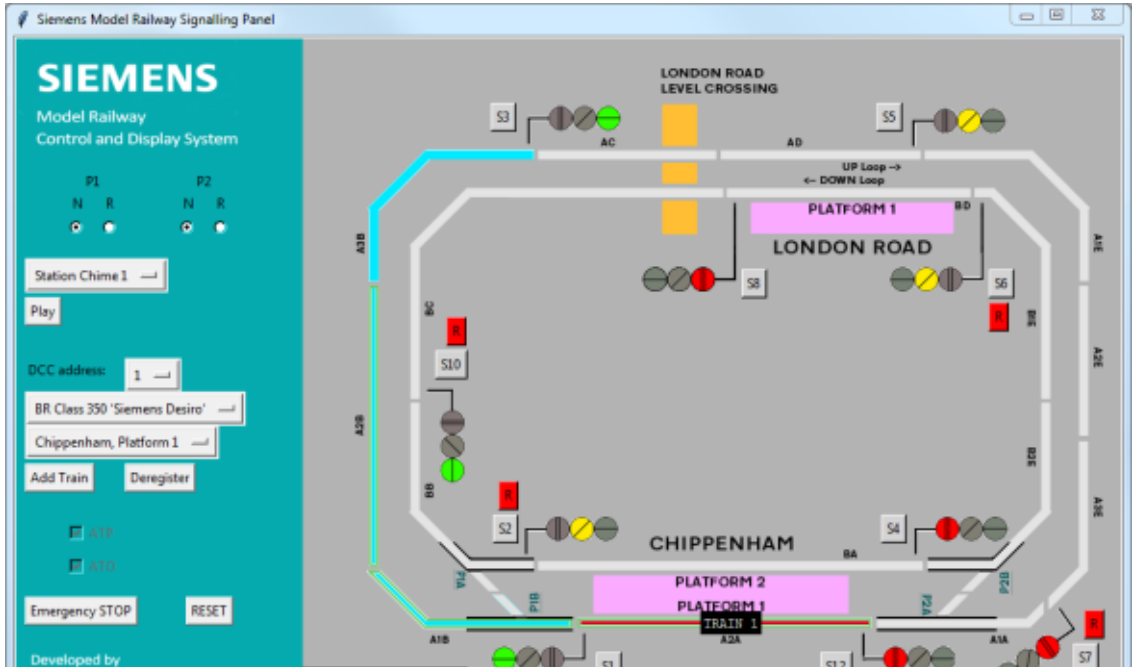
GSM-R or other radio system (e.g. TETRA)
GSM-R or other radio antenna
Driver-machine interface
Interlocking
RBC
CMD
ATO
EVC
Balise antenna
Odometer
Radar
Eurobalise position calibration
Eurobalise position calibration
Track vacancy detection
EVC = European vital computer
RBC = radio block center
CMD = Cold movement detection
ATO = Automatic Train Operation

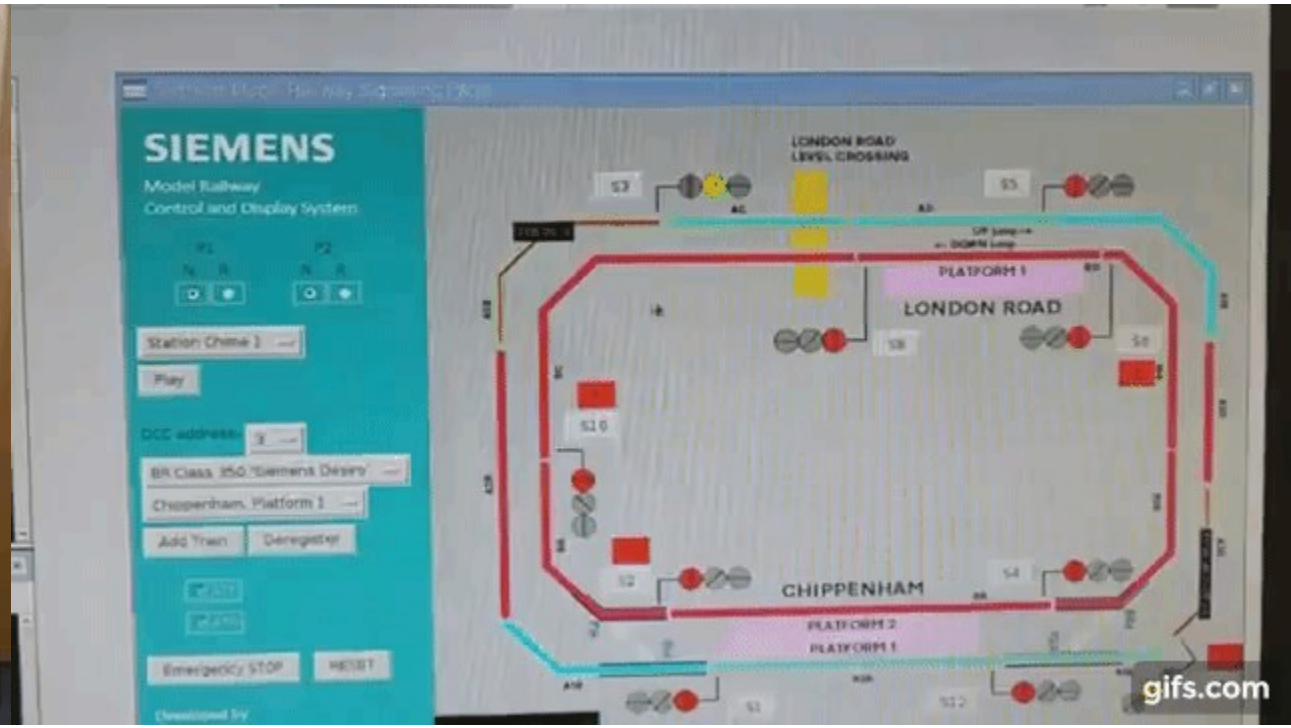
Background

- In 2016, Siemens graduates developed a model railway control system using the Raspberry Pi: **STEMRail**



Background

- **Automatic Train Operation** and **IP Signalling Network**



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What is the STEMRail Model Railway Layout?

- A tool to demonstrate programming, computing, electronics and engineering concepts to young people using technology that is readily available to schools and students.

- Realistic enough to demonstrate railway signalling principles to all ages, yet simple enough to engage young children.

