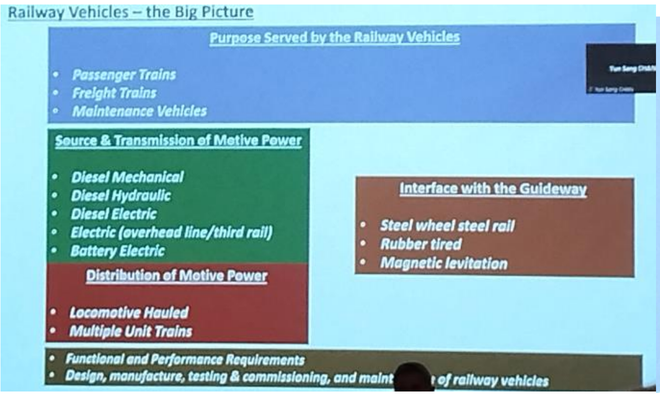
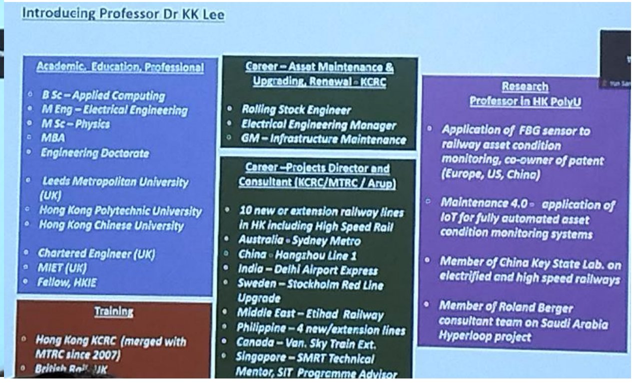
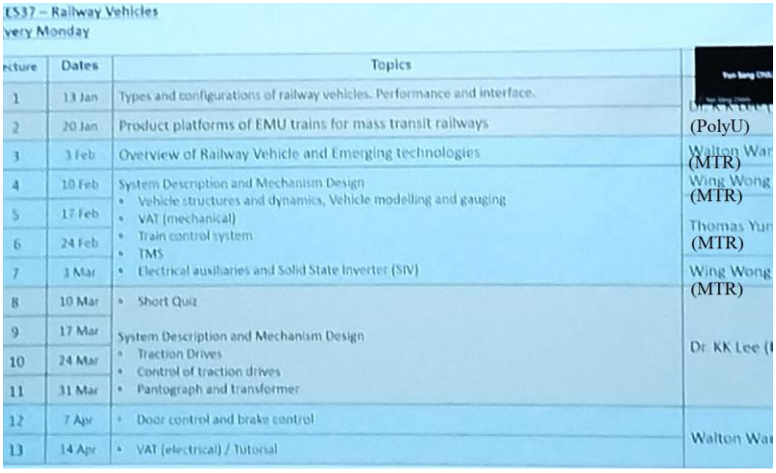
Rolling stock overview



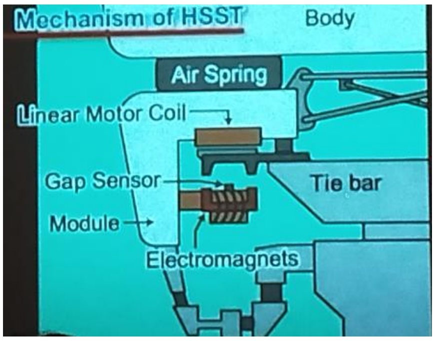



E537 – Railway Vehicles
very Monday

cture	Dates	Topics	
1	13 Jan	Types and configurations of railway vehicles. Performance and interface.	(PolyU)
2	20 Jan	Product platforms of EMU trains for mass transit railways	
3	3 Feb	Overview of Railway Vehicle and Emerging technologies	Walton War (MTR)
4	10 Feb	System Description and Mechanism Design • Vehicle structures and dynamics, Vehicle modelling and gauging	Wing Wong (MTR)
5	17 Feb	• VAT (mechanical)	
6	24 Feb	• Train control system • TMS	Thomas Yun (MTR)
7	3 Mar	• Electrical auxiliaries and Solid State Inverter (SIV)	Wing Wong (MTR)
8	10 Mar	• Short Quiz	
9	17 Mar	System Description and Mechanism Design	Dr KK Lee (
10	24 Mar	• Traction Drives	
11	31 Mar	• Control of traction drives • Pantograph and transformer	
12	7 Apr	• Door control and brake control	Walton Wai
13	14 Apr	• VAT (electrical) / Tutorial	

Purpose:

passenger (Civil aviation: 900km/h; Maglev: 650km/h, e.g., high speed surface transport (HSST) limino line in Aichi, youtu.be/XjwF-STGtfE; HSR: 250~350km/h, natural limit 500km/h, 300+km, significant aerodynamic drag; Regional: 100km+, linking cities; Mass transit (metro): 10~30km, 80~130 km/h, steel wheel less friction, curve radius > 300m; light rail/trams; monorail trains: more friction makes gradient limit higher 3%->8%, less redius allows; automated people mover trains; ART)

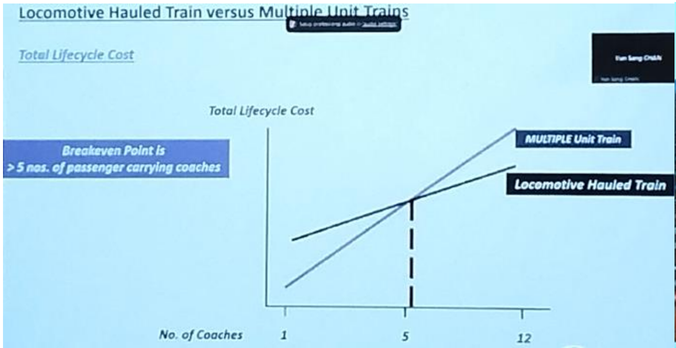


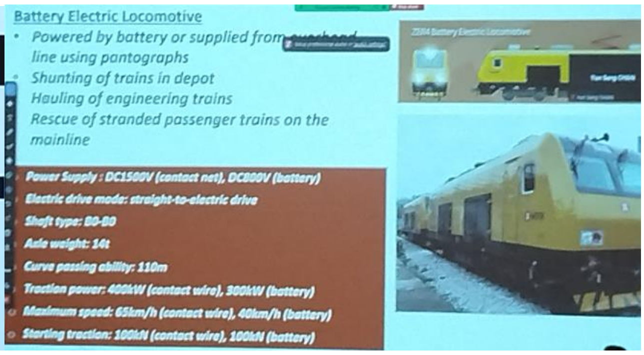
freight (break bulk/general(散杂货) cargo, tank / hopper wagon un/loading, double decker / box)

maintancance (tamping track: balance track (track tamping, absorb vibration energy) more quiet than concrete base but stones can wear out leading to longitudinal level fault, tamping track squeeze the stones under the sleeper to balance pressure between left and right; rail grinder)

Source & trans of motive power: diesel (pollutive and noisy) mech/hydraulic/electronic, electric (overhead line/3rd rail), battery electric, hydrogen fuel cell

Distribution of motive power: locomotive hauled (e.g., DF11 3610kW engine 3040 kW at rail, 245kN max, 160 kN continuous; MTR engineering haul train: DC1500V contact net or 800V battery, B0-B0 shaft, 14t asle weight, 110m radius curve passing, straight-to-electric drive, 400kW 65km/h 100kN by contact wire or 300kW 40km/h 100kN battery), multiple unit trains





Interface with guideway: steel rail steel wheel, rubber tired, maglev

Functional and performance requirements; design, manufacture, testing & commissioning, maintenance of vehicle

China: largest HSR network; USA: largest rail network (mostly freights, very long trains (intermodal train 多式联运列车), 500/5000m train more efficient, 1 train = 275 trucks, problem: very long wait (ambulance wait 20 min), intrastructure), but political reason (automobile, aviation, petrol) reject HSR; Japan: SuperConductingMaglev (SCML, youtu.be/XjwF-STGtfE)

Railway Vehicle Specifications

Eg., MTR WIL (west island line) service requirements (from the view of rolling stock manager) :

Operator tells Rolling Stock Manager the needs (A, service requirement), then the manager tells supplier the needs (B, translation, detailed version with equipment specifications)

Content (WIL, 3 stations, 3km, service requirements document)

1 Intro (purpose and intent, background, appendix)

2 General Requirements (Capacity, safety, infrastructure, environmental, transport integration, compatibility with existing railway, service reliability, economical operation)

3 Operating Pattern (Service Pattern, Hours of Operation, WIL Service levels)

Journal time requirements, 19 hrs per day, 365 days per year. Occasional 24hr work on holidays

Ultimate min headway 105s, max headway 300s

SHW-KET: total journal time < 5.5 min, dwelling time (engineering dwelling (wheel stop to start) 32~47s, station dwelling (door fully open to start closing) 20~35s, system response time 12s)

Civil speed 90 km/h, operation speed 80 km/h

4 Station Operations (Accessibility, Circulation, Signage and Passenger Info, Ticket sales, Station Control, Station and Tunnel Facilities and Equipment and Systems, Emergency Station Operations, Summary of Station Service levels)

5 Train Operations (train, Normal Operations, Degraded train operations, emergency train operations, event recording, depot train operations, summary of train service levels)

6 Maintenance Requirements (Maintenance requirements, Maintainability, Scheduled maintenance, engineering trains, emergency maintenance requirements)

Key items of performance requirements:

Completing the journey within time – tractive effort and braking effort

Achieving the headway required – acceleration / decelerations

- ⇨ Amax operating speed, average acceleration, peak acceleration, service brake deceleration, emergency breake deceleration, minimum curve radius

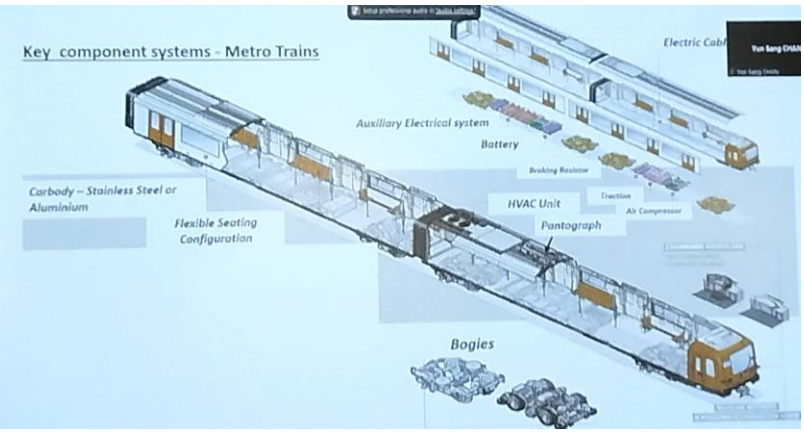
Carry the specified no. of seated and standing passengers per train

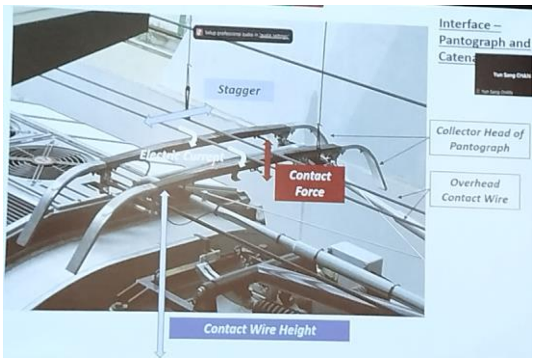
- ⇨ Passenger load AW0~4, Quantity of Seated Passengers (378), Standing Area 193.65 m^2 , Standing Passenger density (AW0~1 0pax/m^2, AW2 2pax/m^2, AW3 4pax/m^2, AW4 6pax/m^2)

