A short history of London Underground

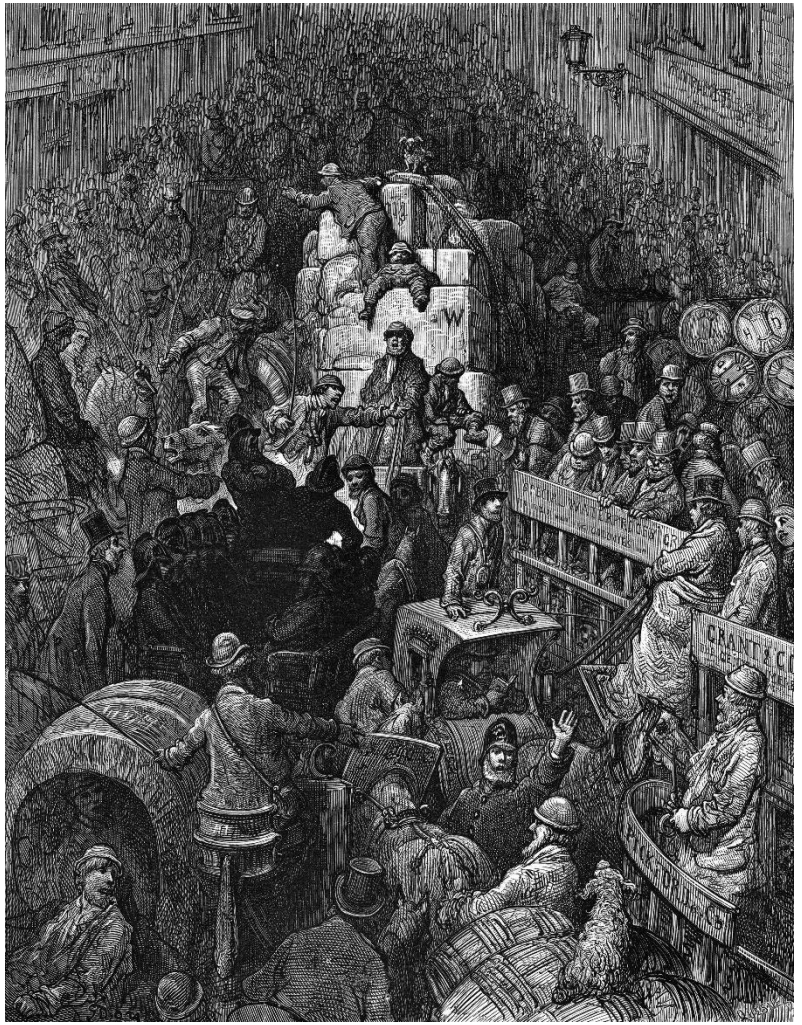
Malcolm Simpson – short career history

- Graduated with degree in electrical engineering from Nottingham University
- Engineering trainee with London Underground Chief Signal Engineer's Department
- 20 years in signalling research and development
- Recruited to improve safety management after Kings Cross fire
- Played a lead role in the redevelopment of London Underground Safety Management System
- Became senior incident investigator within Metronet
- Development Manager in Access Team for engineering works

Background

- London largest city in the world
- Entire city congested
- Construction of “New Road”
- Commerce widely distributed
- Railways deterred from building into city
- Long journeys anywhere within the Metropolis