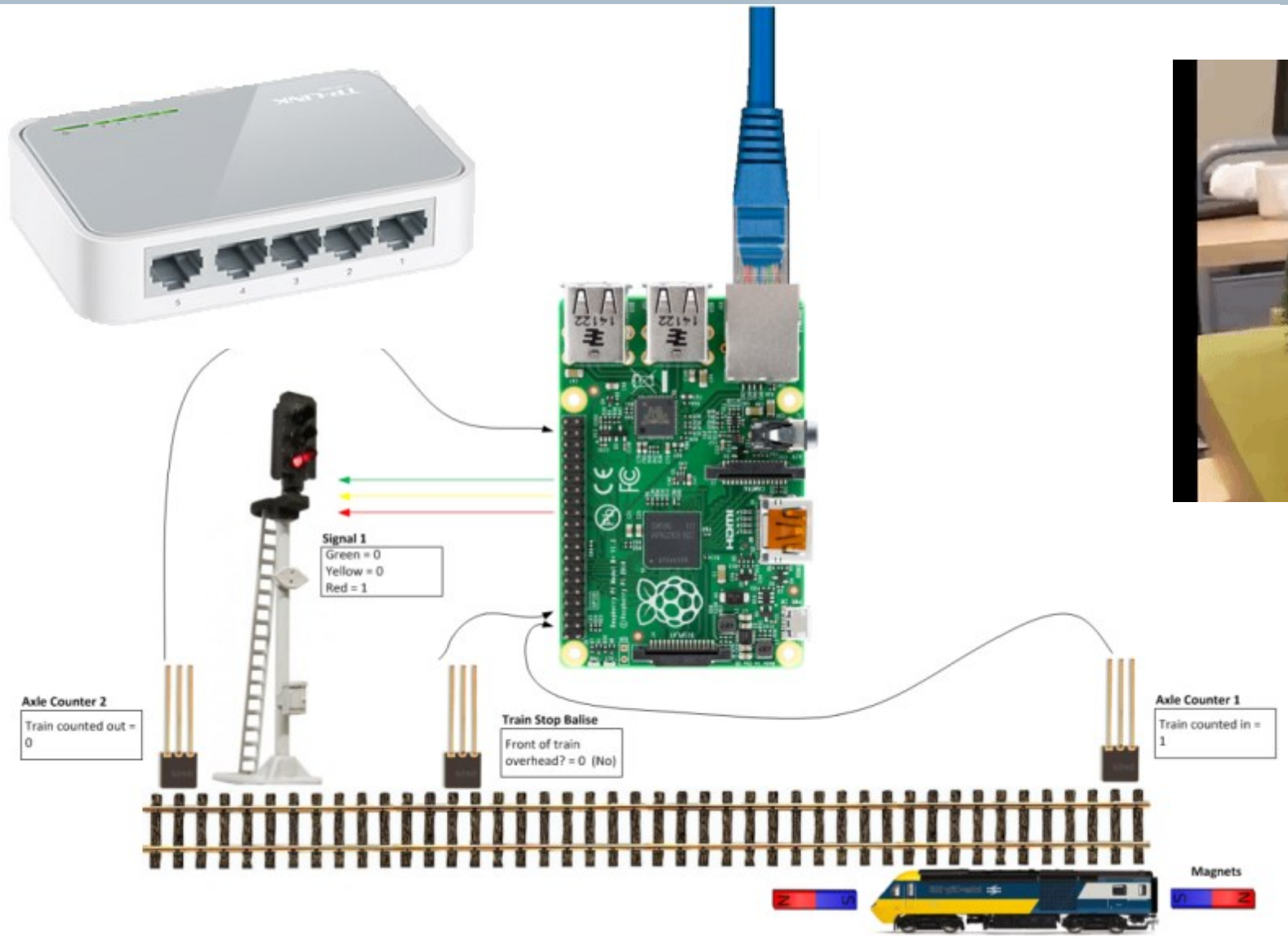
  - **Programming** – Uses Python language as taught in schools

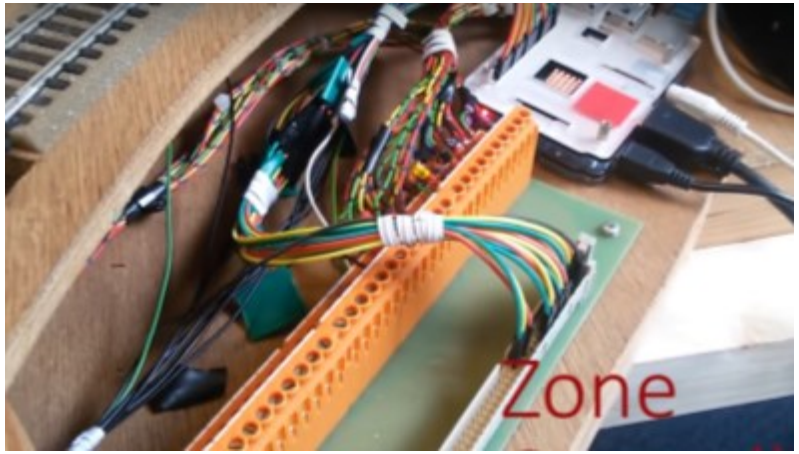
  - **Computing** – The Pi are networked using a simple text protocol

  - **Electronics** – Simple Hall effect sensors and LEDs represent the trackside signalling equipment

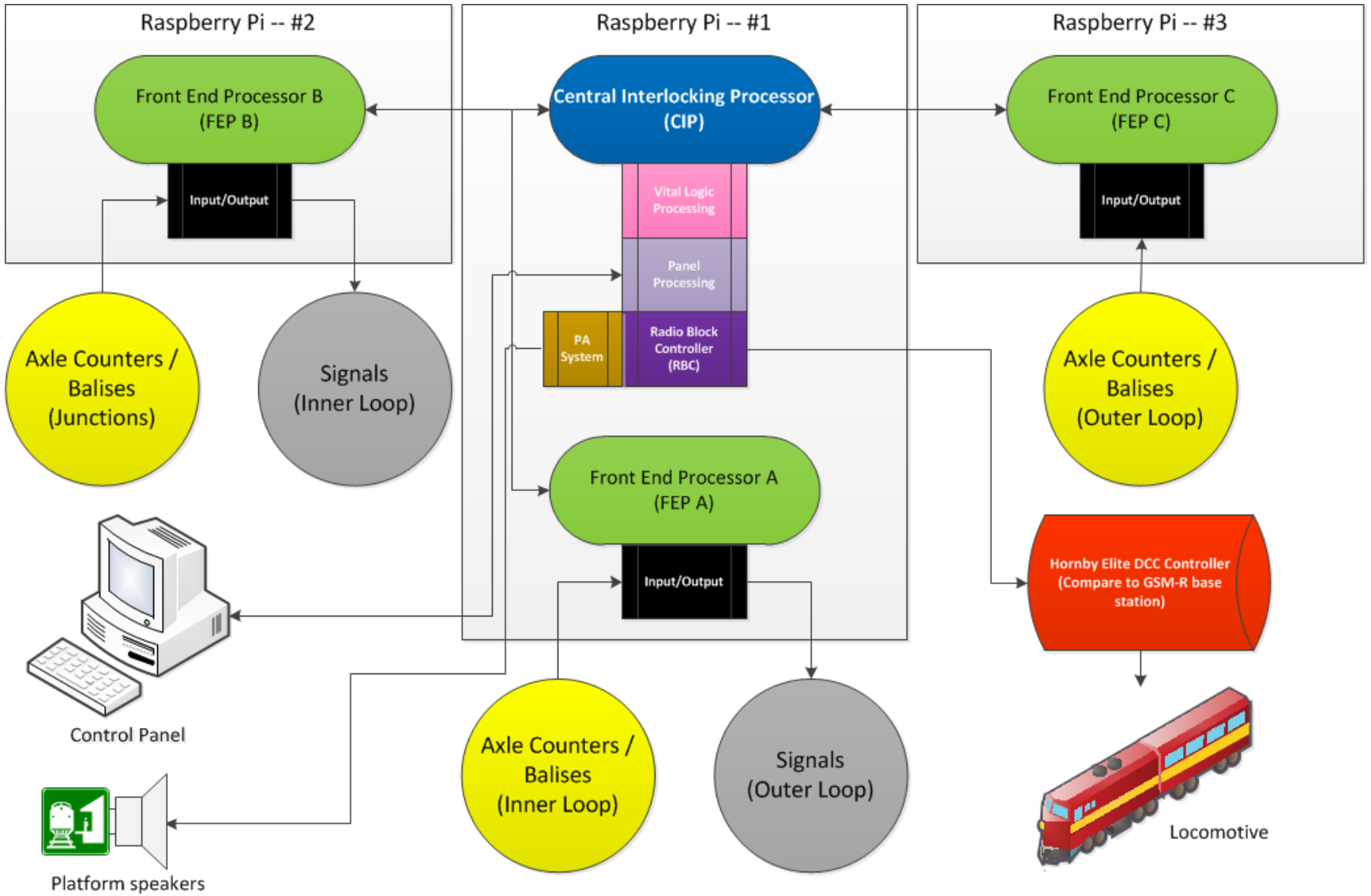
  - **Engineering** – Problem solving, system design and physics such as train braking