Boarding and alighting passengers within station dwell time – number of doors on each side of vehicle

Reliability (Failure per million car * km), Noise and vibration (e.g., ETS to AUS, cultural center), Energy consumptions (Tare weight < 240t, weight penalty)

Key Component systems





Car body including the internal compartment

Running gears including the bogies, suspensions and the wheel sets

Braking systems including air brakes and regenerative brakes

Doors, Couplers and gangway

Air compressor and pneumatic system

Auxilary electrical system

Traction drives incl traction motors and control

Pantographs (集电弓) and high voltage system

Driving cab and driving console (UTO)

Communication systems and train management system

Key Interfaces of Metro Trains

Between Metro Train and	Interfaces				
	Functional	Physical	Spatial	Software	Electrical
Signaling	Braking/ acceleration	Fixing sig. equipment	Accommodate sig. equipment	Traction drive control	Input/Output signals
Tracks		Axial load	Track gauge		Return current through rails
Civil Infrastructure			Structural Gauge		
Traction power supply					Voltage/current
Overhead Catenary		Contact with pantograph	Height and Stagger		Current
Radio	Driver/OCC communication	Fixing radio equipment	Accommodate radio equipment		Input/Output signals
Communication	Passenger Information	Fixing PIS equipment	Accommodate PIS equipment		Input/Output signals

Functional requirements

Driving and control of the train (normal mode (Fully antomated without a train driver), degrade mode of train operation (GoA 1 driving by train driver, GoA 2 Automated with driver opening/closing the door and issue start command ATO, GoA 3 everything is automatic with train attendant and no train driver, GoA 4 driverless), driving console for degraded operation of the train)

Emergency push out of a defective train (push out a defective train stalled on the line at a speed of 10km/h)

Operation and control of the passenger doors

Emergency detrainment of passengers

Train management (Train Management System TMS shall provide centralized function to control and monitor the subsystem operation, fault status and fault data logging and reporting. Try to diagnose, reset or isolate the subsystems and keep running to the nearest station during fault. Critical faults or alarms shall ne sent to the OCC/DCC. Crucial for GoA 4 train.)

Communication with OCC (Passenger Announcement through public address system, monitor the saloon internal and train external environment through CCTV camera)

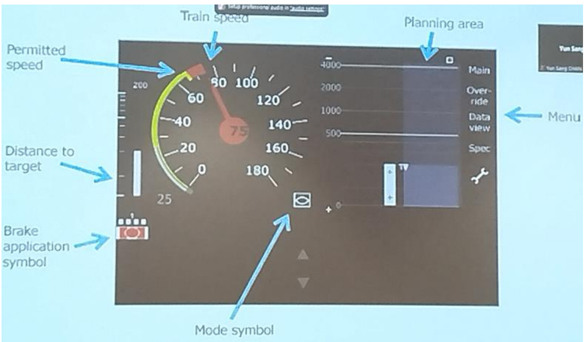
Fire performance and fire fighting provisions of the train

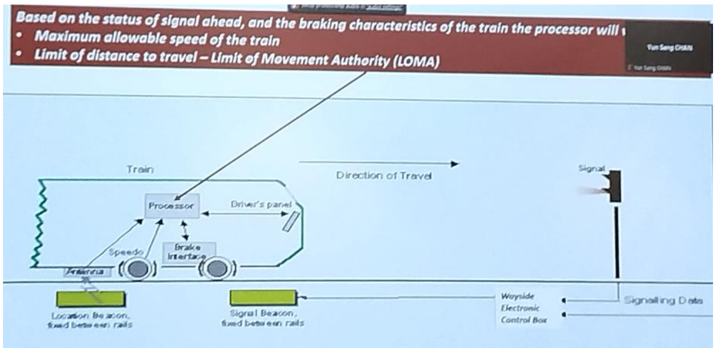
Design life (Sydney metro 35 years, MTR 40 years, Technical spares and software support to be provided by Alstom throughout the design life)

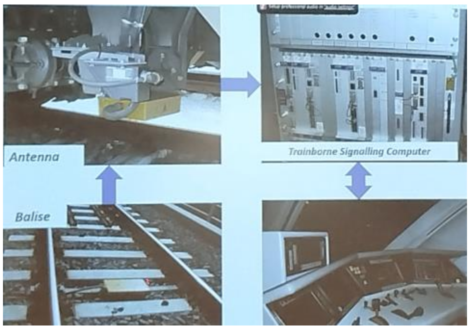
Maintenance of trains (Lifting and jacking points, schedules examinations, overhauls, corrective maintenance. Line replacement unit (LRUs) to facilitate repair work. Important to keep trains moving for passenger service due to public relation)

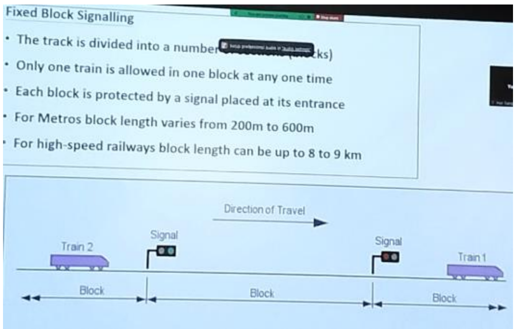
Aesthetic and passenger service requirements. E.g., train color, salon requirements, ventilation…

Auto Train Protection (ATP)

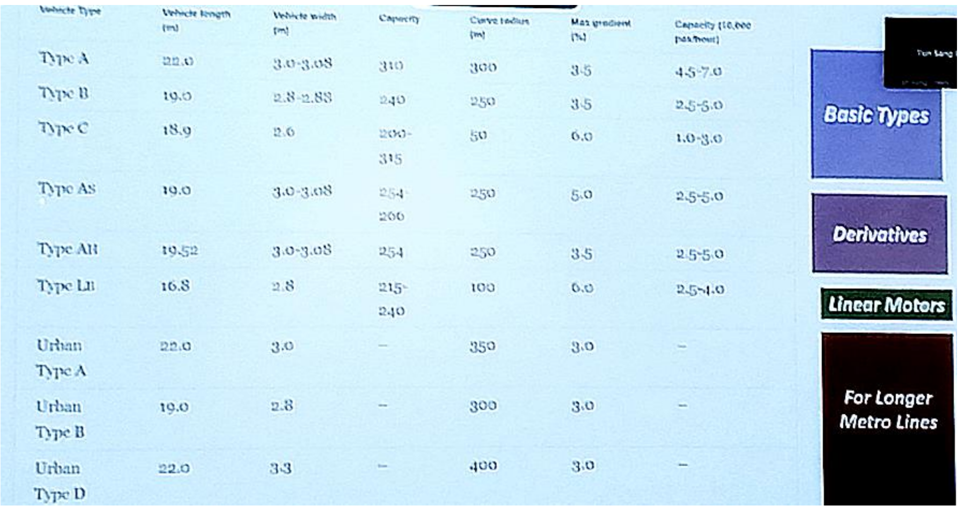






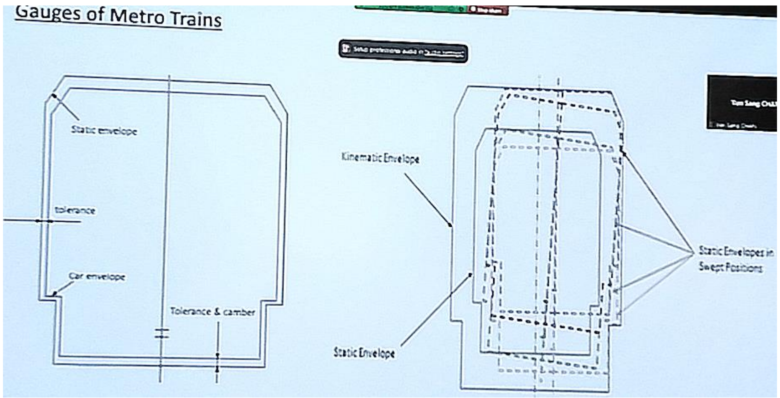


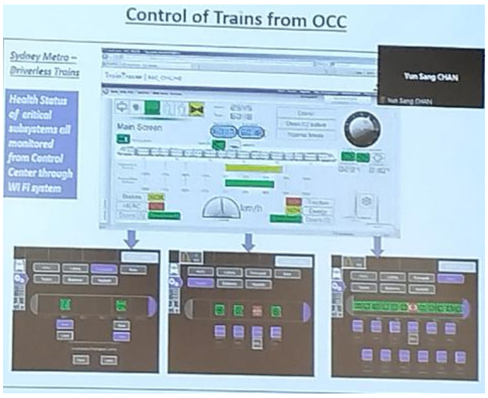
Standard China Metro Trains

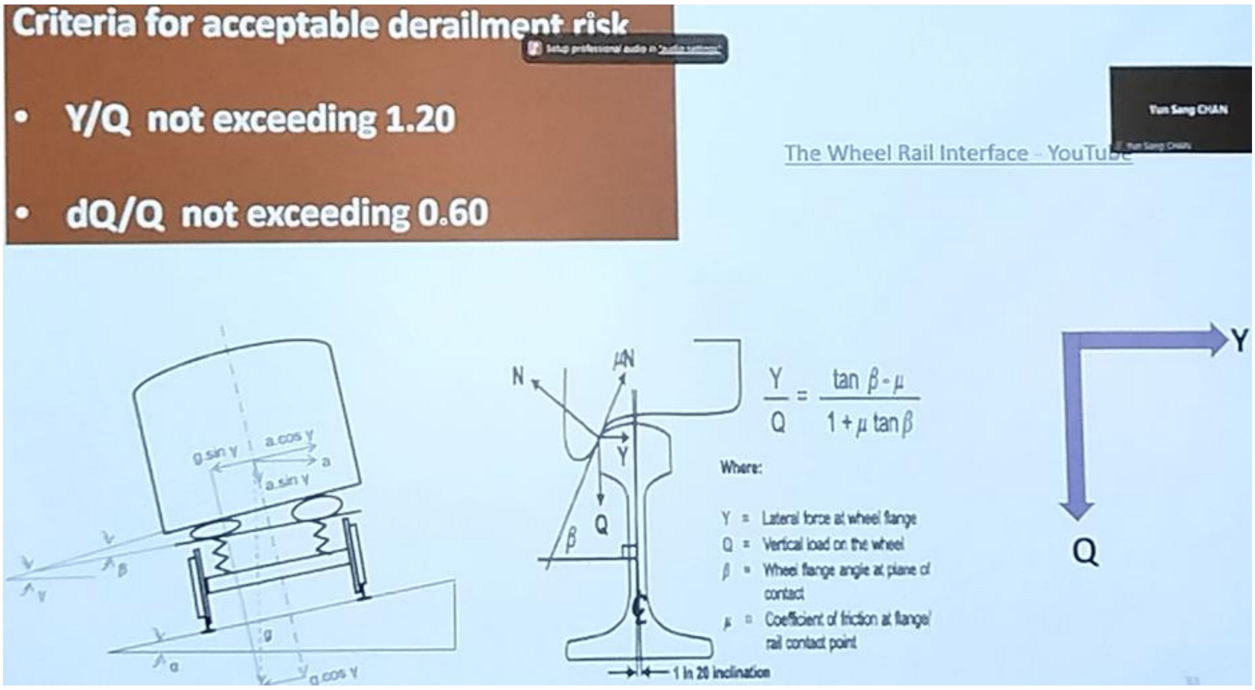


Vehicle Type	Vehicle length (m)	Vehicle width (m)	Capacity	Curve radius (m)	Max gradient (%)	Capacity (10,000 pax/hour)
Type A	22.0	3.0-3.08	310	300	3.5	4.5-7.0
Type B	19.0	2.8-2.88	240	250	3.5	2.5-5.0
Type C	18.9	2.6	200-315	50	6.0	1.0-3.0
Type As	19.0	3.0-3.08	254-266	250	5.0	2.5-5.0
Type AH	19.52	3.0-3.08	254	250	3.5	2.5-5.0
Type LB	16.8	2.8	215-240	100	6.0	2.5-4.0
Urban Type A	22.0	3.0	–	350	3.0	–
Urban Type B	19.0	2.8	–	300	3.0	–
Urban Type D	22.0	3.3	–	400	3.0	–

