Sydney Metro – Australia’s first fully-automated rolling stock

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SUMMARY

Sydney Metro is Australia’s largest public transport project. This new stand-alone fully-automated railway is being delivered in two stages:-

- Sydney Metro Northwest – formerly the 36km North West Rail Link. This project is approximately half complete and will open in 2019 with a metro train every four minutes in the peak. Once commissioned, the Sydney Metro operator, Metro Trains Sydney (MTS) will be responsible for the operation and maintenance of the railway for 15 years.

- Sydney Metro City & Southwest – a new 30km metro line extending from Sydney Metro Northwest at Chatswood, under Sydney Harbour, through the CBD and south west to Bankstown with a possible extension to Liverpool. This stage is due to open in 2024 with the capacity to run a metro train every two minutes each way under the centre of Sydney.

This paper examines the technology to be used on the system that has been successfully implemented around the world, but new to Australia. In particular, this paper looks at the fully automated rolling stock and associated systems to be used in the Sydney Metro Northwest along with provisions for the City & Southwest augmentation.

The associated systems provide a fully integrated project such as :-

- Platform screen doors;
- Communication Based Train Control (CBTC) Signalling system; and,
- Maintenance systems, including maintenance facility and engineering vehicles.

The paper then provides a brief discussion on the testing, commissioning and operational readiness required prior to services commencing.

31 METRO STATIONS

![Figure 1: Sydney Metro Alignment](sydney metro info 1000 by 750)
1. INTRODUCTION & BACKGROUND

Sydney Metro will connect Sydney’s global economic corridor with high growth employment and residential centres as well as providing high quality intermodal connections.

The scope of the project includes:

- Provision of high quality, proven systems including new automated, single-deck trains and platform screen doors capable of achieving and maintaining international benchmarks for reliability, availability and maintainability;
- Conversion and systems upgrade of the existing 13 kilometre Epping to Chatswood railway line;
- Delivery of 23 kilometres of new “greenfield” double track railway, including 15 kilometres in twin tunnels and a four kilometre elevated skytrain viaduct;
- Delivery of eight new stations and station precincts, including:
  - three underground stations (Castle Hill, Showground and Norwest);
  - three stations in open cutting (Cherrybrook, Bella Vista and Cudgegong Road);
  - two elevated stations on the skytrain (Kellyville and Rouse Hill);
  - development of precincts surrounding the station.
- Delivery of a Sydney Metro Trains Facility (SMTF) including an Operations Control Centre (OCC) at Tallawong Road;
- Delivery of bus, pedestrian, bicycle, taxi and kiss and ride access facilities at all new stations;
- Delivery of 4,000 commuter car parking spaces in total at Cherrybrook, Showground, Bella Vista, Kellyville and Cudgegong Road stations;
- Delivery of multi-modal transport interchange facilities at all Stations, including major interchanges at Rouse Hill and Castle Hill;
- Delivery of ancillary infrastructure to complement Sydney Metro Northwest, including public domain works and landscaping; and,

- The conversion of the existing heavy rail Epping to Chatswood Rail Link (ECRL) to the metro system. This involves the conversion to the metro signalling system and retrofitting four existing stations with platform edge barrier technology.
- Provision to accommodate future extensions of the new metro system.

2. TRAINS

2.1 Overall description – Alstom Metropolis

Sydney’s new metro train, designed by Alstom in France, is adapted for Sydney but the product is based on the international Metropolis train platform, which is used in 25 cities including metros in Singapore, Barcelona and Amsterdam. The train is designed to UIC, ISO and EN standards. The train will be manufactured and assembled by Alstom in India with sub-systems being procured from across the world.

The train is required to deliver 98 per cent on time running reliability, mandated in the contract with Sydney Metro Northwest operator, Metro Trains Sydney.

![Figure 2: Train Configuration](image1)

![Figure 3: Sydney Metro Train](image2)
automation is to be delivered in Australia. In addition, the trains work hand-in-hand with the Australian-first platform screen door and edge barrier technology being introduced on Sydney Metro. This fail safe interlocking technology keeps people and objects away from tracks and allows trains to get in and out of stations much faster. It also encourages customers getting on and off trains faster, reducing the amount of time trains wait at station and improving service reliability.

2.2 Fire Standards

The trains will be designed and manufactured to the latest European wide fire standards, EN 45545. This set of fire standards has been introduced across Europe for rail operators, manufacturers and suppliers to standardise performance levels of rail cars.