STEMRail Hardware





System Architecture



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STEMRail Software

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Control Systems and Object Oriented Programming

Computer programs are made up of a **data** and **algorithms** that manipulate that data.

Data

Algorithms

The greater the **throttle** and lower the **gear**, the greater the **force** pushing the car forward.

$$f = m \cdot a$$

Force is divided by the car's **mass** to determine **acceleration**.

Acceleration multiplied by **Time elapsed** = **Speed**

LAWS OF PHYSICS

STEMRail Object Oriented Control – Data

Track Section Objects

Defined Attributes:
- Track ID Number (location)
- Speed Limit
- GIF images

Variables:
- Occupied / Clear
- Routed / Not Routed
- ID# of Train in Section

Points Objects

Defined Attributes:
- Point ID Number
- Tracks involved
- GIF images
- Button

Variables:
- Normal Lie / Reverse Lie

Train Objects

Defined Attributes:
- Train ID Number
- Train Type

Variables:
- ID# of Current Track
- Direction of Travel
- Target Speed
- Halt Flag
- Emergency Stop Flag

Signal Objects

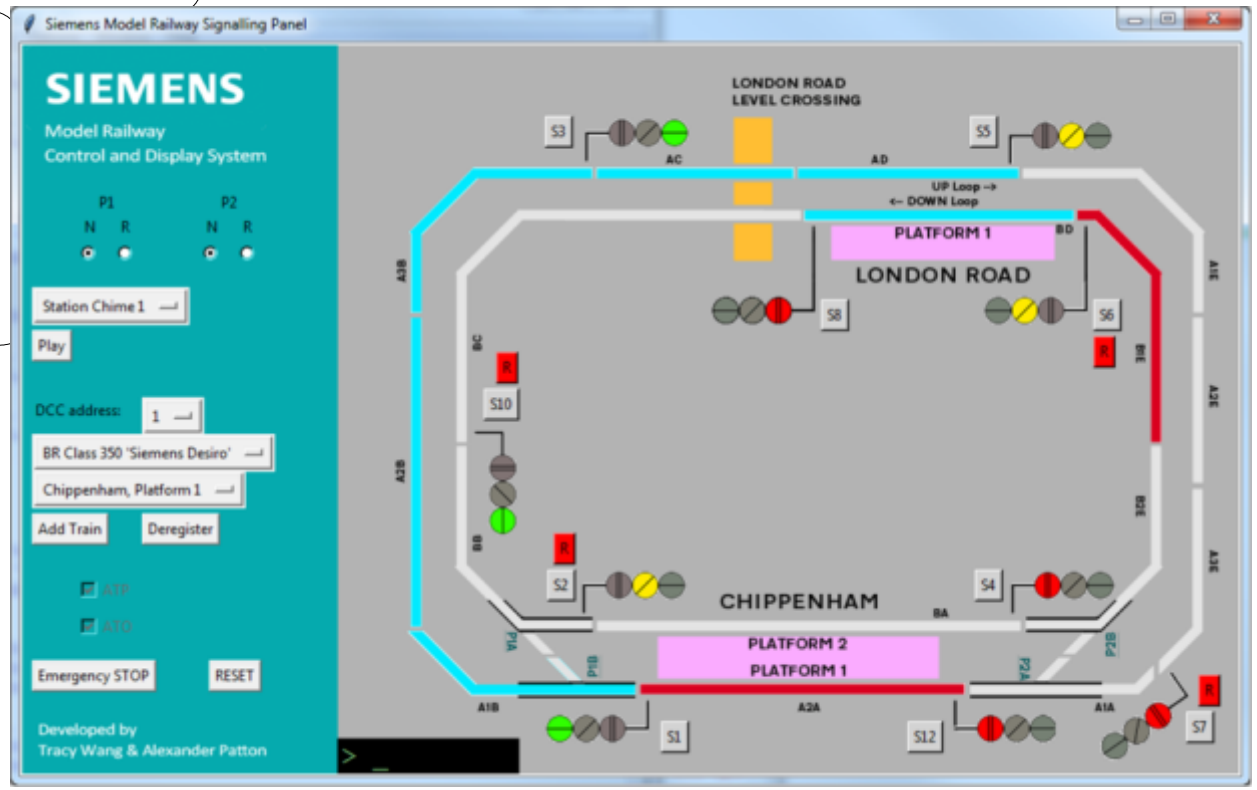
Defined Attributes:
- Signal ID Number
- List of track sections and points being protected
- GIF images

Variables:
- Aspect (Red / Yellow / Green)
- Force Signal to Red (Yes / No)