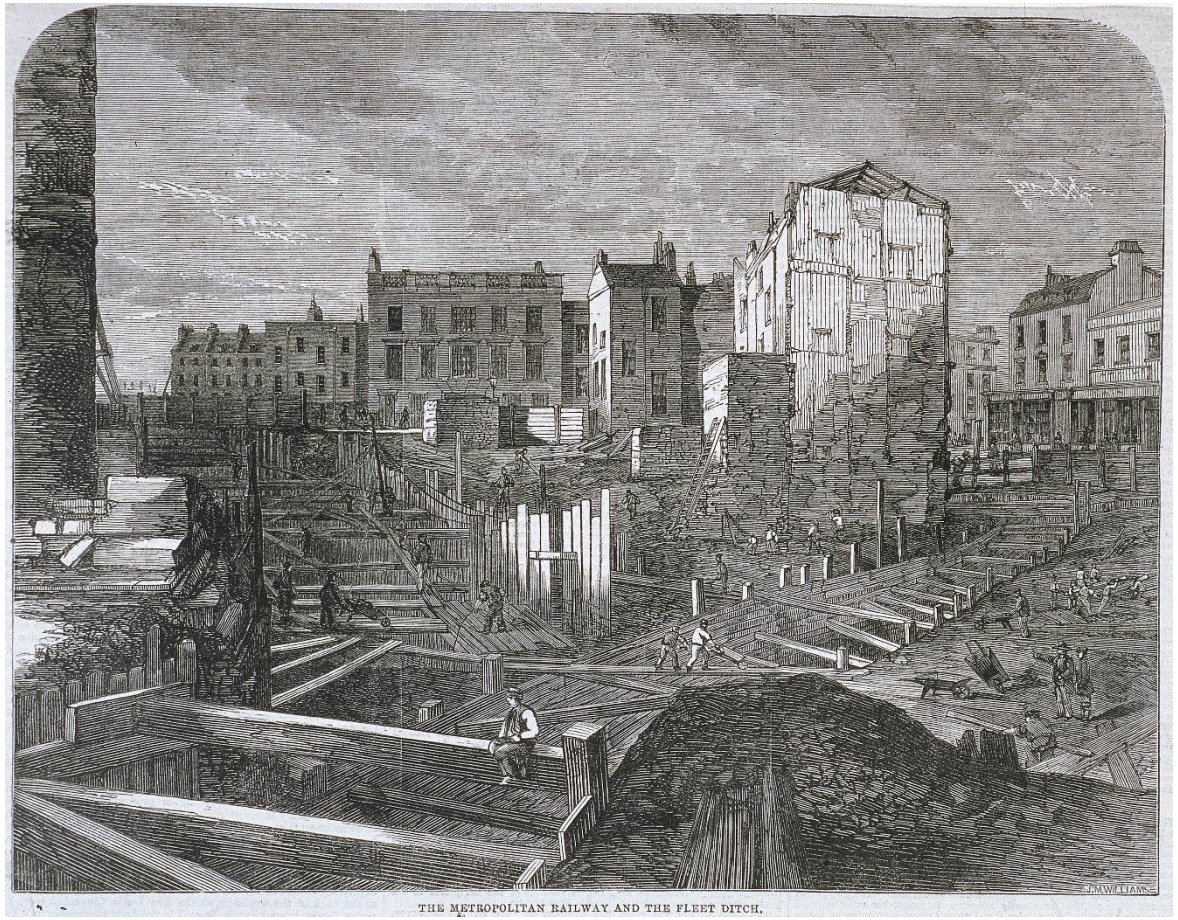
Congested London – Gustav Dore



A beginning – The Metropolitan Railway

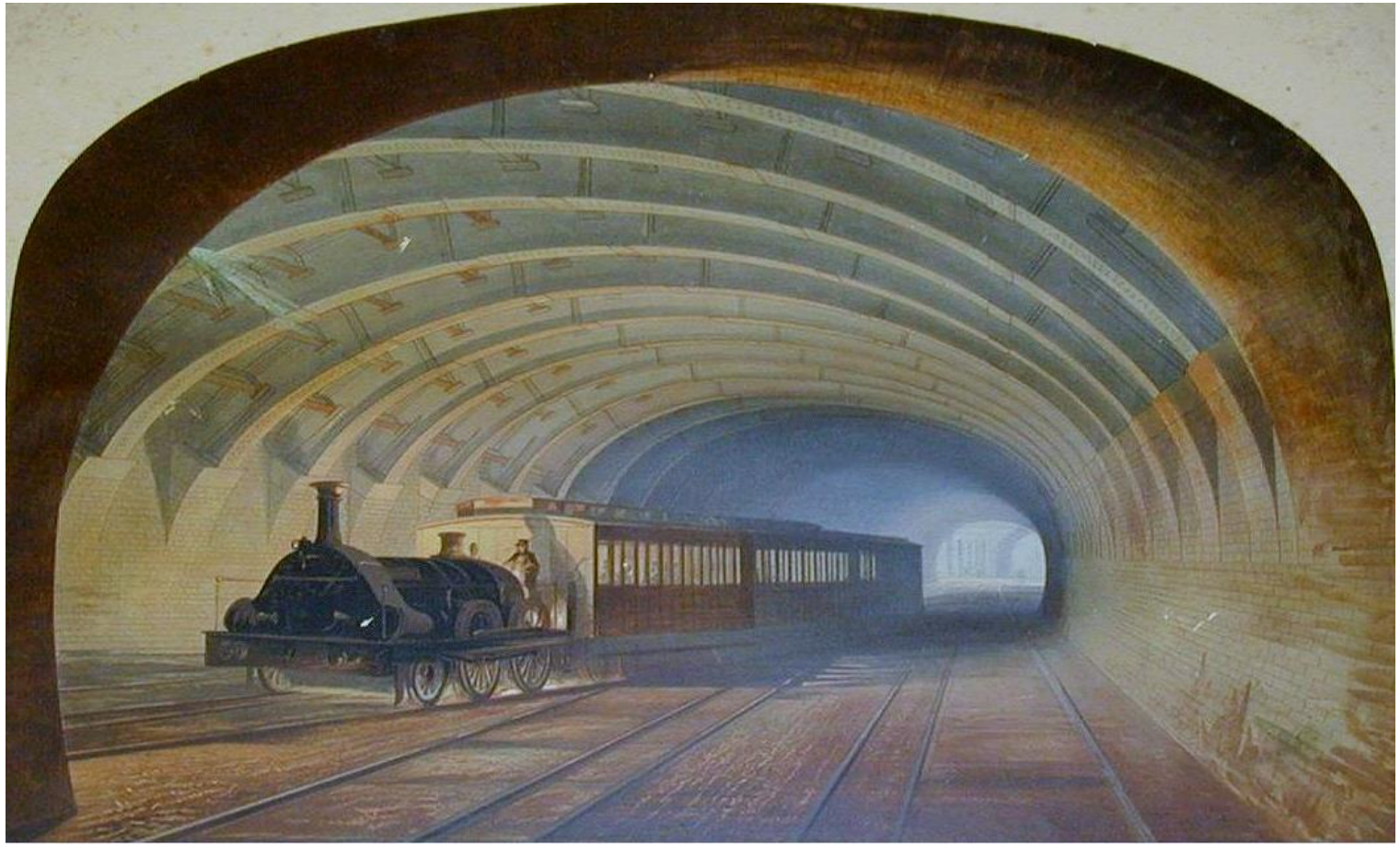
- Charles Pearson encourages the building of railways within the city
- Evolution to Metropolitan Railway
- Difficulty in raising funds
- Construction took from 1860 to 1863
- Cut and cover construction
- Widespread disruption during construction – collapse of Fleet Sewer
- MR purchases own locomotives after falling out with GWR
- Reached Hammersmith in 1864 and Moorgate in 1865

The Metropolitan Railway and the Fleet Sewer



THE METROPOLITAN RAILWAY AND THE FLEET DITCH.