Derailment Avoidance

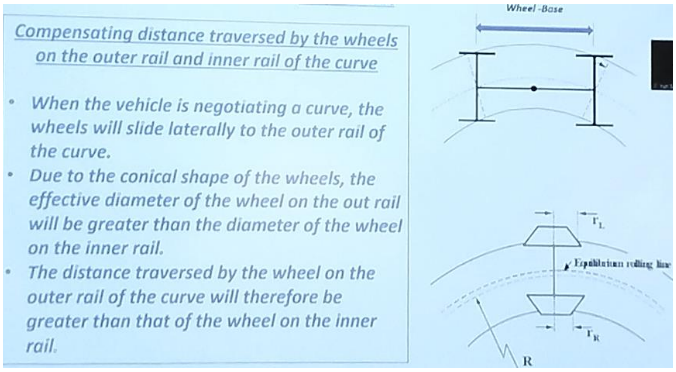




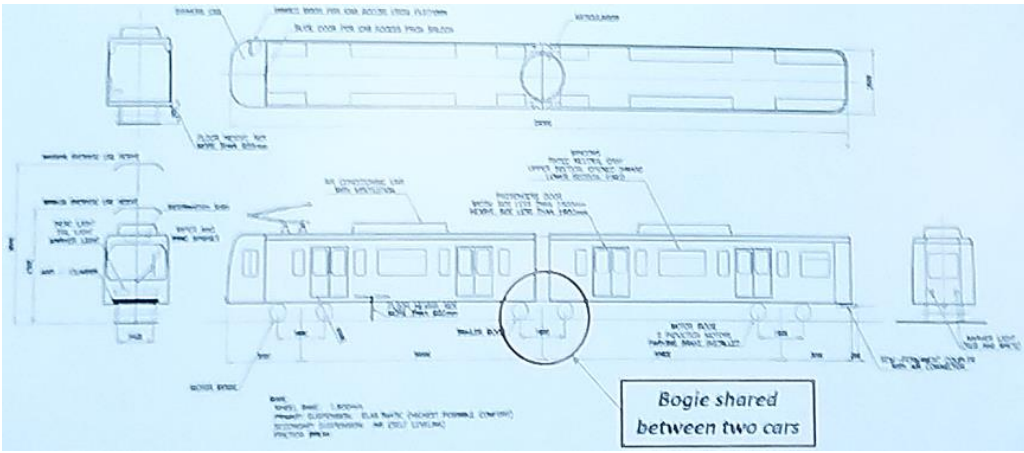


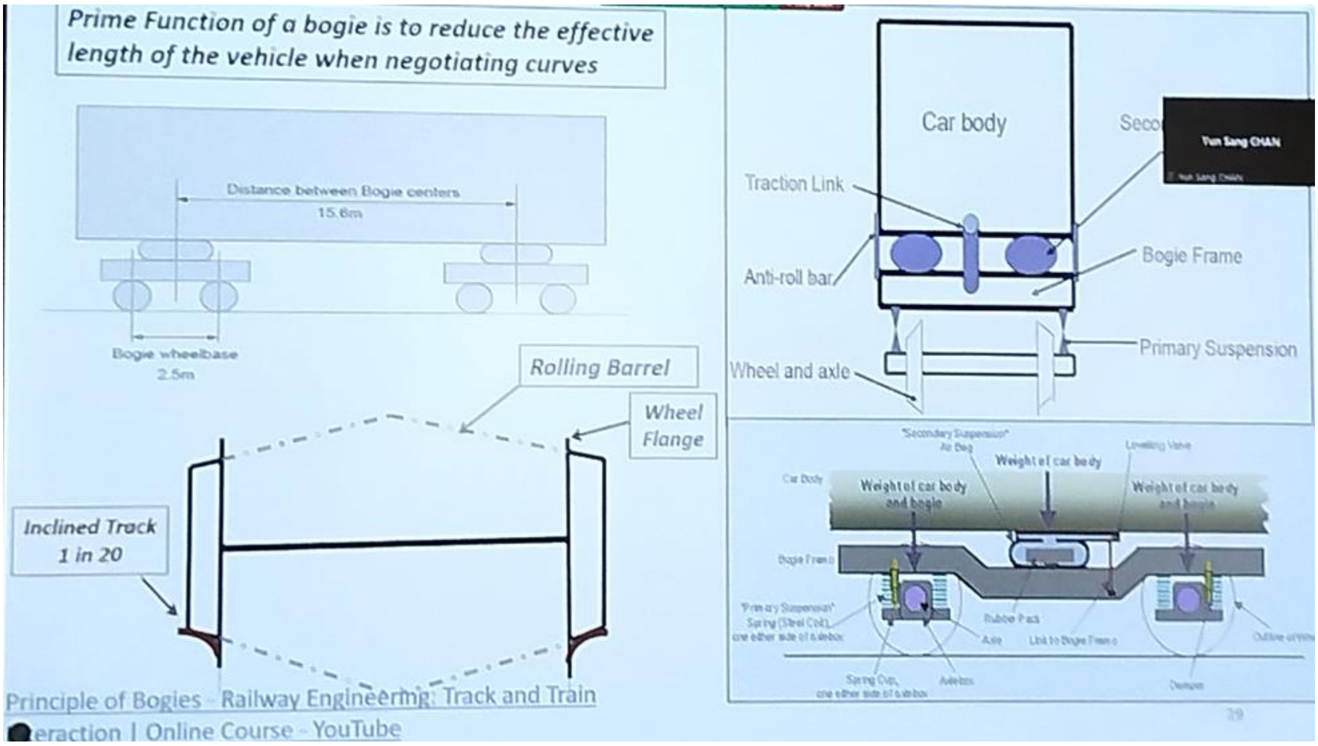
Decrease the Curve radius passing requirements

Cone as wheel: https://www.youtube.com/watch?v=vkzgcJGdUnA



Articulated bogie



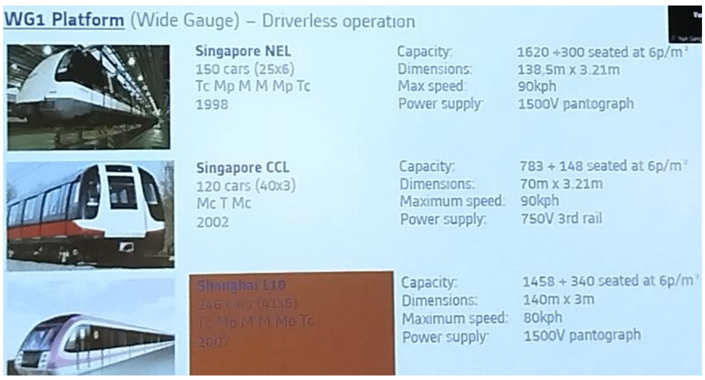


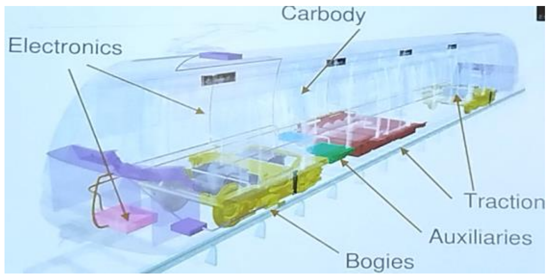
Product Platforms for Metro Trains

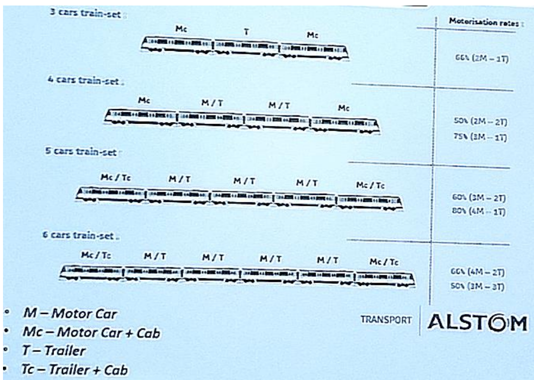
Custom-designed: Design and manufacture for specific order, expersive, long delivery time 4~5 years

Standard product platforms: modular metro trains (configurable), minor customization possible, extensive use of standard components, design process shortened, much cheaper, 2~3 years of delivery time, more secure after sale tech support by vendor.

- Metropolis™ principle (popular in Australia and mainland china, 10k+ used worldwide)



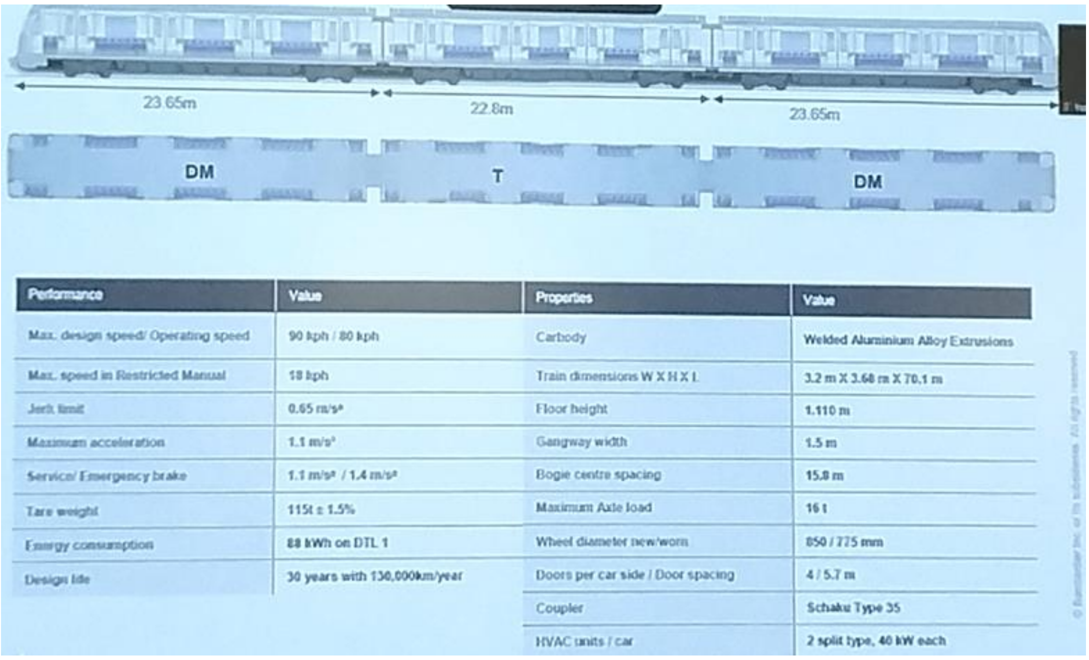




Width*	to 3.2 m
Length*	From 18 to 24 m
Number of doors per side	3 to 5
Passenger capacity (6p/m²)	Up to over 300 passengers per car
Seating arrangements	Longitudinal, Transversal, Mixed
Bogies max axle loads	14,5 t /17 t
Bogies max axle loads	80 km/h to 100 km/h
Supply voltage	750V_{DC}, 1500V_{DC}, 3000V_{DC}, 25kVac
Carbody material	Aluminium or Stainless steel
Power supply	By catenary or 3rd rail
HVAC	Roof integrated HVAC
Track gauge	1435 mm, 1600 mm