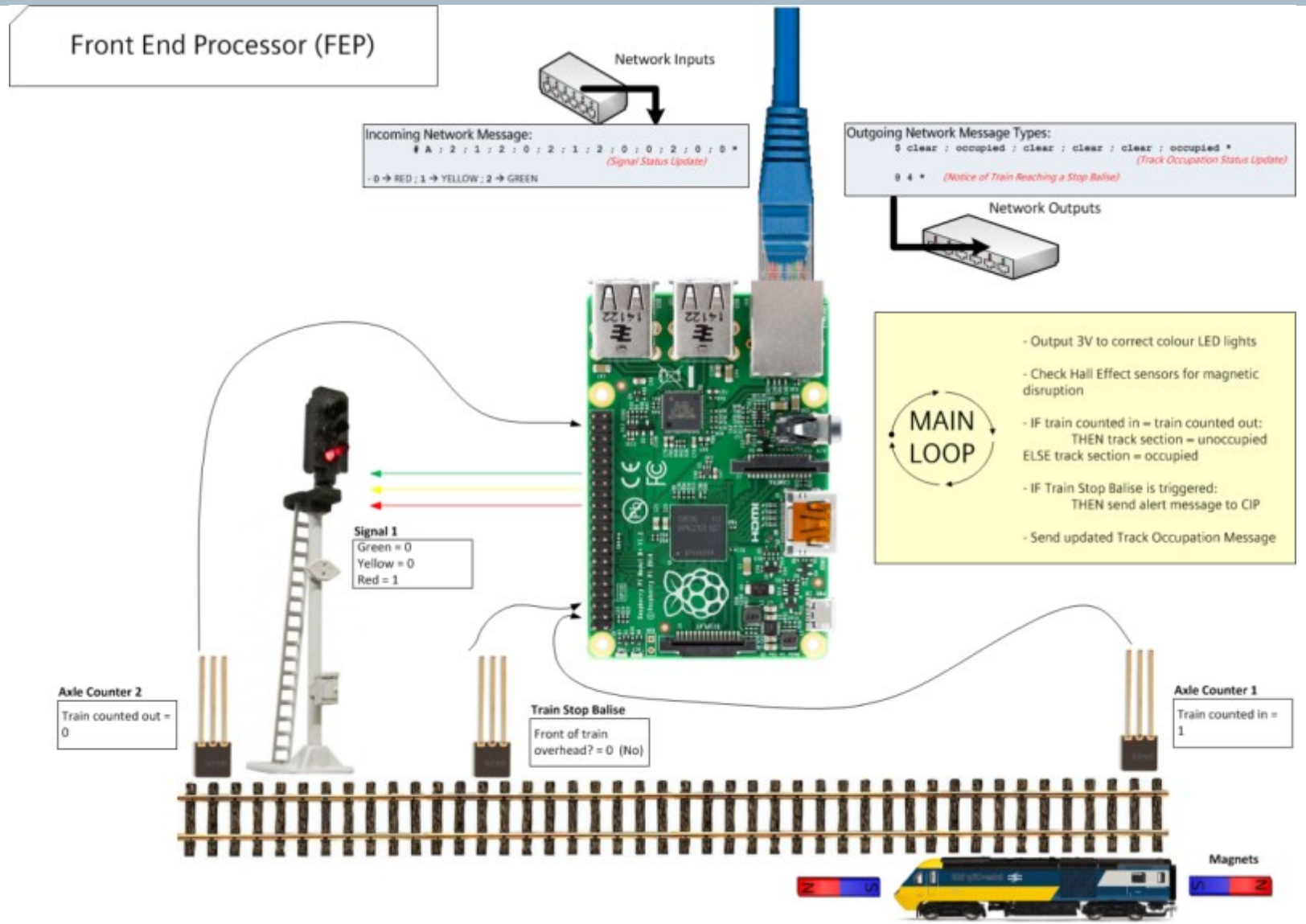
Route Objects

Defined Attributes:
- Direction
- List of Track Sections Covered
- List of Points Required

Variables:
- Set / Not Set



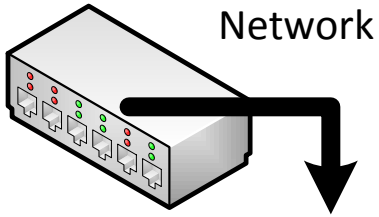
STEMRail Object Oriented Control – Algorithms



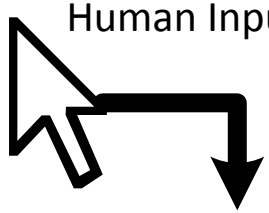
STEMRail Object Oriented Control – Algorithms

Algorithms

Network Inputs



Human Inputs



Incoming Network Message:

`# clear ; occupied ; clear ; clear *`

(Track Status Update)

- Update the state of each Track Object
- FOR EACH Signal Object:
  - IF train in section THEN set signal red
  - ELSEIF next signal is red THEN set signal yellow
  - ELSE set signal green

User clicks:

`Set route from Signal 1 to Signal 3`

- Check if the route is valid
  - next_signal(Signal 1) MUST = Signal 3
  - Signal1.direction MUST = Signal3.direction
- For each Track Object in Route Object, set to Routed if unoccupied

Generate Movement Authority and Calculate Target Speed

For each train: Load the speed limit of the current track section.

Movement Authority Level = 1

Is the next track section clear and routed? Is there no red signal within braking distance?

YES TO BOTH: **Movement Authority Level = 2**

Is the next next track section also clear and routed? Is there no red signal in the next two tracks?

YES TO BOTH: **Movement Authority Level = 3**

Was the trainstop balise in the current track section just triggered? Does MA Level = 1?

YES TO BOTH: **Set the halt flag until MA Level > 1.**

Target Speed = % of Speed Limit

MA Level 1 : 27.5%

MA Level 2 : 75%

MA Level 3 : 100%

STEMRail Object Oriented Control – Algorithms

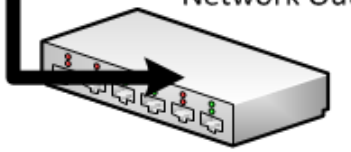
Send Outgoing Network Message:

`# A ; 2 ; 1 ; 2 ; 0 ; 2 ; 1 ; 2 ; 0 ; 0 ; 2 ; 0 ; 0 *`

(Signal Status Update)

- 0 → RED ; 1 → YELLOW ; 2 → GREEN

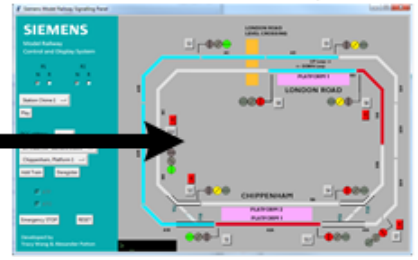
Network Outputs



Display Images on Screen:

```
Signal_1_red.gif ;
Track_A1B_blue.gif ; etc.
```

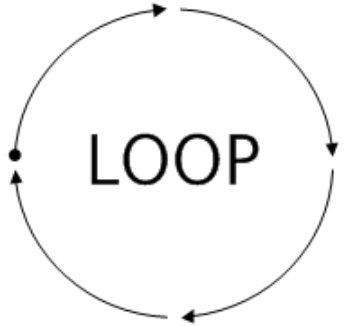
Human Outputs



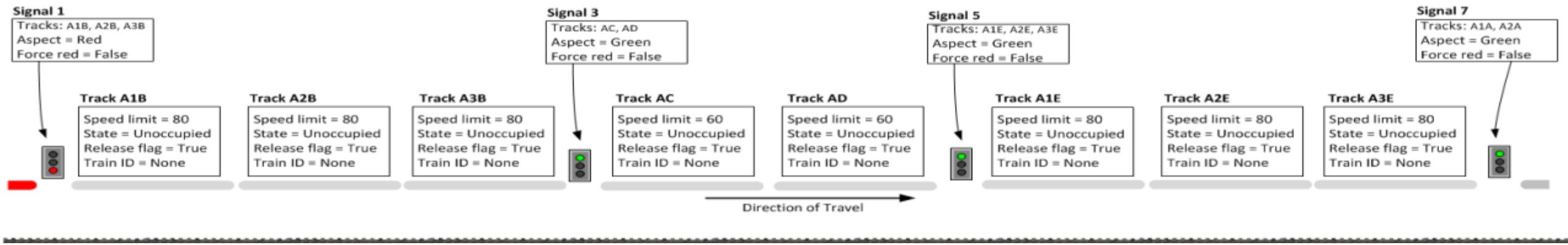
Broadcast Train Speeds:

```
Train 1 set to 60 mph
Train 3 set to 80 mph
```