The Metropolitan Railway shortly after opening



Along the Thames – The Metropolitan District Railway

- Metropolitan District Railway Company formed in 1864
- New line to the south of the Metropolitan Railway alongside the Thames linked to the Metropolitan Railway to form a circle
- Both MR and MDR faced problems in raising capital
- A huge construction project – brick kilns at Earls Court
- The two companies did not work co-operatively
- MR opened to South Kensington in 1968 with MDR to Westminster
- Circle not completed for 10 years

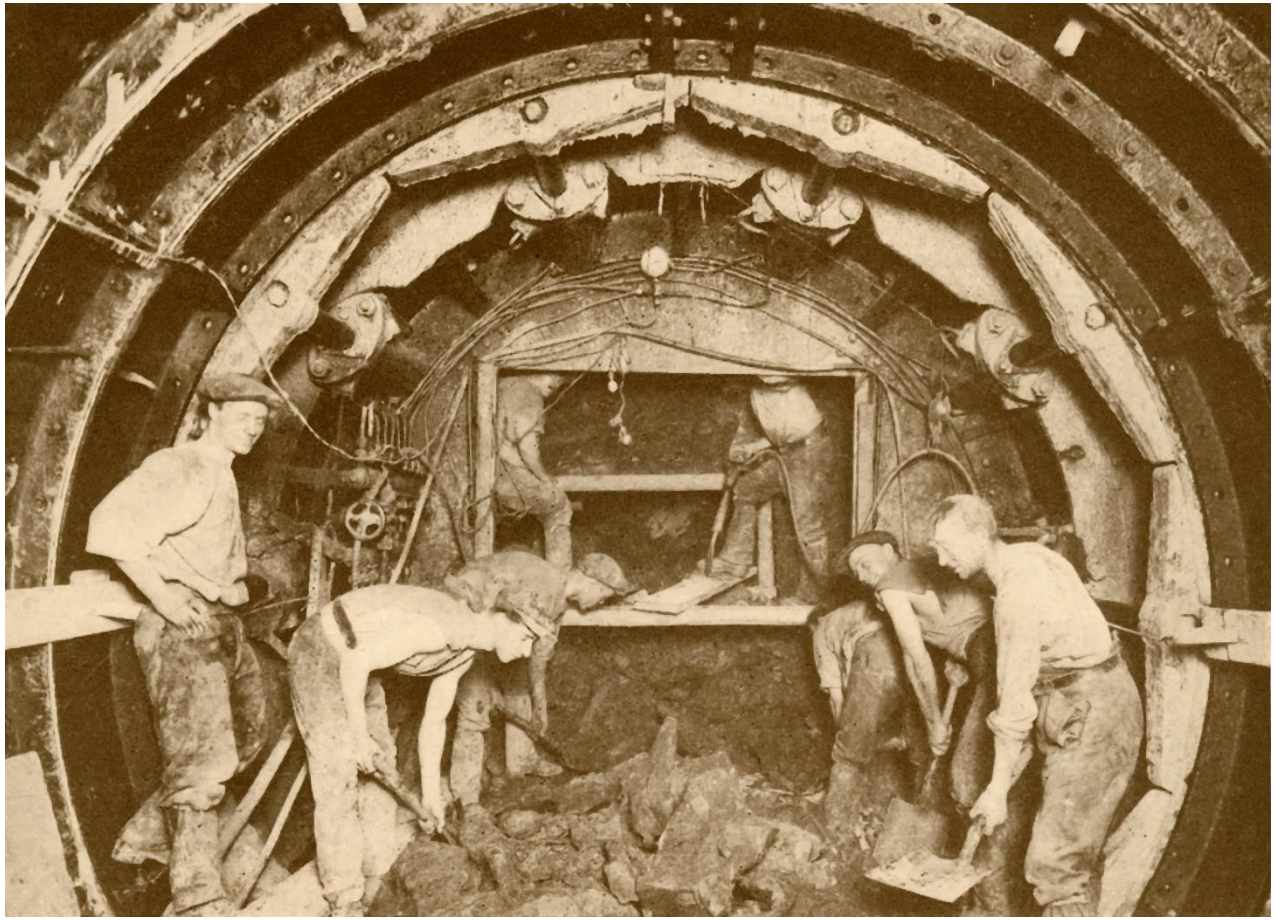
Early expansion – out to the suburbs

- Metropolitan Railway to Willesden Green and onwards to Harrow and Rickmansworth
- Metropolitan District Railway to Richmond, Ealingand Hounslow

The origins of the Tube Railway

- Marc Isambard Brunel – the Wapping and Rotherhithe tunnel
- The use of shields for tunnel construction
- The Barlow shield and the Tower Subway