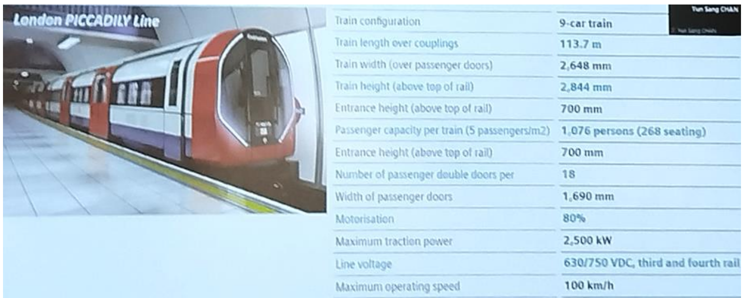
- Xtrapolis Trains (suburb-city commuting, station dwell time more relaxed, 100~160km/h)

- Bombardier MOVIA

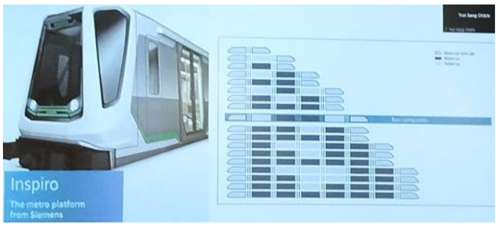


Performance	Value	Properties	Value
Max. design speed/ Operating speed	90 kph / 80 kph	Carbody	Welded Aluminium Alloy Extrusions
Max. speed in Restricted Manual	18 kph	Train dimensions W X H X L	3.2 m X 3.68 m X 70.1 m
Jerk limit	0.65 m/s³	Floor height	1.110 m
Maximum acceleration	1.1 m/s²	Gangway width	1.5 m
Service/ Emergency brake	1.1 m/s² / 1.4 m/s²	Bogie centre spacing	15.8 m
Tare weight	115t ± 1.5%	Maximum Axle load	16 t
Energy consumption	88 kWh on DTL 1	Wheel diameter new/worn	850 / 775 mm
Design life	30 years with 130,000km/year	Doors per car side / Door spacing	4 / 5.7 m
		Coupler	Schaku Type 35
		HVAC units / car	2 split type, 40 kW each

- Siemenes Inspiro metro trains



Train configuration	9-car train
Train length over couplings	113.7 m
Train width (over passenger doors)	2,648 mm
Train height (above top of rail)	2,844 mm
Entrance height (above top of rail)	700 mm
Passenger capacity per train (5 passengers/m2)	1,076 persons (268 seating)
Entrance height (above top of rail)	700 mm
Number of passenger double doors per	18
Width of passenger doors	1,690 mm
Motorisation	80%
Maximum traction power	2,500 kW
Line voltage	630/750 VDC, third and fourth rail
Maximum operating speed	100 km/h



- CRRC (60% rolling stock market share globally, totally dominated in mainland China, more advanced tech and equipment)

Overview of Rolling Stock and Emerging Tech

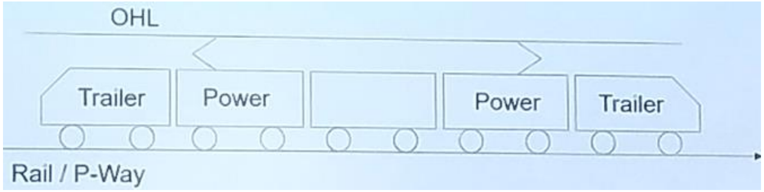
Rolling stock in MTR: Passenger trains (Electric Multiple Unit EMU), Locomotives, wagons (flat/high platform, well), Special purpose and engineering ehicles (Ultrasonic Testing Vehicle, Rail Grinding Unit, Track Geometry and Overhead Line Inspection Vehicle, Temper Machine, etc.)

Centralized Tractive Effort vs Distributed Tractive Effort:

Centralized~ (e.g., locomotive + wagon/coach): simpler and cheaper, less noise, less maintenance cost

Distributed~ (e.g., EMU/DMU): Better energy efficiency, Better control but complex, more expensive. Lighter axle load -> less rail wear. Suitable for frequent start-stop operation (such as metro).

EMU



Cab car (trailer car) non-power: evenly distributed of weight, power car vs wheel wear affect signalling system positioning (wheel odometer will be negatively affected on powered car, or creeping 糯动)

Power Supply AC 25kV 50Hz single phase (regional or sub-urban), DC 1500V/750V (for metro or light rail) or 600V (for tramway).

AC: Less transmission loss, require larger clearance due to high voltage level, neutral zone issue

DC: larger transmission loss, fully connected network for energy harvest

In MTR, 1500 DC is used for URL for high power transmission efficiency, 750 DC is used for LRT for safety as overhead line is closer to passengers. 25kV used for EAL. Construction cost constrains the voltage used.

Power supply system: overhead line (up to 1500DC and 25 kV AC, more space required, complex, higher install cost, flexible), or 3rd rail (normally low voltage DC for safety, need to prevent electric shock hazard, limited space, simpler, cheaper installation cost, power loss and speed limit exist).



Catenary Wire (接触网线): use contact wire to transmit power to pantograph, size of the contact wire restrict the amount of current flow, bad tolerance of train vibration, double contact wire will be used if necessary.

Conductor Rail: A solid conductor for transmitting power to pantograph, relieved restriction on current flow, minimized risk for breakage of contact wire, high installation cost.

<u>Rolling stock</u>

Structure:

Carbody material: aluminum alloy (lighter), stainless steel (cheaper)

Tare weight (皮重): max axle loading requirement

Load cases (载荷工况): proof and fatigue

Coupler (for connecting two cars/units):

Automatic coupler: mechanical connection between units, capable of gathering, engaging and coupling on a combined horizontal reverse curve and vertical curve

Gangway: Provided between coupled vehicles (except the driving cabs), complete weather/draughtproof, coupler compatible, compiled with the emergency evacuation

Brake:

Pneumatic brake (气动制动器) : brake by pneumatic actuator acting on wheel, auto adjust to compensate the brake block/pad and wheel wear

Parking brake (驻车制动器): hold the train consist at designed loading condition, force on individual axles (not to lock the axle)

Pantograph: collect electrical power from the overhead line

Bogie and suspension:

Support carbody firmly and provide suspension (absorbing vibration) to the carbody, increase curve tolerance

Minimize derailment risk, minimize track forces (when train runs on curves at high speed), minimize generation of track corrugation and wheel flange / rail side wear.

Door: Pneumatic drive and electric drive, equipped with egress feature and emergency door arrangement

Propulsion and Vehicle Control: To propel the train at a controlled manner, ensure all safety interlocks are properly met before the train can have power to move, provide sufficient propulsion under different load

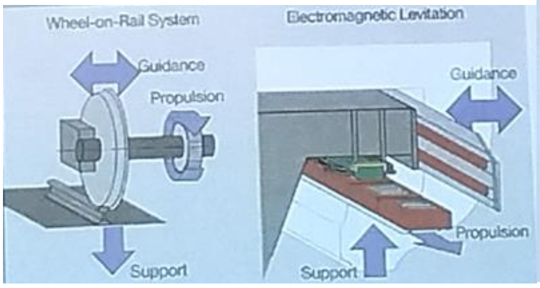
Auxiliary supply: SIV to provide 3-phase ac output, Battery charger to provide 110V DC to charge stand-by battery for 110V control circuitry.

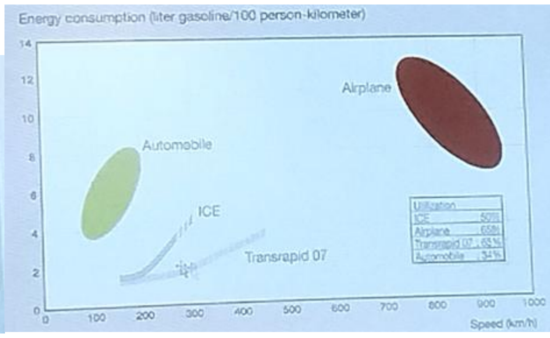
PA, Radio & Communications

New types of rolling stock

Low floor level light rail (no platform, level 300~400mm, track curve low to 20~50m, total train length 20~35m, speed normally 40km/h, axle load normally 10~12 kN)

Maglev (sectionalize to reduce high power consumption due to polarity switching, yet more efficient than plane)

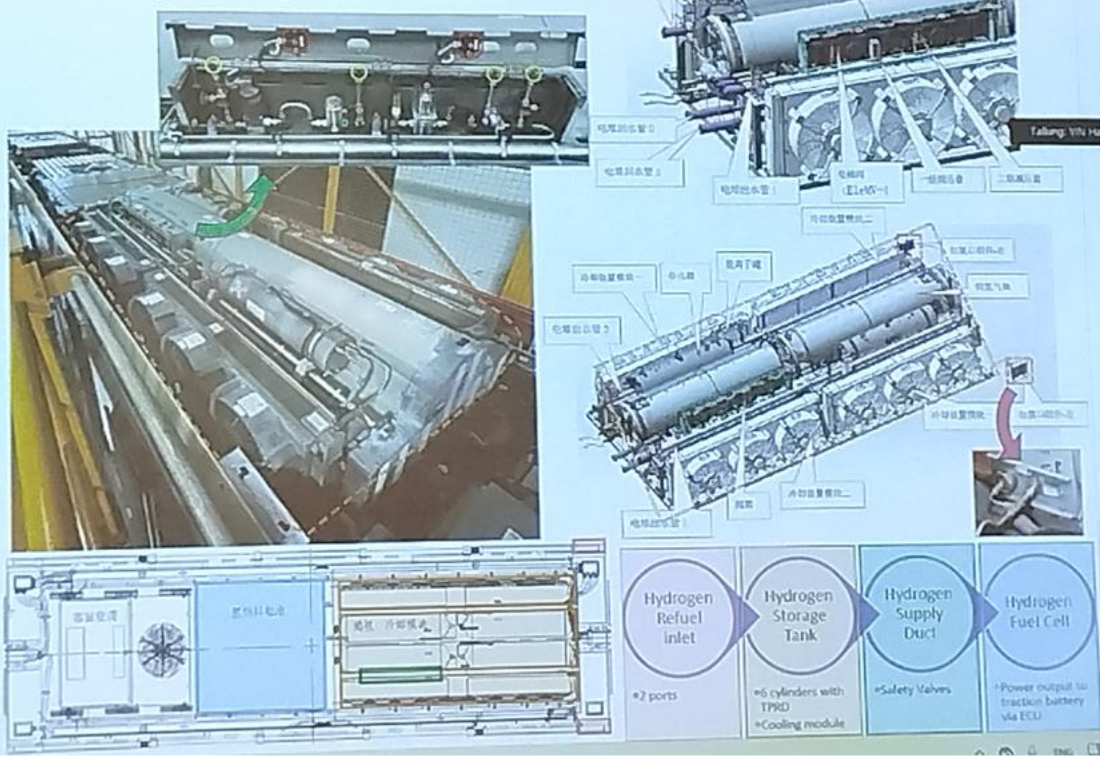




Hydrogen power

MTR Hydrogen LRV

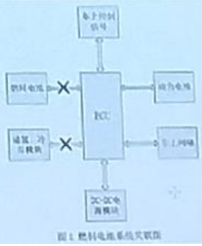
Hydrogen System



Hydrogen leakage alarm system

Category		Level 1 Alarm	Level 2 Alarm	Level 3 Alarm	Triggering Criteria
Hydrogen Leakage		0.6%	1.2%	2.0%	Any 1 of 11 Hydrogen leakage detectors
Over temperature		60°C	80°C	85°C	Any 1 of 6 Thermal sensors If the temp over 105°C → Auto release H2 gas … cylinder via Thermal pressure relief device (TPRD)
Over Pressure (H2 tank)		38.5 MPa	43.75 MPa	45 MPa	Any 1 of 6 High pressure sensors at H2 cylinder cap → Auto release H2 gas inside the cylinder via Thermal pressure relief device (TPRD)
Over Pressure (H2 supply duct)		1.2 MPa	1.25 MPa	1.3 MPa	Low pressure sensor along H2 supply duct → Auto release H2 gas along supply duct via Thermal pressure relief device (TPRD)
Overflow		Shut off fuel cell (degraded mode)			Depends on flow pressure setting at each valves
Auto-Protection Mechanism	*H2 Tank*	Nil	Stop outflow to supply duct	Stop outflow to supply duct	Coordinated protection system by energy control unit (ECU)
	H2 Supply duct		Shut off the EM valve to supply the fuel cell system	Shut off the EM valve to supply the fuel cell system	
	H2 Fuel Cell		Shut off the FC system	Emergency Shut off the FC system	
Train Condition		Normal	Traction battery power only. No Degradation. No change to max speed		
TCap/DSO action		Self-reset successfully → Nil Alarm persist → Evacuate			