Train Controller Outputs



Object Oriented Programming



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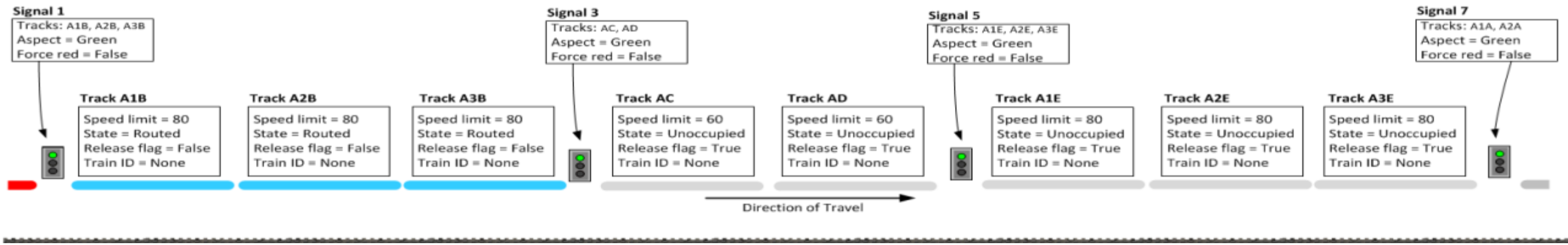

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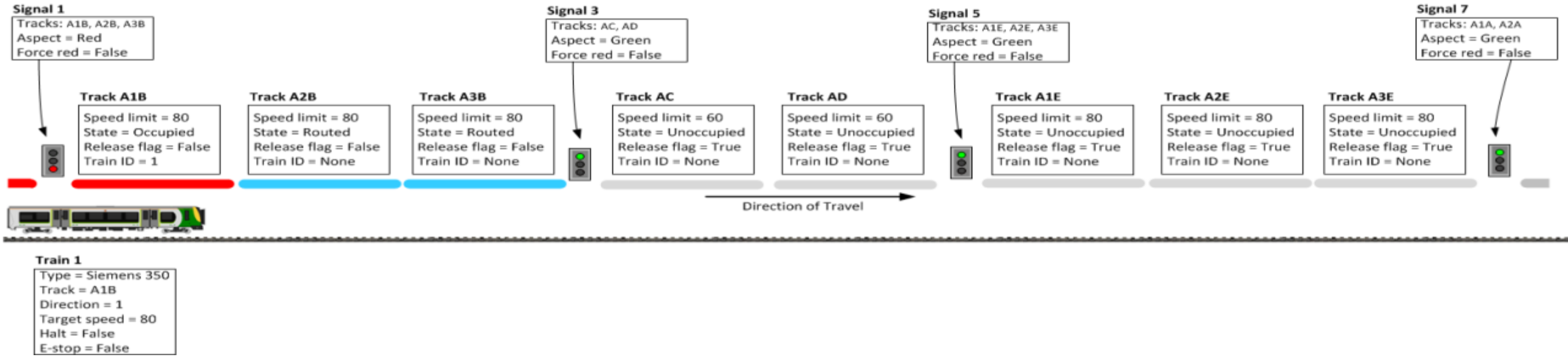

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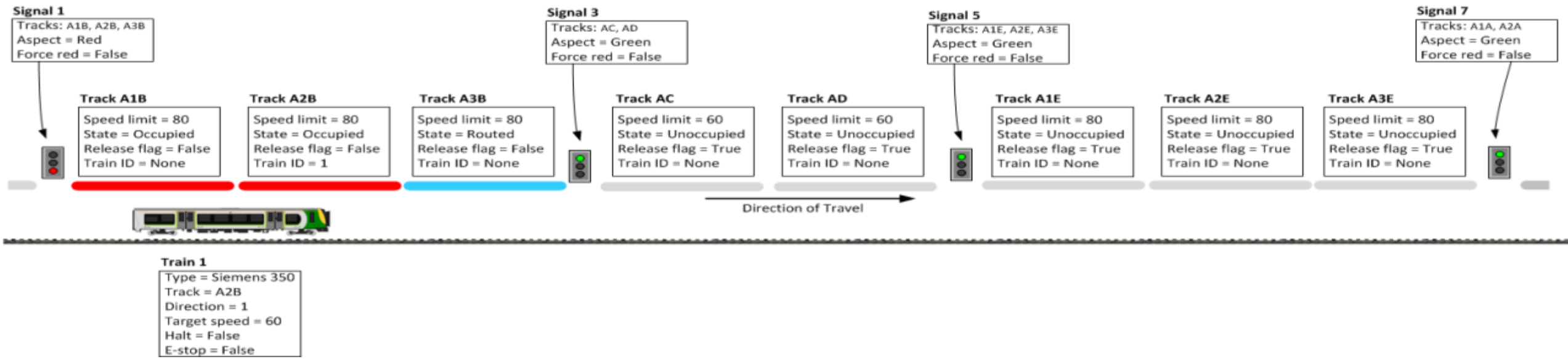

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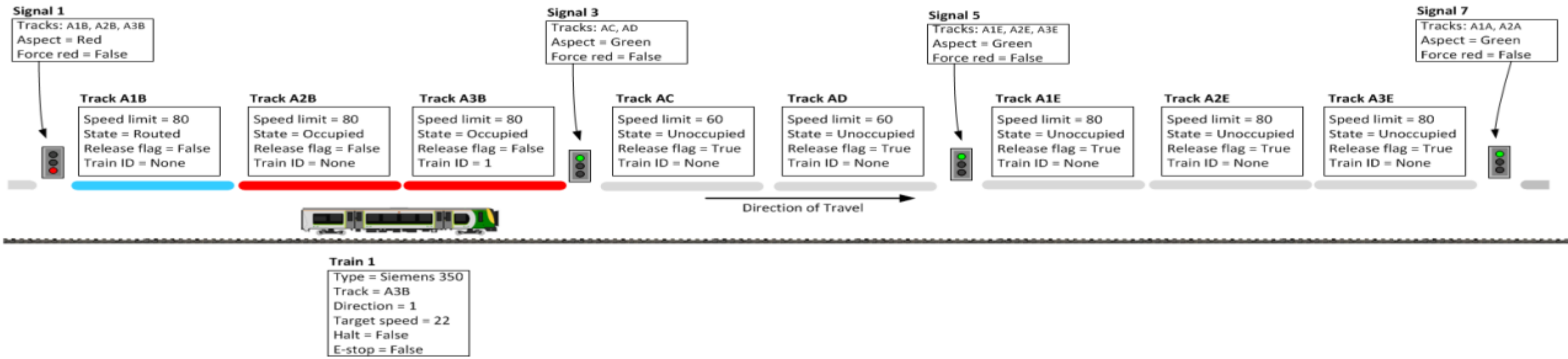