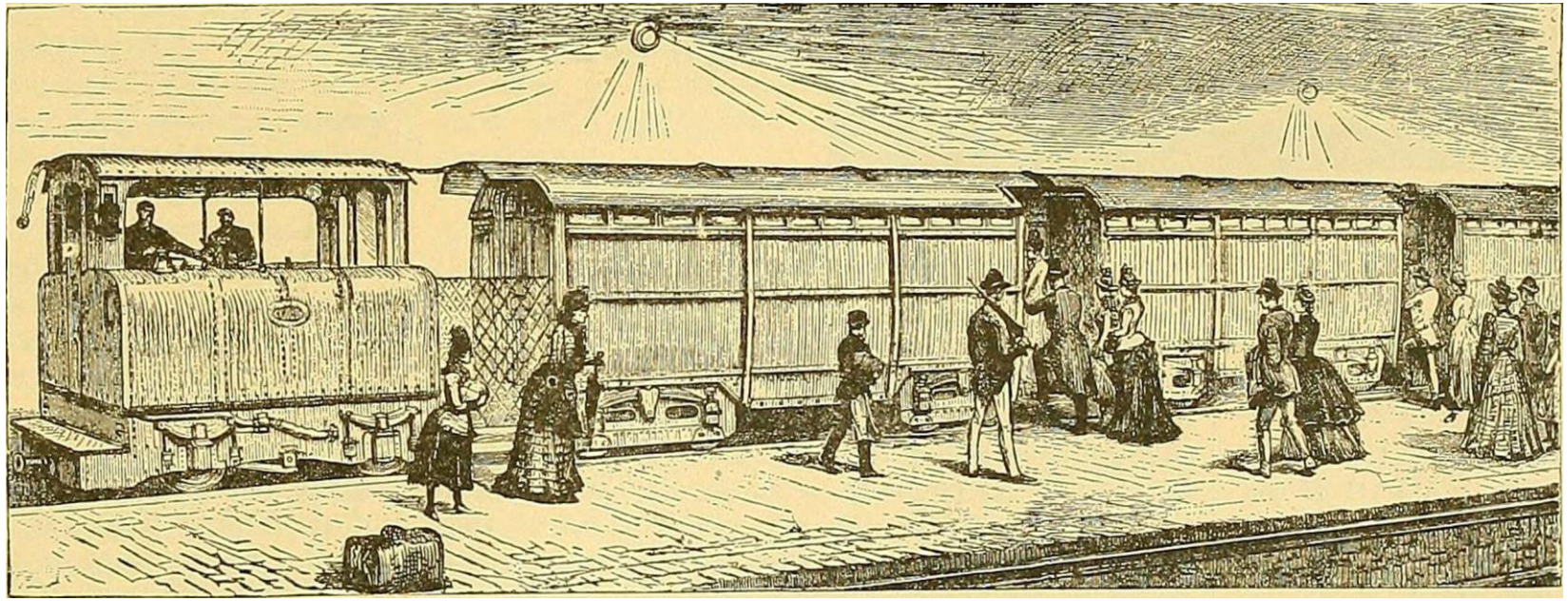
Using a shield to excavate a tunnel



The City and South London Railway and other early tube railways

- James Greathead and an improved tunnelling shield
- First tube railway authorised in 1886 between King William Street to Elephant and Castle
- Extension quickly authorised to Stockwell – opened in 1890
- Waterloo and City Line opened in 1898
- Great Northern and City opened in 1902
- Central London railway opened in 1900
- Failure of Royal Commission to establish funding plan

First trains on the City and South London Railway



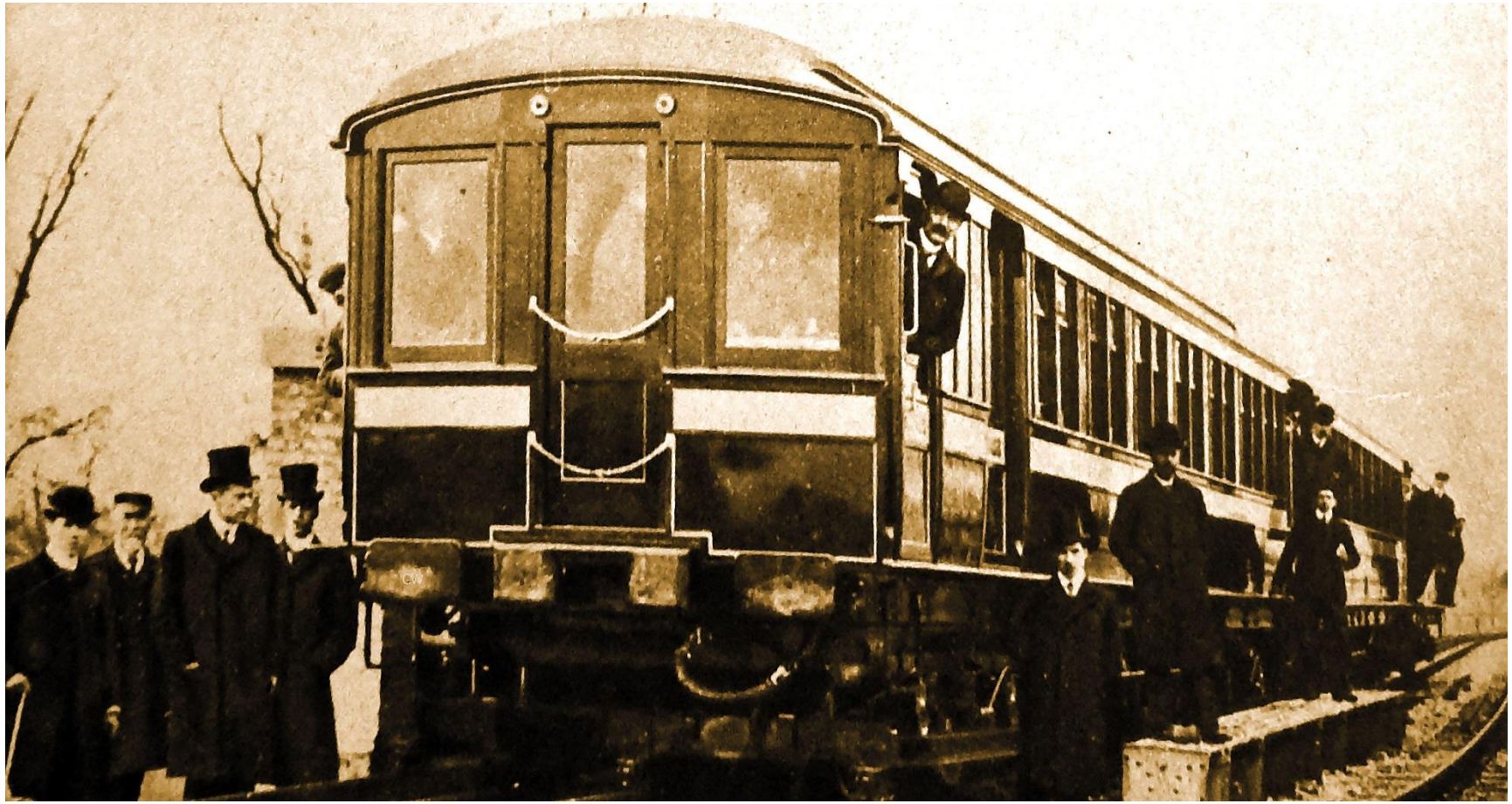
Enter the “entrepreneurs” of dubious repute