1. All protection valves are automatic; no manual valve actuations are needed under the safety control.
2. With 24V power, Hydrogen detectors, ECU, and TCMS are working.
3. Status of Valves (except Manual valves) will be displayed on TCMS



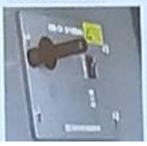
22/2/2024

MTR Corporation

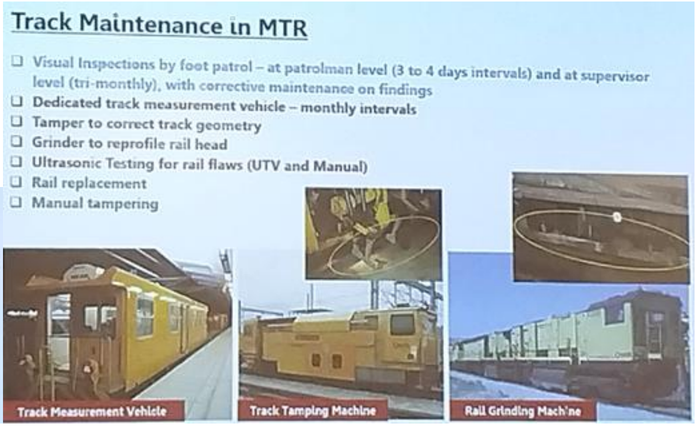
TCMS Display

Hydrogen Leakage Demo Video

Alarm buzzer

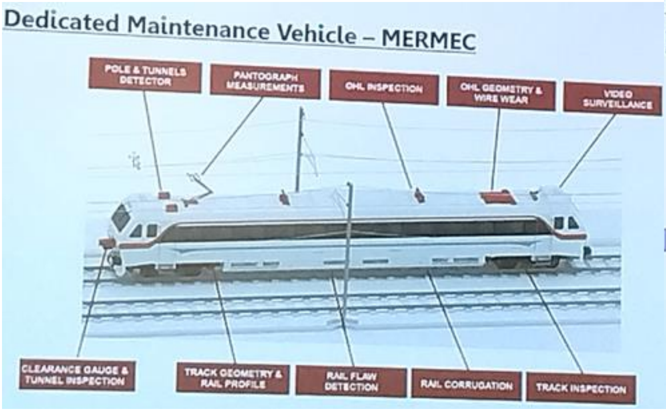


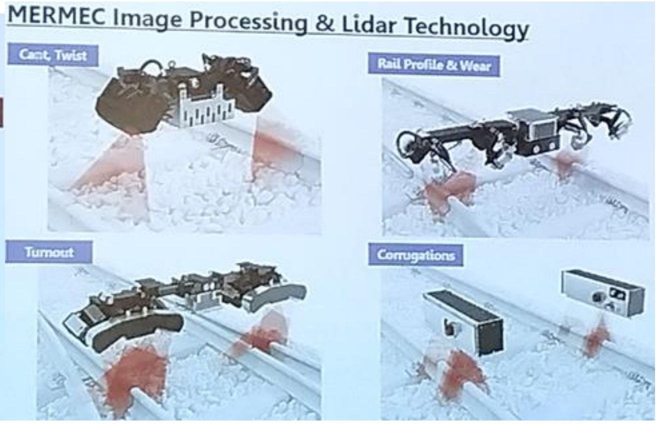
Themes of new technologies: speed, comfort (incl. noise), energy efficiency, construction/maintenance cost



Emerging Technology

- With the advancement of technology, the Railway world is subject to have big changes. This includes
  - Railway vehicles with using alternative energy
  - Equipment/measuring tools that enable continuous monitoring
  - Equipment that enhances maintenance, and etc.





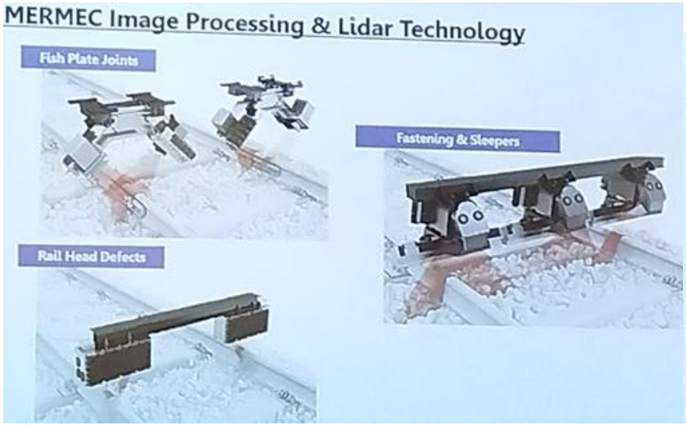


Image Processing & Dimensional Measurement Technology

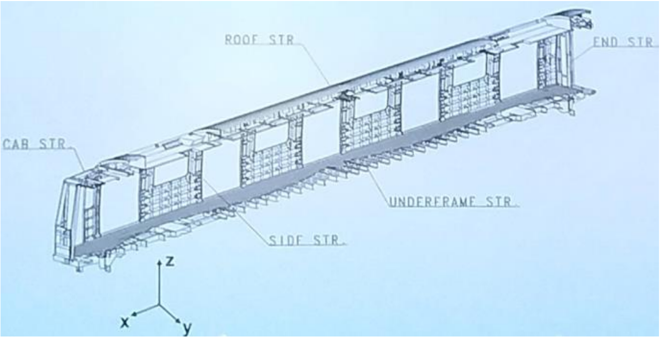
- Lidar technology –
  - Well proven for track geometry, rail wear and rail profile applications
  - Poor performance of image processing technology on identification of track defects due to:
    - Exceedingly large memory is required
    - Complex image benchmarking process (actual versus baseline)
    - Contamination of rail surface and other track components
    - Very high nuisance rate
- On Board Railway Inspection System (ORIS) deployed in South Island Line (East)
- Alstom Health Hub System in Sydney Metro Northwest

Overhead line Condition Monitoring System

- Measuring equipment equipped on the train roof of a passenger train
- Mainly high-speed camera to obtain footage and photos for monitoring and measurement.
- Computer system installed in the cabinet of train compartment

Vehicle Structure

General



Material: carbon steel (have the problem of volatile to humid climate, deform in repair), stainless steel (corrosion), aluminum alloy, composite materials

Method of construction: welding, riveting

Evaluation matrix: cost, weight, manufacturing technologies

Key requirement

Not exceeding max permitted tare train weight, such as 310 t for a 8 car train

Not exceeding max axle loading requirements, such as 17 t per axle

Weight management from design to manufacture, such as for passenger train assuming 60 kg per person

Weight tests in testing and commissioning

Strength requirements: proof loads (specified loading conditions without permanent deformation or any form of damage or deterioration, in most extreme case), fatigue loads, collision and energy absorption (such as ref design codes: GM/RT2100, BS EN 12663)

Proof load (specified loading conditions without permanent deformation or any form of damage or deterioration):

Carbody End Loads (compressive load & tensile load at coupler for, compressive load at window sill and cant rail for)

Traction and Breaking loads

Passenger load, lifting and jacking load (for transporting the train to the rail company)

Twist load (such as rescue in the event of derailment)

Fatigue load (withstand the defined fatigue loads using the specified fatigue assessment methods)

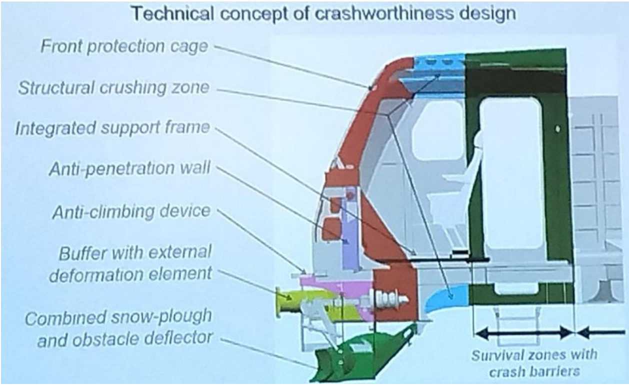
Load cases: vertical, lateral, longitudinal, (roll, pitch, yaw), passenger loading / unloading

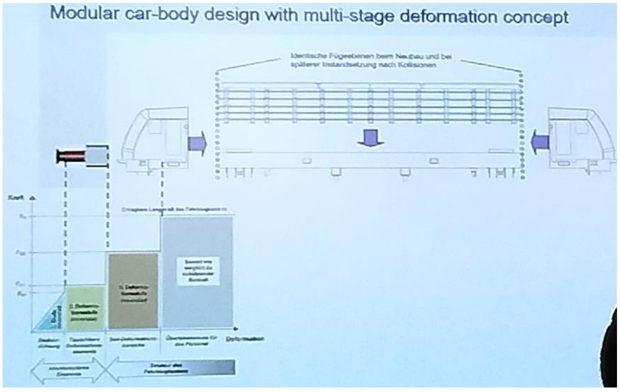
Collision and Energy Absorption:

Prevent damage in collision, by the couplers and anti-climbers by means of plastic collision

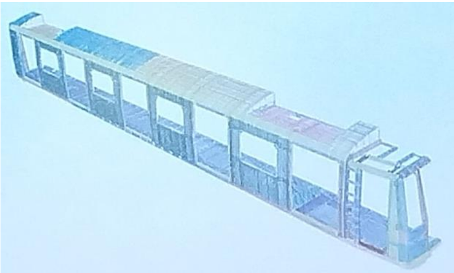
Withstand defined train collision scenarios without causing damage to the car structure (such as: an 22.5km/h 8-car train in tare condition collides with a similar train with parking brakes applied)

Expected deformation not reach defined survival zones (with crash barriers)

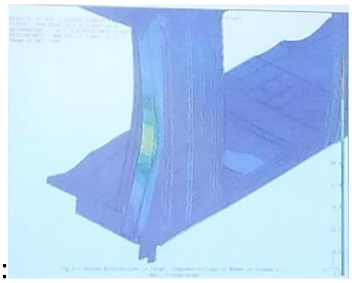




Finite Element Model: used for structural analysis to verify the overall strength of vehicle body



Finite element analysis typical result:



Normally high-stress parts: bolster, corners

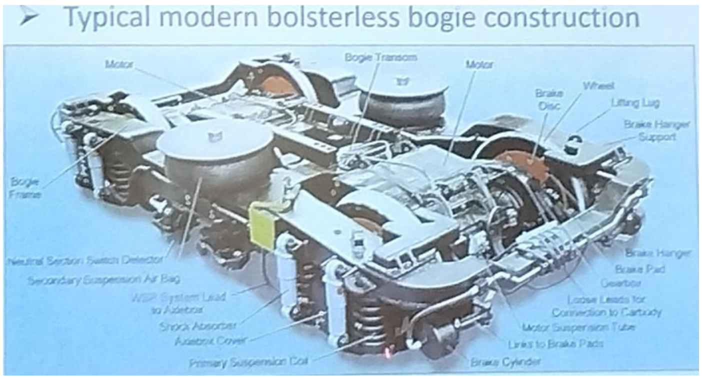
Model Simplification: symmetrical train => consider only half of the train in longitudinal direction

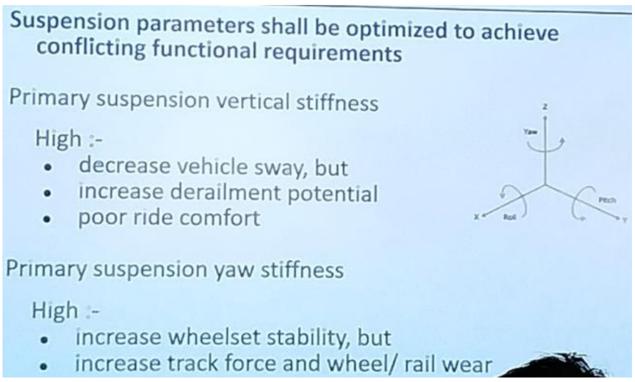
Boundary conditions: Application of constraints

Element Type, size

Vehicle Dynamics

Bogies and Suspension: Support vehicle carbody, maintain vehicle sway within specific gauge outline, run stablu on straight and curved track, ensure good ride comfort by absorbing vibration generated by track irregularities, minimize derailment potential at curve transitions, minimize track force when train runs on curves at high speed, minimize generation of track corrugation and wheel flange/rail side wear.

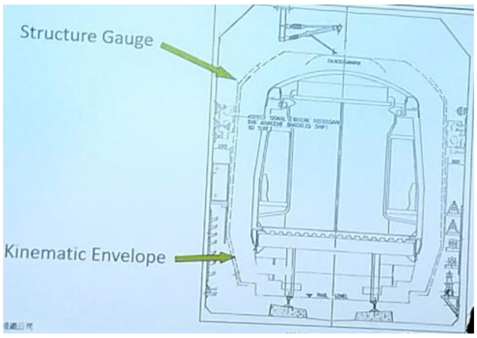


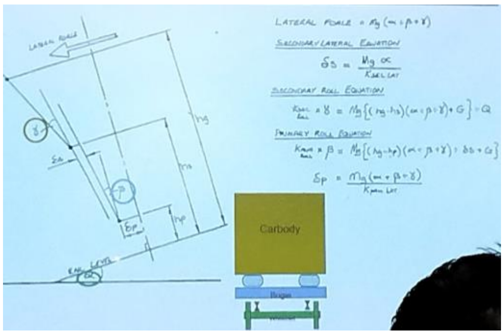


Gauging

Structure gauge: a line around the track within which no structure or trackside equipment should be placed.

Kinematic Envelope: the envelope of body profile plus sway movement





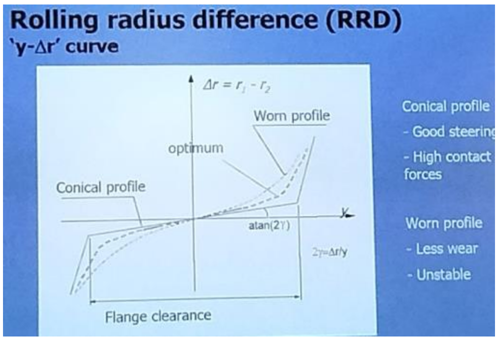
Structure gauge assessment is needed

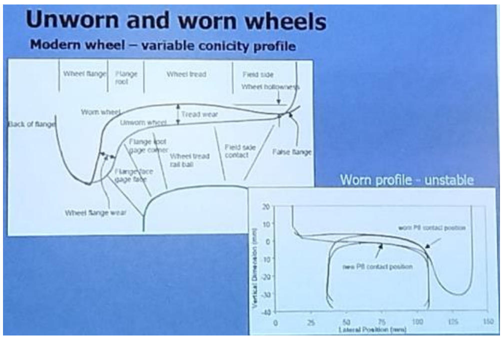
The amount of space required for the safe passage of a railwau vehicle is significantly geater than its static body profile. (such as track input, track movement over the maintenance cycles, component deterioration, wear, curve overthrows, external forces such as winds in open sections)

Conditions for Kinematics Envelope (KE): train speed, wheel wear and suspension creep, vehicle curving and lateral accelerations (combined effect), air suspension (inflated or deflated), car loadings, max car build tolerances, force of side wind, suspension parameters at the worst case, track parameters plus tolerances, max installed cant

Stability

Wheel-rail guidance: conical wheel





Shall be designed to be dynamically stable under all operating conditions including: all speed range, new and worn wheel profile with different conically range

Vehicle becomes unstable at some sufficiently high speed or at high conicity (loads to a continuous oscillation)

Improvement by wheel or rail profile optim or by suspension modification

Ride comfort

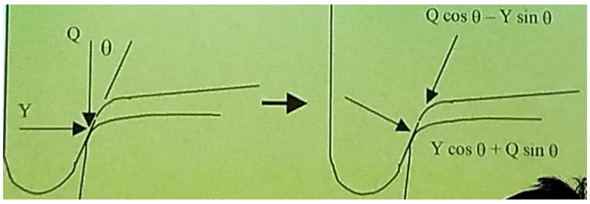
EMU ride performance level weighted with the vehicle ride acceleration

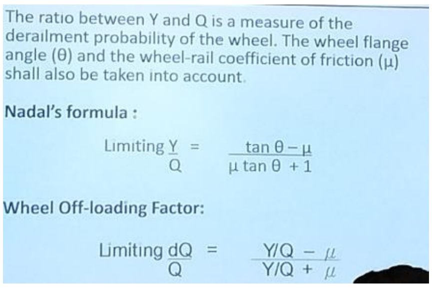
Vertical journey avg <= 0.010g, lateral journey avg <= 0.013g, Longitudinal journey ang <= 0.004g, Vertical 99% <= 0.020g, Lateral 99% <= 0.026g

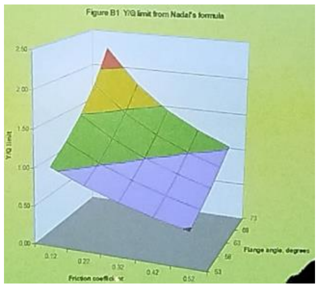
Journey average = arithmetic mean of the weighted r.m.s. accelerations evaluated at 10s intervals over the full length of the running lines. Shall only be measured when travelling at the min speed such as 25 km/h.

Wheel off-loading (flange climbing derailment): wheel climb up the gauge corner of the rail until the flange tip is rolling on the rail head

Factors Y: lateral force on the wheel pushing it into flange contact with the rail, and Q: vertical load to move the wheel down the gauge face of the rail







For a typical wheel profile with 68∘ flange angle and 0.32 friction: Y/Q limit = 1.20, dQ/Q limit = 0.60

Bogies rotational resistance (X-factor): measurement of the resistance to the rotation of the bogie under the vehicle

X = T / (W * 2a), where T = torque to rotate the bogie, W = average axle load on the bogie rotated, a = bogie semi-wheel base

To avoid excessive torques at the minimum radius curve, X-factor shall not exceed 0.1.

Overturning: requirement: min wheel loads shall always > 0 (no complete wheel-offloading)

EMU Electrical System

<u>General Config of EMU</u>

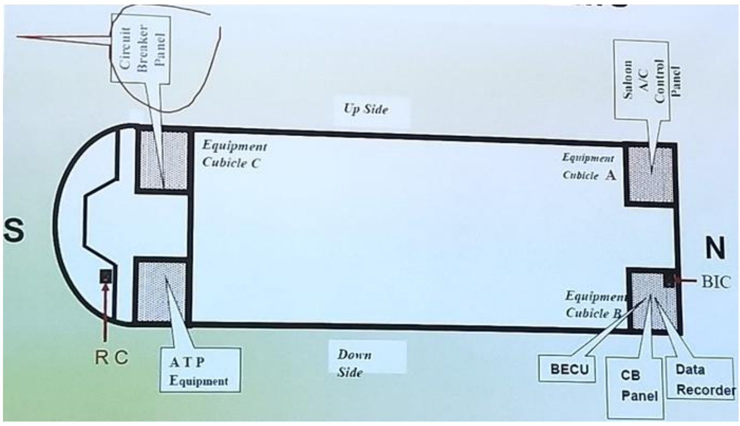
Typical example: C-train on URL

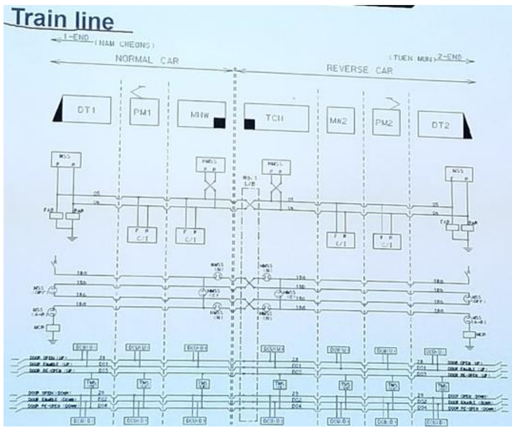
8 car train = 3 units (A-C-B – B1-C1 – B-C-A)

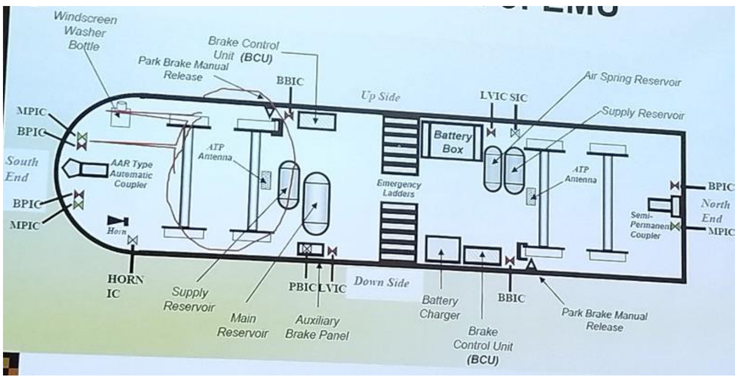
A Trailer car with cab

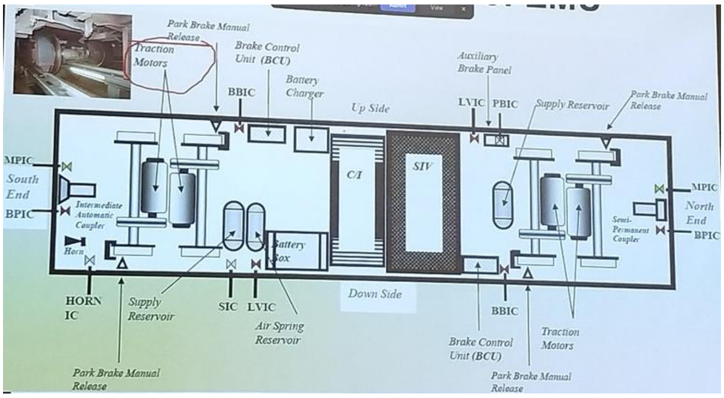
B / B1 motor car

C with air compressor & pantograph, (C1 + hostler cab)