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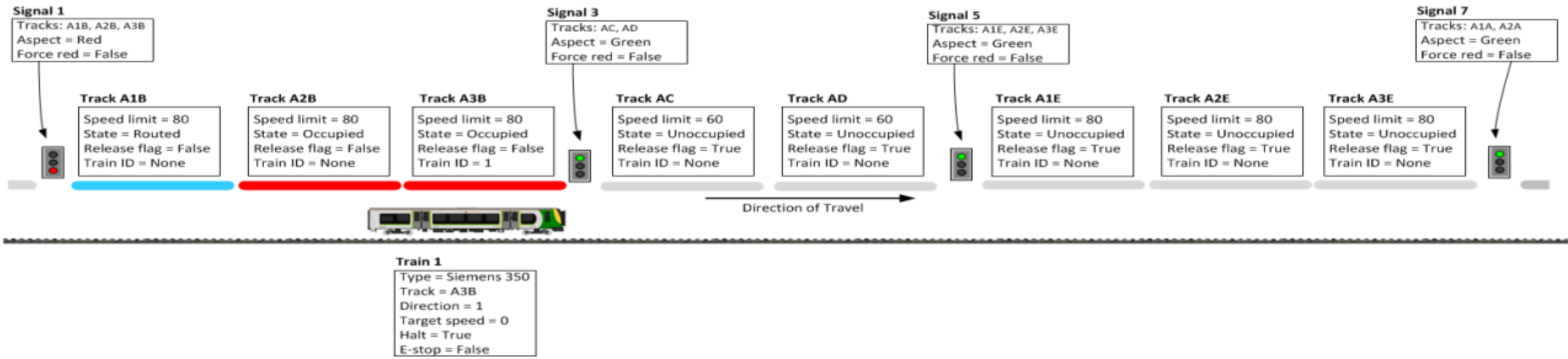

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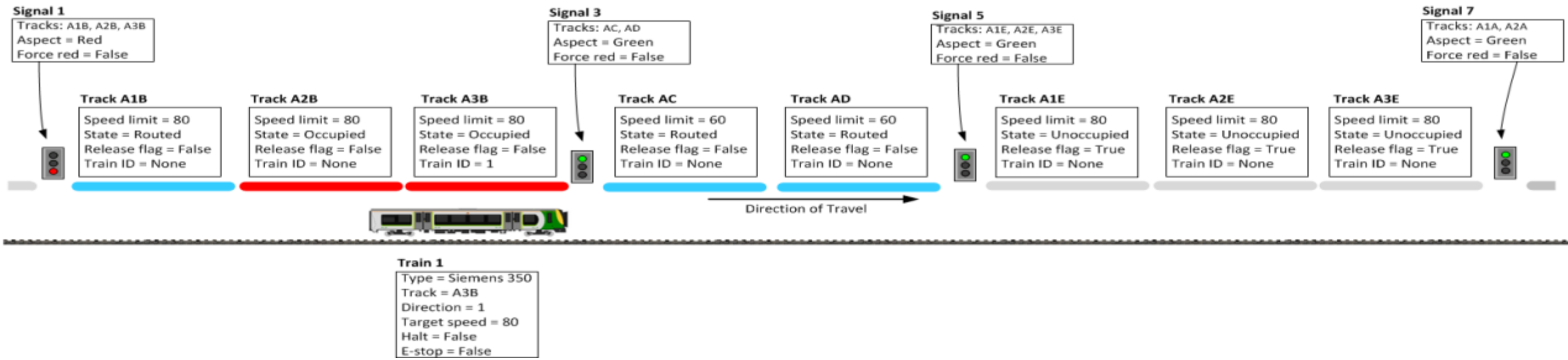

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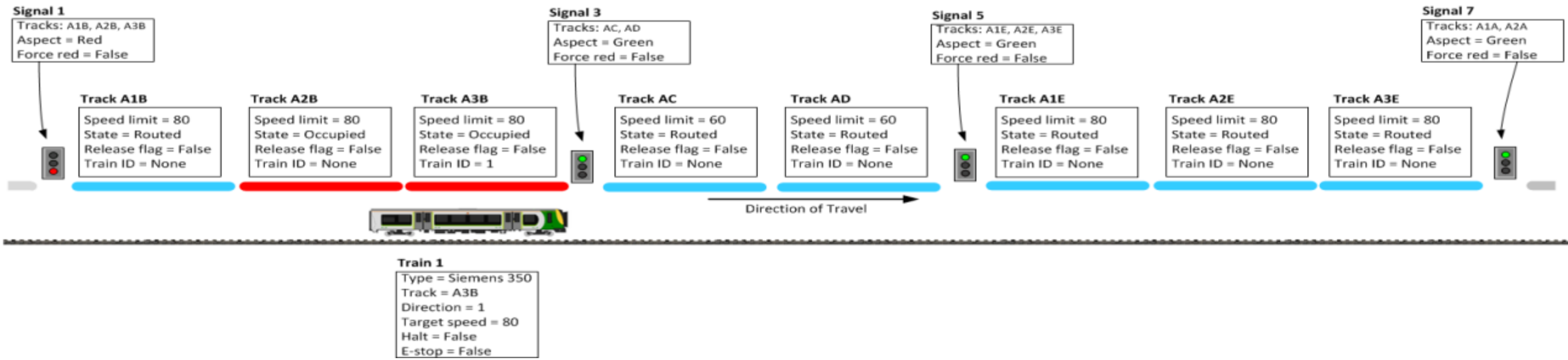

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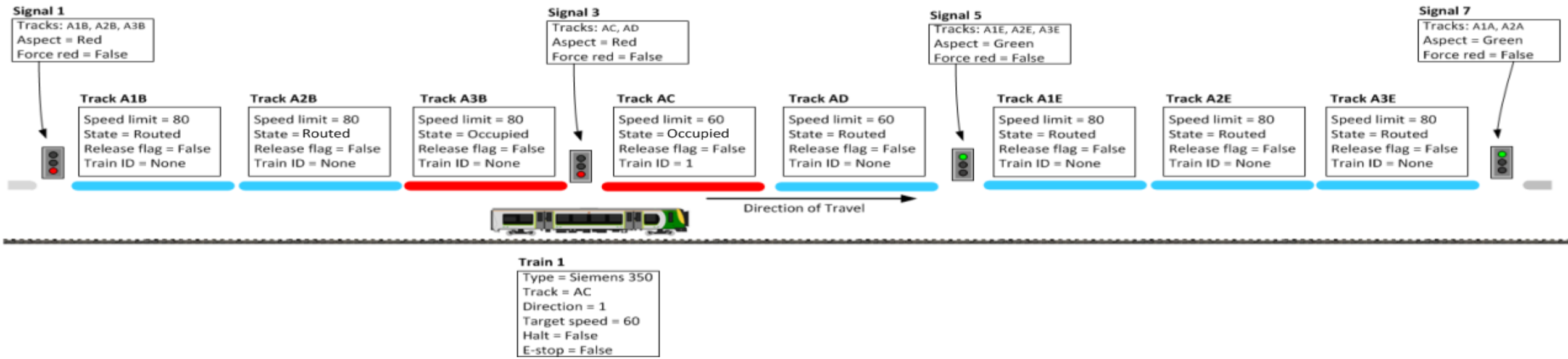