- Company struggling to build Baker Street to Waterloo Railway
- Whitaker Wright offered to raise funds to complete construction
- Bond issue failed
- Wright committed fraud and then fled to New York
- Arrested and brought back for trial
- Sentenced to 7 years in prison
- Then…….

And another one!

- Charles Tyson Yerkes – wheeling and dealing in Chicago, prison sentence for bribery and corruption
- Moved to London in 1900 and formed Underground Electric Railways of London
- Raised funds to take over several struggling railway companies to allow construction to be completed
- Influenced choice of electrification system for sub-surface railways
- Metropolitan and Metropolitan District lines speedily electrified

Early Metropolitan railway train



Up to and through the First World war

- Debt restructured and London Electric railway Company formed
- New company inherited Lord Ashfield and Frank Pick
- Strong stewardship and improved revenues
- Other tube lines taken over
- Bakerloo Line extended in conjunction with L&NWR
- Metropolitan railway consolidated under new leadership
- Loss of staff to services and some bomb damage

Lord Ashfield and Frank Pick

Through the 1920s

- Early LER extensions but revenues disappoint
- Government Loan guarantees –Trade facilities Act 1921
- Northern Line significantly developed and part rebuilt
- Metropolitan Railway development of “Metroland” and extension to Watford
- Following improvement of loan scheme and plans for northern extension of Piccadilly Line developed – construction started in 1930

Camden Tunnels on the Northern Line

Formation of the London Passenger Transport Board

- After considerable debate legislation passed
- Common ownership but no subsidy
- LPTB commenced operation on 1 July 1933
- Further government loans
- The 1935 to 1940 New Works Programme
- Northern Line GN Northern Heights extensions
- Central Line extensions eastwards and westwards
- Bakerloo Line link from Baker Street to Finchley Road

The Second World War period

- Most extensions placed on hold
- Initial refusal for tube stations to be used as air raid shelters
- Tube staff become Air Raid Precautions wardens
- Tube stations become air raid shelters
- Several stations hit by bombs: Balham(68),Bounds Green (17), Bank (56), Sloane Square (82) – numbers killed in brackets
- 22,500 staff called up for war service
- Unused Central Line tunnel used as linear war factory

Tube station as air raid shelter

Bomb damage at Balham station

Nationalisation – the first time

- Significant increase in traffic after the war
- Damage repair needed but inadequate funding
- LPTB nationalised against expectations becoming London Transport Executive reporting to the British Transport Commission
- Central Line completed and opened in 1949
- Much of Northern Line planned extensions abandoned

In the doldrums in the 1950s

- Little progress on development in this decade
- Network becomes “tired” suffering from ageing trains and equipment
- Fires occurring on older trains
- Aluminium bodied trains ordered for Piccadilly and Central Lines
- Improvements on the Metropolitan Line
- Preparations made for construction of the Victoria Line

Not so Swinging 60s

- Overall travel conditions continue to deteriorate
- Increased car ownership leading to reduced ridership
- Difficulties in attracting staff
- Victoria Line built and opened in stages from 1968
- Greater London Council created in 1965
- GLC seeks funding for motorway box schemes

The 1970s – political wars commence

- GLC took over responsibility for London transport on 1 January 1970
- Some funding for improvements – Heathrow extension and first stage of Jubilee Line
- Moorgate tunnel end accident – February 1975
- Further decline and war between Tories leading the GLC and London Transport senior management
- Appointment of Leslie Chapman to the board and aftermath

The 1980s political wars continue and a second nationalisation

- Labour concentrates on pledges in their winning manifesto
- Fares fair and the consequences
- Zonal fare structure and the Travel Card
- Nationalisation of London Transport and formation of London Regional Transport with London Underground Ltd as subsidiary
- Abolition of the GLC
- Kings Cross station fire
- Docklands Light Railway and planning for the Jubilee Line extension

Fares fair!