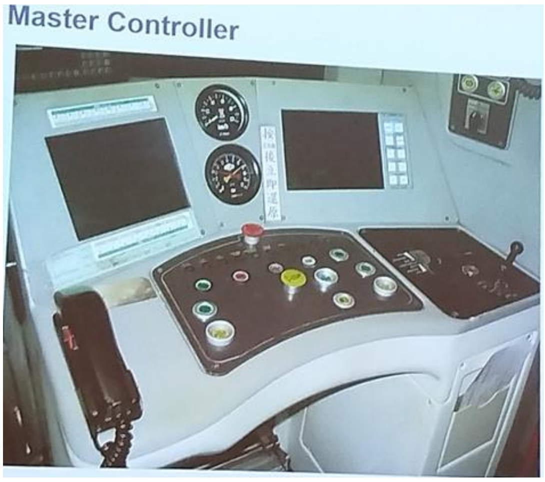


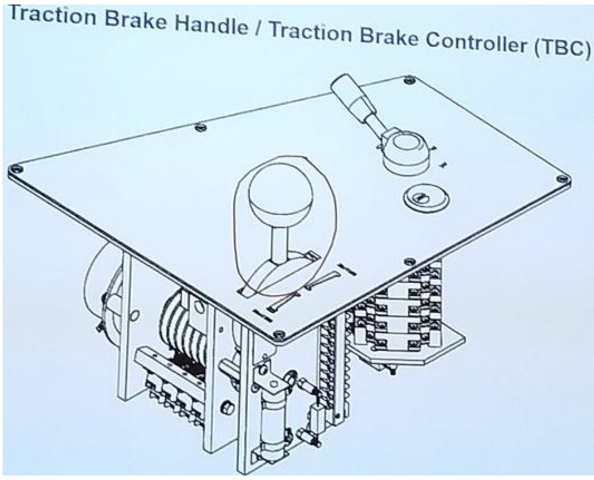


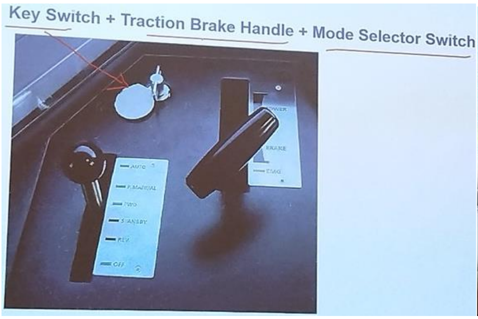


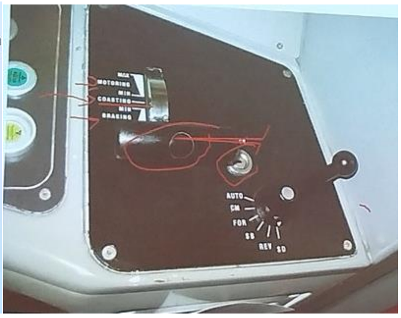


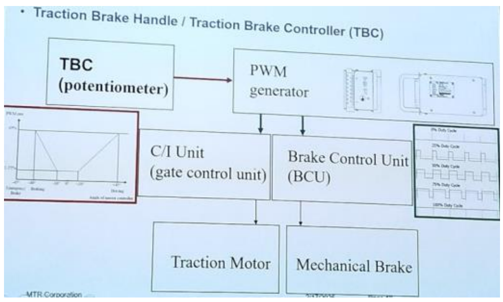
Vehicle Operation Control System and Modes











Operation Principle:

Insert and rotate driver’s key to release the locking from the mode selector

Driver’s key cannot be removed when the mode selector moved away

Press down TBC/Deadman Switch

Modes

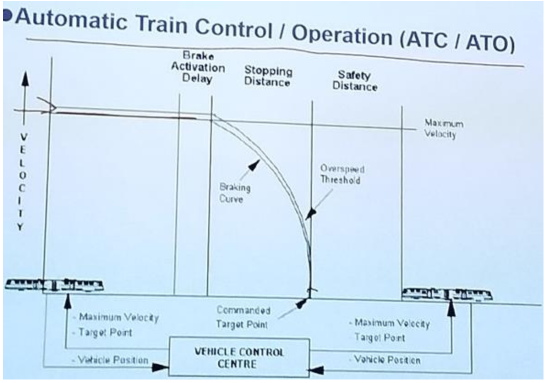
Shut down: Only mode not requiring a key, emergency/parking brake applied, no control on traction & brake & passenger doors, only aux power control & minimum control and facilities available

Standby Mode: Key required, brake may be released, no control & traction & brake, control of door & comm available

Restricted Manual (RM) Mode: brake control amiable for traction & drive, fixed speed limit for driving in “Line of Sight Driving”

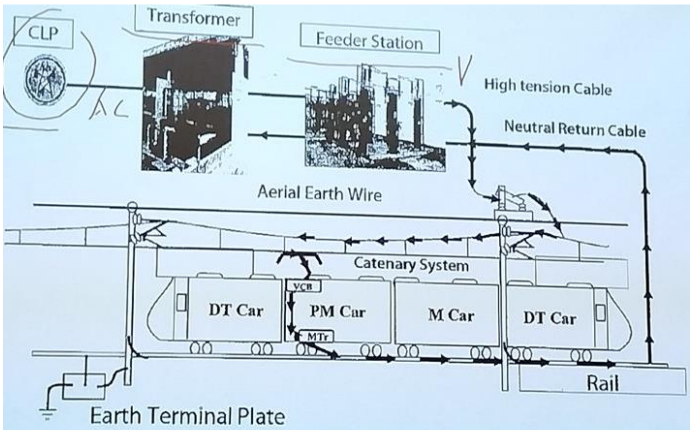
Coded Manual Mode: Speed Limit varies according to ATP system, not "Line of Sight Driving", normally used as a degraded recovery mode for Auto Mode.

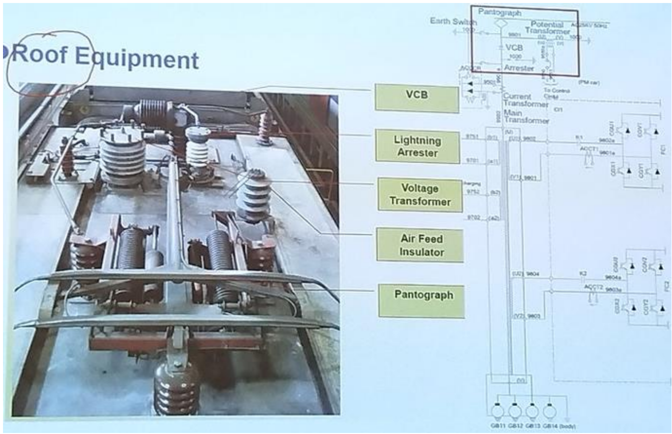
Auto Mode: Auto traction and brake control



Other modes: wash mode (for passing through wash plant), get home mode (for moving a failed train to siding / depot), high speed RM mode, Constant slow speed mode (similar to cruise control on automobiles)

Electrical Power System

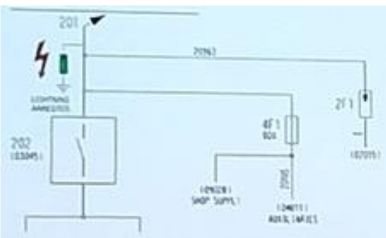


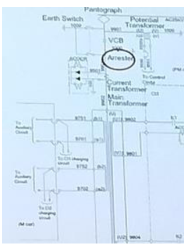


Pantograph: 3 units: PM1, PM2, PMH car. Operated by (main / auxiliary) compressed air

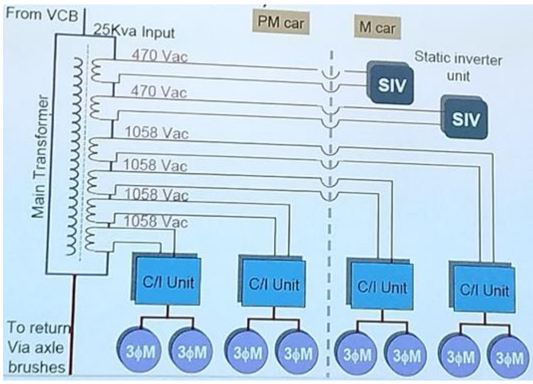
VCB (Vehicle circuit breaker) opens if: loss of air pressure in the VCB, primary or secondary overload, when train enter a neutral section, when PDPB or ATPB (aux trip PB) is pressed, tripping of VCB, earth fault detected in power cable, traction motor overload, control air pressure is reduced, APC (auto power control) fails

Surge arrestor (or lightning arrestor 避雷器): to protect the downstream equipment against external event, e.g., lightning, arrestor counter is installed for monitoring the remaining life time.

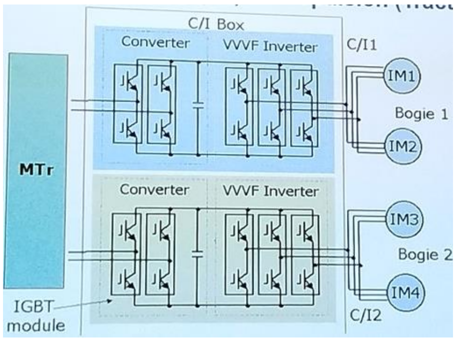




Main Transformer (MTr): step down 25kV AC to different voltage levels (470Vac, 1058Vac), and safeguard electrical system.



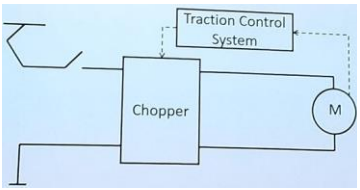
Converter/Inverter (CI) unit in propulsion (traction) system: To drive traction motor

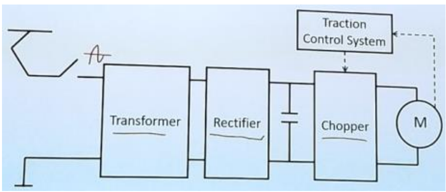


use back/forward PWM and IGBT (power-switching element, capable of turning on/off by controlling gate drive, enables the four control modes of powering/regeneration and forward/reverse) to Traction Break Controller (TBC).