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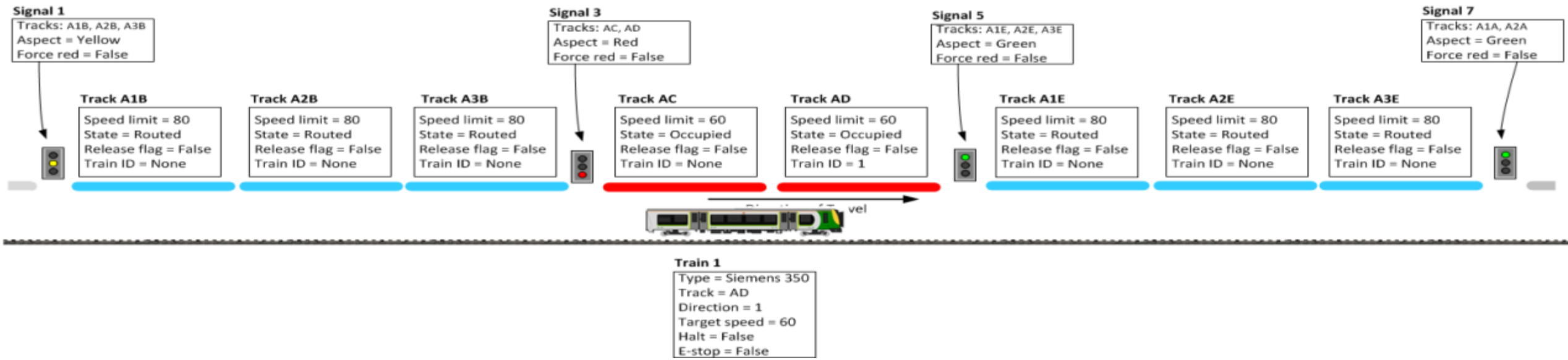

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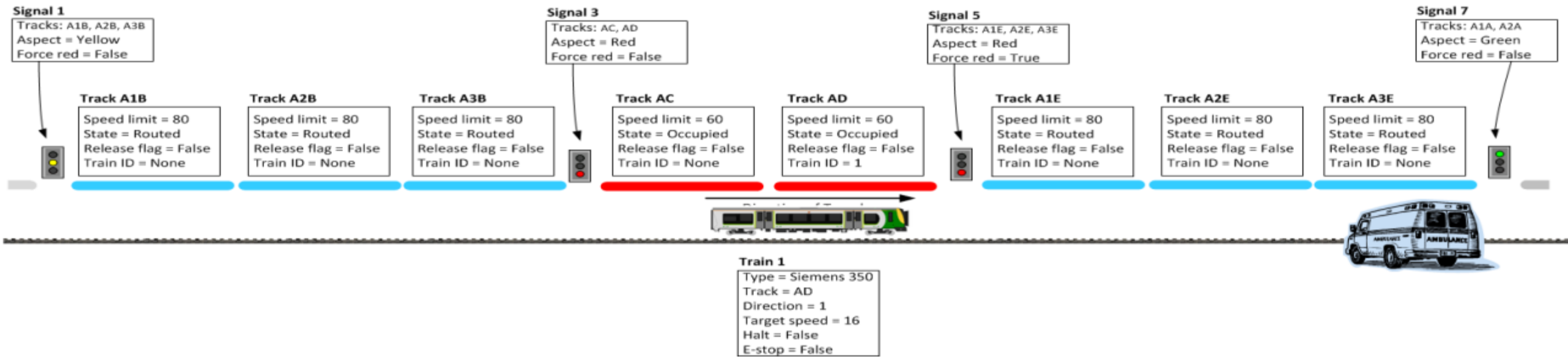