21 MARCH
London Transport
100% Increase
from
Westminster
KEEP FARES FAIR
FLE 224T

The 1990s and the Jubilee Line Extension

- Authorised in 1992 but Docklands developers collapsed
- Grant funding by government
- Cost increase from £2.2Bn to £3.9Bn – 70%
- Problems with Jubilee Line signalling – moving block failure
- Jubilee Line extension opens in 1999
- Labour government decides to create Public Private Partnership

The Public Private Partnership and the 2000s

- Consultancy on options
- PPP proceeded with at much higher price than anticipated
- Greater London Authority set up and Ken Livingstone becomes first Mayor
- Transport for London established reporting to transport Commissioner
- Metronet consortium goes into administration after poor cost control
- Tubelines Consortium is sold to Transport for London
- Exchequer obliged to pay £2Bn compensation to Metronet consortium
- Bombing attacks on the underground network

Victoria Line new train

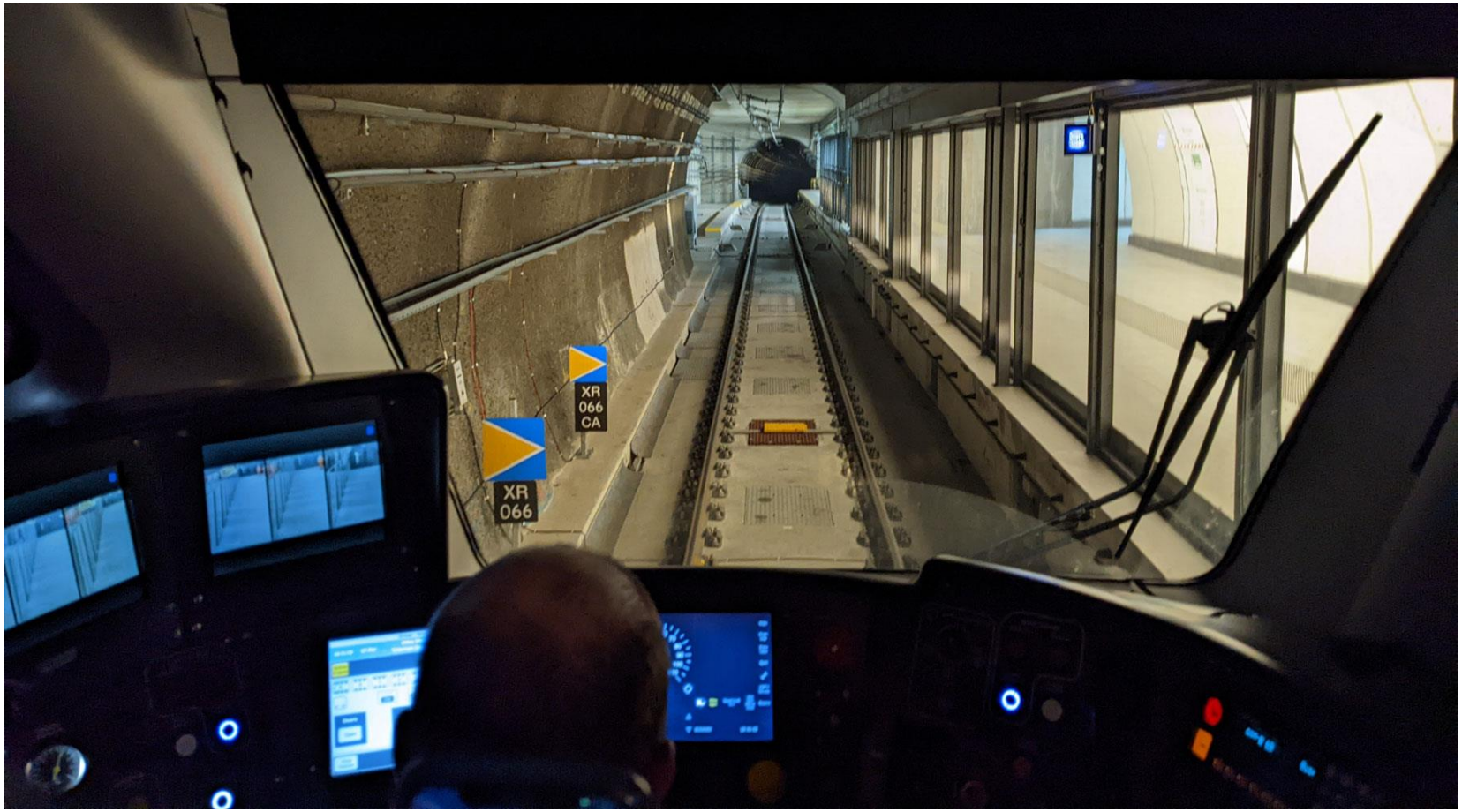
Onwards into the second decade of the twenty first century

- Victoria Line re-signalling delivered late but proves reliable
- Sub Surface Lines re-signalling contract with Siemens (former Westinghouse) cancelled
- New contract signed in 2011 with Bombardier for resignalling
- Contract with Bombardier for resignalling cancelled in 2015
- LU has to write off £67m unavoidable costs due to contract terms
- New contract signed with Thales for resignalling as no other bidders
- Elizabeth Line (Crossrail) opening
- in stages from May 2022

Elizabeth Line opening

Elizabeth Line opening

Elizabeth Line – view from cab



Electrical Systems on London Underground

Traction and Trains – City and South London Railway

- Separate locos and trailers – UK built
- Third rail traction supply
- Locos heavy and underpowered
- Capacity problems
- Inadequate generating capacity

Traction and Trains – other tube lines

- Waterloo and City Line – American built multiple units with traction motors distribute along train and cabs at each end
- Great Northern and City Line similarly equipped
- Central London Railway – large heavy camel back locos hauling trailers – suffered from vibration and potential threat of property damage
- Central London Railway trains replaced by multiple units within 5 years

Traction and Trains – electrification of Sub Surface lines

- Competing electrification systems
- Arbitration
- Speedy electrification
- Multiple Units from outset
- Metropolitan Railway deployed electric locos for outer suburban services