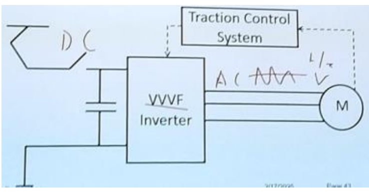
IGBT: 

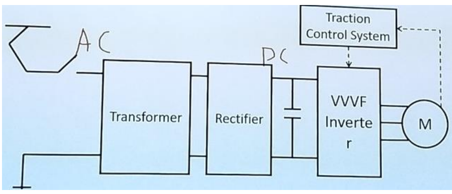
DC traction system: DC – DC (DC power supply -> Chopper -> DC traction motor, e.g., M-train in URL), AC – DC traction system (AC power supply -> Rectify -> Chopper -> DC traction motor, e.g., MLR train in EAL)

DC – DC: 

AC – DC: 

AC traction system: DC – AC (DC power supply -> VVVF inverter -> AC traction motor, e.g., Lantau Line train, K-train in URL), AC – DC – AC (AC power supply -> Rectify -> VVVF inverter -> AC traction motor, for precise control to ensure smooth de/acceleration, e.g., SP1900/1950 in TML)

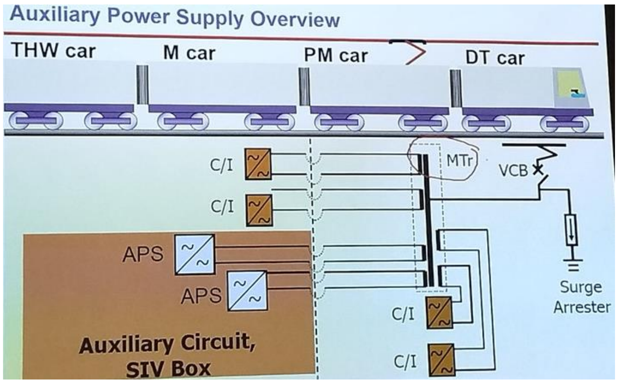
DC – AC: 

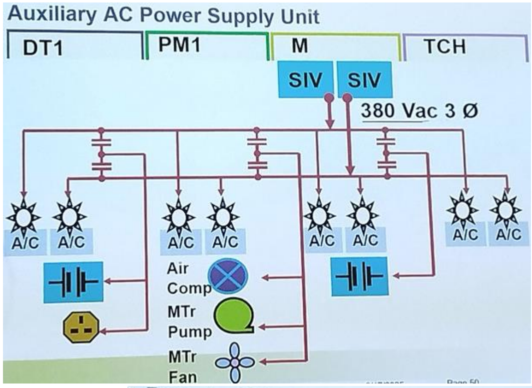
AC – DC – AC: 

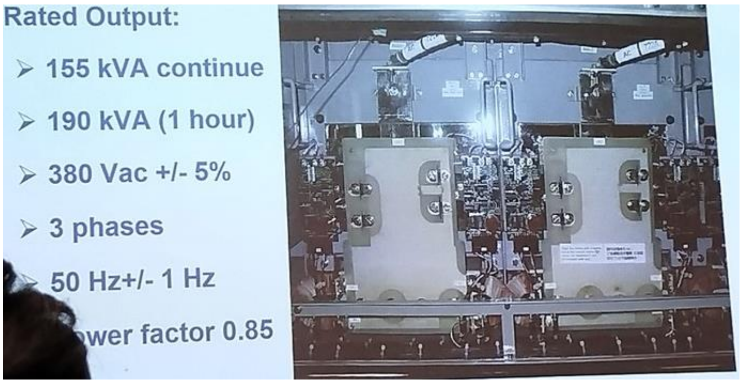
Function: Powering control (acceleration), regenerative braking control (deceleration), wheel slip/slide and adhesion control (wheel burn can occur when ωr ≠ v)

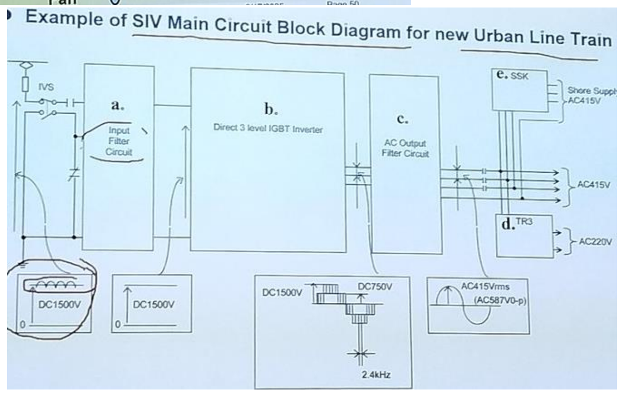
Propulsion system: youtu.be/Um6JdFr_Gbo, C/I Unit youtu.be/Z8sHKKkAG1s

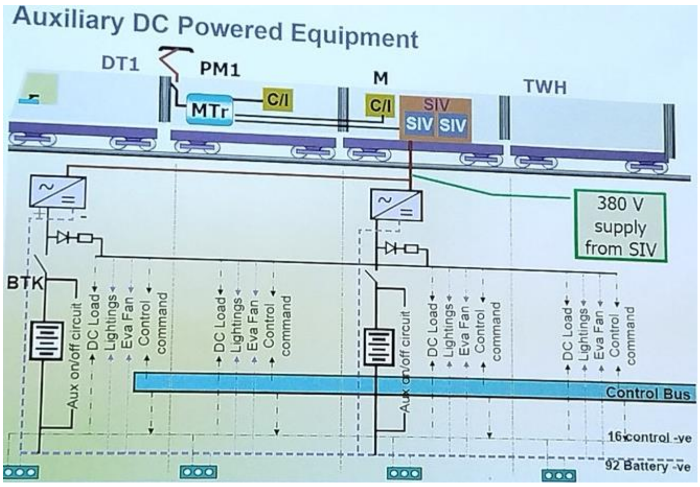
Static Inverter (SIV) System











Supplies aux AC power for the train consist and battery charger (DC power). MTr -> SIV -> 3-phase AC feeder line

2 units (SIV no. 1 and no.2) in one SIV module to supply low voltage AC to each feeder line (no.1 and no.2)

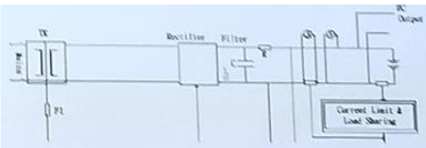
SIV consist of Input filter circuit, IGBT converter/inverter (to rectify AC input voltage to e.g. 380Vac 50Hz 3-phase constant freq/voltage), AC output filter circuit

Input filter circuit reduce the rectifired ripple from DC line voltage and reduces harmonic currents from the power supply inverter circuit entering the overhead line.

The IGBT power supply inverter converts line voltage to square wave alternating voltage and stabilize the SIV output voltage using PWM control

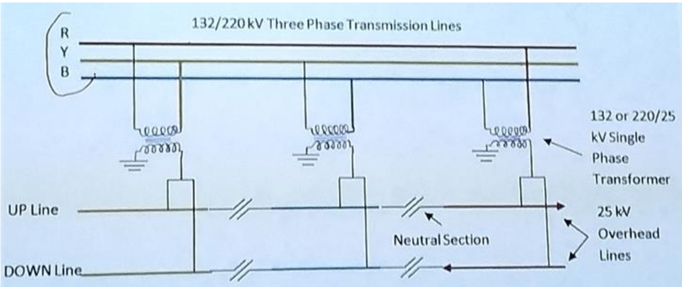
The AC output filter provides galvanic isolation (电流隔离) from line voltage by use of a step-down transformer and reduces the switching ripple and harmonics

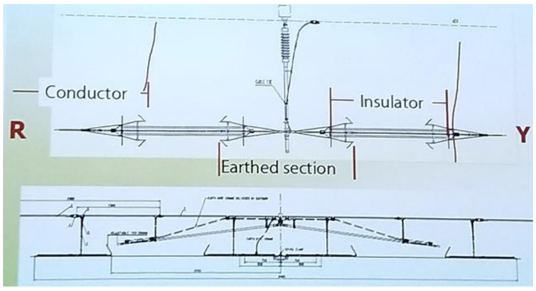
Aux power: battery charger is connected to a single-phase AC main supply and produces DC voltage suitable to charge the battery and power the load. Output voltage of the rectifier is held at a constant voltage. Output/charging current is limited to avoid overload.



https://www.youtube.com/watch?v=zMpMNnZXxYQ

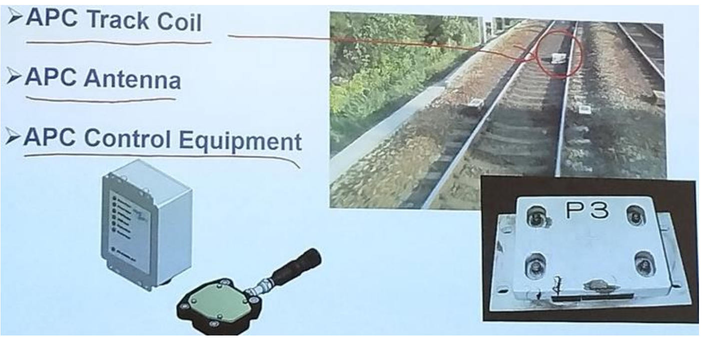
Automatics Power Control (APC)

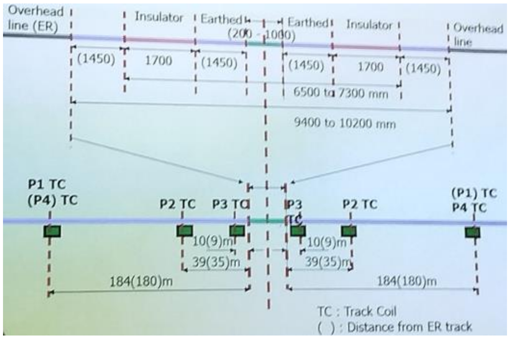




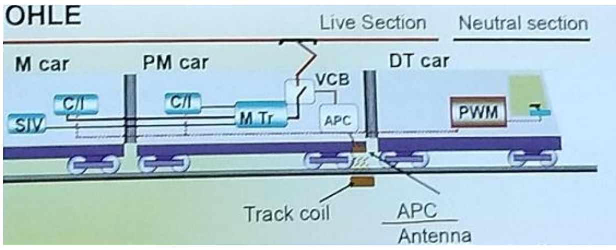
Neutral zone: between conductor and insulator section, to separate different phases. Train must pass through neutral zone by momentum. Pantograph must disconnect from overhead line to avoid fresh over.

APC System main equipment: track coil (info tag, use RFID), APC antenna, APC control equipment





APC System: Detects the approaching of neutral section. Switches VCB off/on while train entering and out from the neutral section, and transmit such info to propulsion control equipment (SIV and TMS)



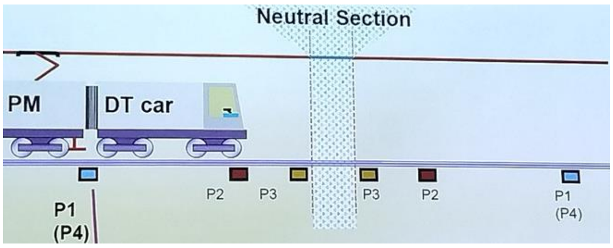
Track Coil P1 (Before entering Neutral zone): backup control when one APC equipment in the train fails

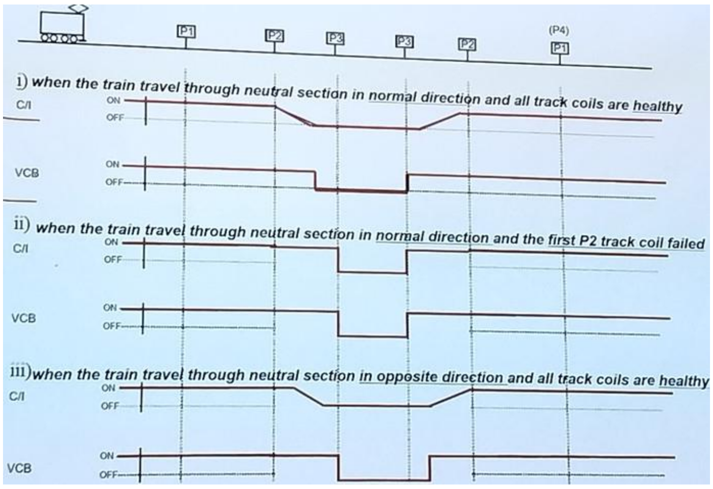
Track Coil P2 (Before entering Neutral zone): Decreases motor current. After that, the propulsion equipment opens the VCB, Simultaneously the SIV is switched off.

Track Coil P3 (Before entering Neutral zone): Direct VCB off control. APC opens the VCB immediately if VCB is not opened by propulsion system while APC detect this track coil signal.

Track Coil P3 (After Neutral zone): For VCB re-closing control by APC. APC passes info to propulsion system to gradually increase the motor current after detection of line voltage.

Track Coil P2 (After Neutral zone): Backup control when APC equipment fails.





<u>Vehicle Control Circuit</u>

<u>Train Management system</u>

<u>Passenger information system</u>