Object Oriented Programming

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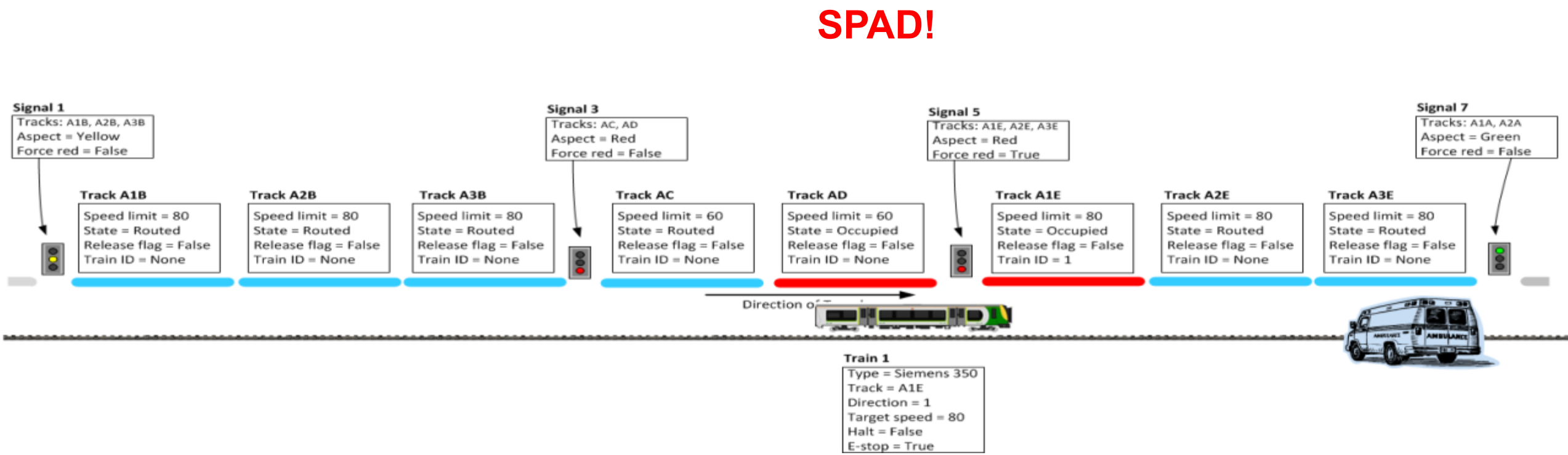
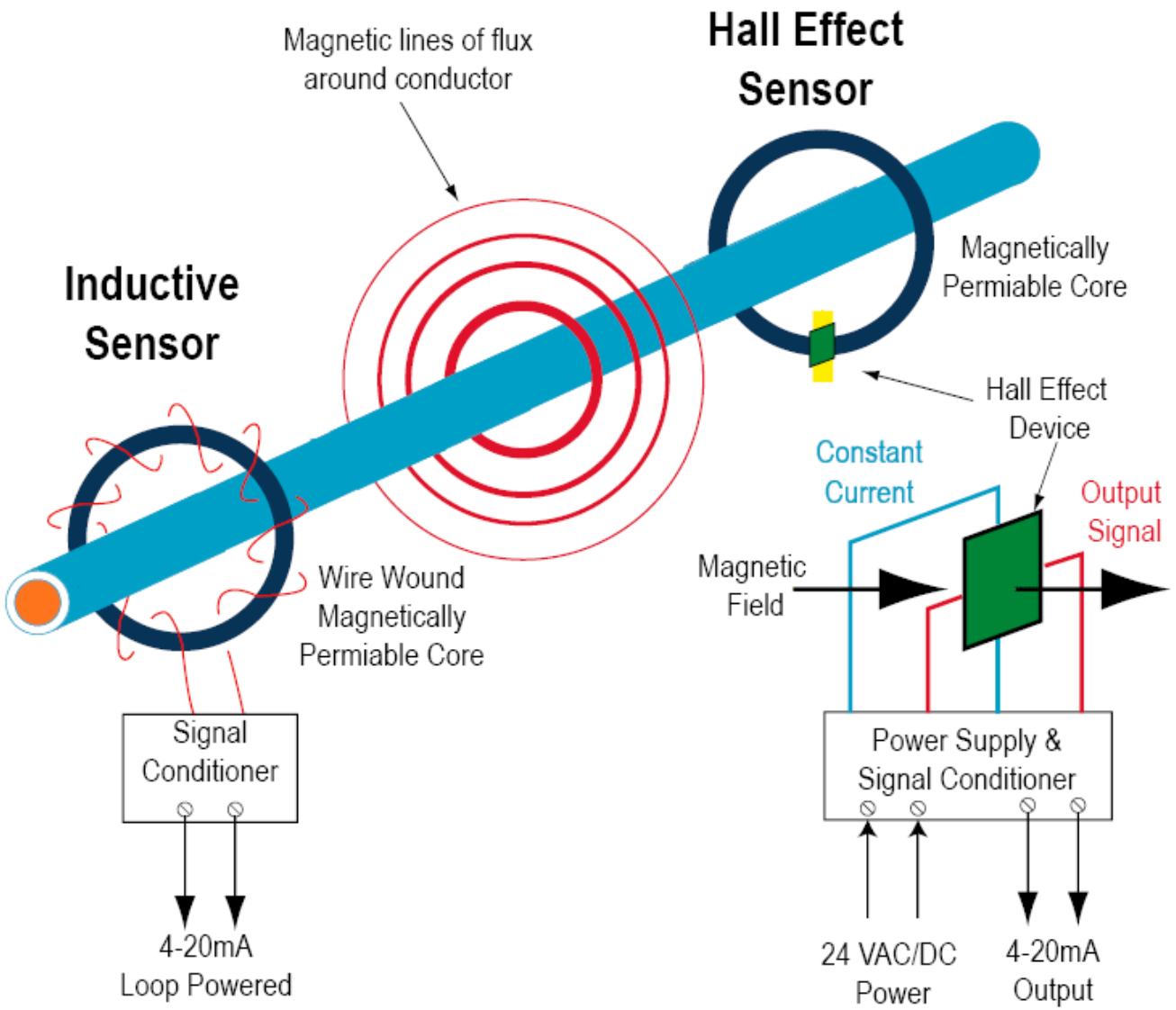
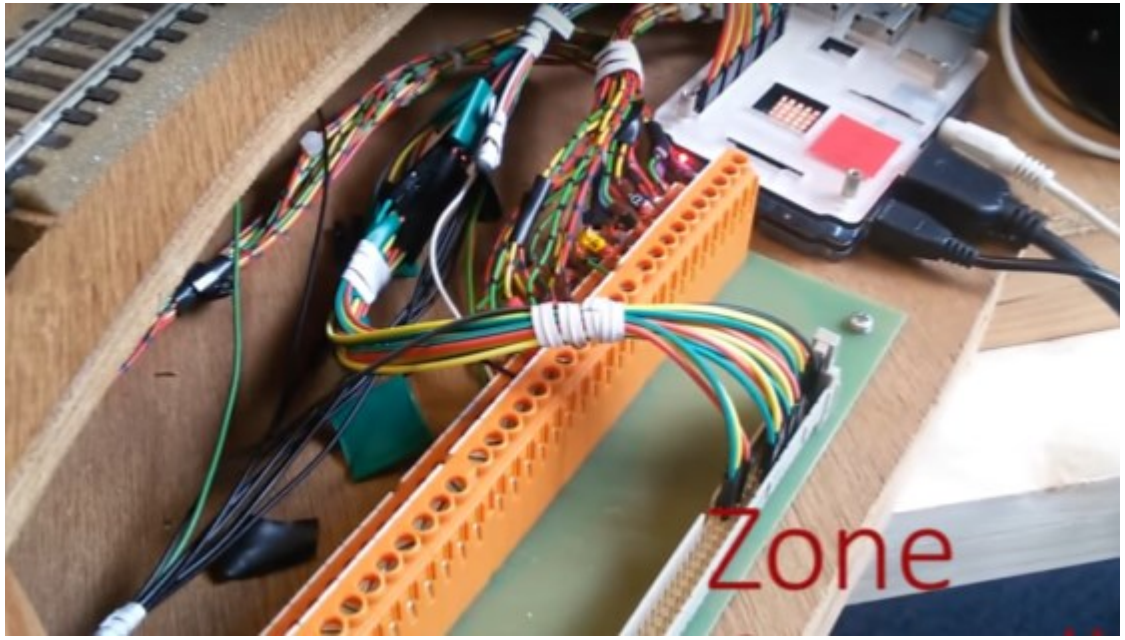
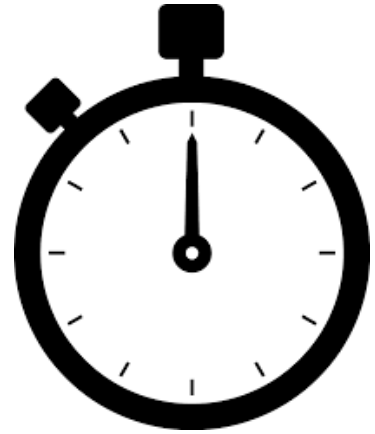


Real World Challenges – Electromagnetic Interference



Real World Challenges – Human Factors





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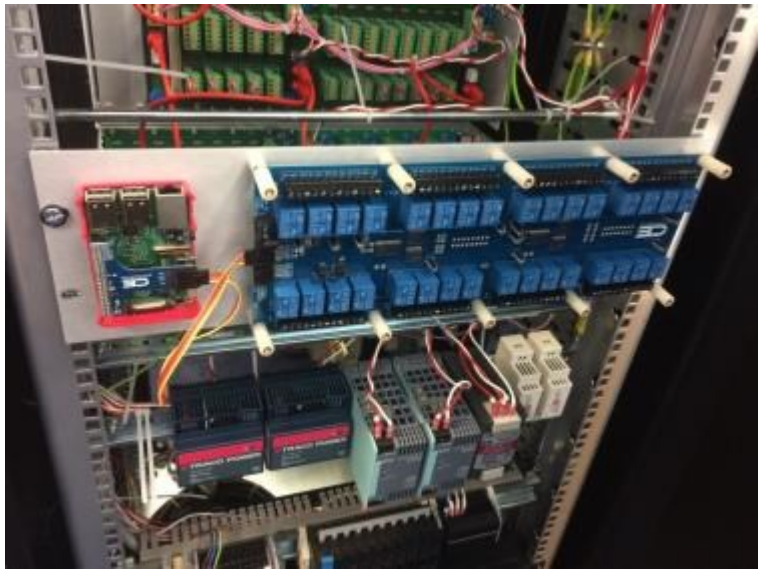
Raspberry Pi – Taking it Further



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Questions

Model Railway Control with a Raspberry Pi

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Thank you

Model Railway Control with a Raspberry Pi