Traction and Trains – from 1910 to 1960

- Early trains had short lives
- Relatively limited improvement in train design and traction control
- Replacement of relays and contactors by pneumatic rotary contactors
- Use of aluminium in train body construction for lightness
- Deterioration of electrical insulation caused train fires forcing replacement of fleets with little advance in technology

Traction and Trains – control of traction power by electronic devices

- Experimental Tube Train using thyristor control of traction power
- Concern regarding interference to signalling systems
- Central Line fleet replaced in 1992 with thyristor controlled traction after evaluation of prototypes
- Signalling track circuits replaced by traction immune blockjointless track circuits
- Reliability problems with DC traction motors
- DC motors being replaced with 3 phase AC motors at half life overhaul
- All subsequent fleets introduced with AC motors using triac or Insulated Gate Bipolar Transistors for control purposes

Signalling and Control Systems – Early block control

- Mechanically operated points and signals with signal box at each station
- Spagnoletti electric telegraph to control block working between signal boxes to prevent a signal clearing until line ahead no longer occupied
- All signals oil or gas illuminated – reluctant change to electrical illumination
- City and South London Railway introduced treadles to detect when train exited block section
- Points not interlocked with signals until legally required

Signalling and Control Systems – introduction of track circuits and trainstops

- Track circuits with insulated blockjoints developed in USA
- Track circuits used experimentally between Ealing and South Harrow in 1905 – extended to all Sub Surface lines as electrified
- Initially polarised DC track circuits used – replaced by AC track circuits to provide better traction immunity
- Introduction of trainstops to enforce signals

Signalling and Control Systems – developing the technology

- Only limited change in technology in next 40 years
- Process of refinement and standardisation continued
- Introduction of centralised control of several interlockings
- Push button control of routes
- Mechanical interlocking retained but improved by using single shaft instead of lever and linkages

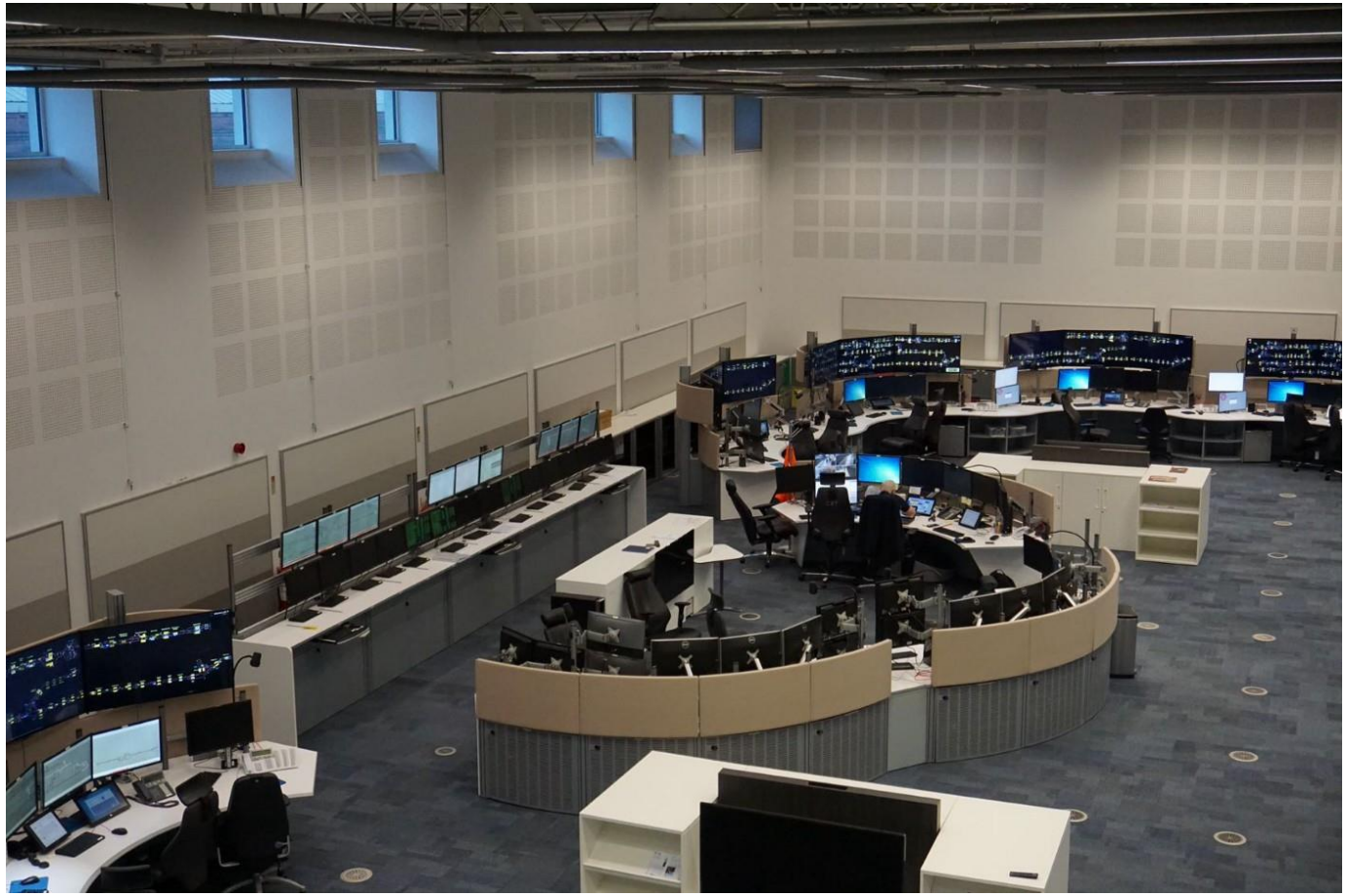
Signal and Control Systems – Programme Machines

- Programme Machines developed – could store local routing, destination and timetable information
- Similar to pianolas with storage by holes punched in melamine roll
- Once the timetable point was reached the route was checked and set if clear
- Once train passed programme Machine stepped to next line of data
- Limitation due to number of possible bits of data that could be punched
- Started to be replaced by small process control computers in the 1970s

Signal and Control Systems – Victoria Line

- Locally sited Programme Machines provided with central supervision
- Introduction of coded track circuits allowing information to be securely transmitted to trains (Automatic Train Operation)
- Second non-vital system provided to control train movement

Modern Control Room - Hammersmith



Signal and Control Systems – Blockjointless track Circuits

- Early 1970s system failed due to potential wrong side failures caused by stray currents flowing between two similarly coded track circuits
- Fresh approach in 1980s using validated single channel software
- Coded signal validated using Fast Fourier transform process in software
- Successfully deployed on Bakerloo Line in late 1980s
- Initial track connection problems caused track circuit to be 10^{5} times less reliable than a traditional track circuit
- Fully deployed during the resignalling of the Central Line in the early 1990s

Signal and Control Systems – Transmission based signalling

- Both the Jubilee and Northern Lines have been resignalled in recent years using a SELTRAC (now Thales) transmission based system
- Uses twin conductors transposed at intervals to provide positional information (along with transponders)
- The conductors carry data signals defining the limit to which a train may travel
- Technology is now approaching 40 years old but has been regularly upgraded
- The Sub Surface Lines are being currently resignalled using a development of this using fixed position antenna to transmit data to trains

Signal and Control Systems – Problems of ageing equipment

- Turbulence within programme of signalling upgrades has resulted in some installations remaining in service for 60 years
- From 1990s onwards problems have been experienced with cable insulation degradation
- In one case chemical decomposition resulted in copper migration into the insulation and credible wrong side failure conditions
- Hurried and expensive programme of rewiring of considerable number of installations

Signalling and Control Systems – Elizabeth Line

- Triumph in terms of customer experience
- Considerable delay due to signalling system and station completion problems
- Signalling system was novel and untested
- Signalling system must be integrated with new Elizabeth Line provision and existing Network Rail systems
- Adequate functional reliability took long time to achieve
- Not enough attention given to System Integration and other Assurance requirements

Lifts

- Lifts were provided from the start on City and South London Line
- Initially hydraulic lifts but soon converted to electric operation
- Electric Lifts installed on Central London Railway from opening
- Lifts were standardised on Otis designs
- Some lifts were converted from manual to automatic operation
- Lifts not generally installed on stations from 1913 onwards
- Many converted from DC power to AC power
- In more recent years small lifts installed for persons with impaired mobility

Escalators

- Escalators developed in the USA
- First escalator installed on the underground at Earls Court in 1911
- Soon used for all new stations and upgrades
- Initially DC powered but many now converted to run on AC
- Maintenance and upgrading is time consuming and disruptive
- Many escalators were upgraded to remove flammable components after Kings Cross station fire
- In early 2000s serious problems occurred with cracking in drive components

Ventilation

- No ventilation initially provided
- Omission was rectified and over many years ventilation was improved
- After Kings Cross station fire the importance of good ventilation was recognised
- All new lines and stations now provided with better ventilation so that in the event of fire smoke can be managed and extracted

Station Systems

- Following Kings Cross station fire station electrical and communications systems were enhanced
- Fire and smoke detection systems fitted
- Closed circuit TV monitoring installed throughout stations
- Public communications systems improved
- Radio communication provided for all staff
- Communications system long provided from driver to controllerbut required train to be stationary
- Leaky feeder radio provided from 1986 but upgraded to digital system by Connect project

Accidents – Moorgate Tunnel End Collision

- On 28 February 1975 at 0846 Northern Line train collided with tunnel end at Moorgate station
- Train driven under green signals
- Driver made no attempt to slow or stop the train
- First 3 cars collapsed into each other
- 43 persons were killed and 73 hospitalised
- Precursor events – 7 buffer end collisions with out-of-service trains
- Changes made to time control clearing of signals, resistance inserted into traction system, improved signage, fixed trainstops and crash dollies

Moorgate Tunnel end collision

Accidents – Arcing Fire on Piccadilly Line Train

- Caused by two trains being present in same traction section with opposite polarity traction faults (between Wood Green and Bounds Green stations)
- First train entered service with hard positive traction fault following collision with rail chairs
- Second train heading towards same traction system with intermittent negative earth fault
- Second train enters the same traction section and arc strikes between collection shoe and adjacent axle casing – arc spreads to car floor
- Train is disabled and confused communication before traction discharged
- Passengers evacuated through smoke filled tunnels
- HMRI enquiry and recommendations regarding fault clearance and communications

Accidents - Kings Cross Station Fire

- Dropped match ignites fire under escalator – over-greased, litter
- Fire reported but initial actions flawed
- Rapid spread and near explosion into ticket hall
- 31 deaths and more than 60 injuries
- Fennell Inquiry – many recommendations
- Removal of flammable materials and sources of ignition
- Installation of fire and smoke detection systems, CCTV and radio communication systems
- Radical overhaul of staff management and supervision and enhanced training

Kings Cross station fire