The existing Duggan method (each car which does not exceed an energy release of 10MW) is still applied.

2.3 Carbody

The carbody is made from stainless steel and layout is optimised in order to seek a good balance among various constraints:

- Axle load evenly distributed between axles of the same car;
- Axle load evenly distributed between axles of various cars;
- Underframe equipment layout respecting cooling air circuit;
- Electrical constraints such as minimising distance between battery charger and battery; and,
- Allocated volume and weight for each equipment.

It is intended to use some standard layouts used on previous projects.

Each train-set is fitted with one automatic coupler at each end. Semi-permanent couplers make the links between cars under the interconnecting gangways.

2.4 Traction, Auxiliaries & Braking

The traction converter is a part of the complete traction drive. Its function is to transform DC line current into three-phase Variable Voltage Variable Frequency current for the asynchronous traction motors.

The propulsion system is based on Alstom proprietary propulsion technology OpTONIX. More than 5000 Alstom inverters are in operation all over the world.

Recent projects applications are Shanghai L10, Nanjing L2 and Beijing L6.

The propulsion system incorporates three main elements:

- Inverter using IGBT power modules;
- TCU microprocessor control; and,
- AC motors.

These three components are designed specifically to work together to achieve a drive with maximum efficiency using the properties of each building block to its fullest potential.

Figure 4: Traction Motor

The traction motor is three-phase squirrel cage asynchronous, four-poles and self-ventilated.

Two Motor Cars are equipped with a pantograph providing of current collection from Overhead Catenary 1500 Vdc line.

The train has a maximum design speed of 110km/hr and a maximum operating speed of 100km/hr.

The Auxiliary converter Unit (ACU) is mounted on the under-frame of a TC car. It receives DC supply voltage coming from the pantograph on that car.

Figure 5: Traction case electrical scheme
The Auxiliary converter unit generates the following output voltages:

- 415V 3-phase AC, 50 Hz providing the power to train’s auxiliary systems such as HVAC, compressors, fans;
- 72V DC to charge the train batteries and to supply the TCMS, Converter control equipment and train lighting; and,
- 230V 1-phase AC, 50Hz providing the power for maintenance testing devices.

The following brake system type and performance are to be used:

- Electro Dynamic Brake: It is a wear-less brake using electromagnetic brake force generated by the traction motors. This is available on motor cars (MC & MPC) only and not on trailer cars (TC). The dynamic brake consists of regenerative and resistive brakes;
- Mechanical Friction Brake: Directly acting on brake discs units. This is available on all cars (only wheel mounted disc brake units); and,
- Electro-Pneumatic Controlled Spring Parking Brake: Performing also immobilization brake functions.

### 2.5 Bogies & Suspension

The common basis which characterise the bogie comprises:

A running gear consisting:

- Wheel sets including axle boxes and bearings;
- Bogie frame;
- Primary suspension with damper and travel stops; and,
- Leading trailer car bogies will include an obstacle detection bar fitted to the bogie frame.

A secondary suspension subsystem comprising:

- Air spring;
- Emergency springs;
- Vertical and lateral damping devices
  - Travel stop arrangement; and,
  - Anti-roll management.

### 2.6 Saloon Interior & Mockup

The saloon interior of the train includes the following features:

- Aesthetically designed and engineered interiors incorporating disability requirements such as 30 percent interior contrasting to handrails, accessible, and safety components, 12 wheelchair allocations per train, and accessible help points;
- Single deck with metro style longitudinal seating including inter-car gangways with no inter-car doors. Customers will be able to see from one end of the train to the other. Unlike many metros it will have padded fabric covers on the seating, which have hard plastic or steel seats;
- Two multi-purpose areas per train for prams, luggage and bicycles as well as...
wheelchair spaces and separate priority seating for those with reduced mobility;

- Passenger Announcement Communication Integrated System (PACIS) with Train Control Management System (TCMS) via Ethernet backbone will provide two way communications with the Operation Control Centre (OCC) through a Passenger Help Point button;

- Passenger Information Displays (PID), and cameras will be worked in conjunction with the PA announcements to provide matching visual information to hearing impaired passengers;

- Signage complementing interior styling;

- Driver's desk for depot operations and recovery; and,

- End detrainment at both lead ends.

There are 2 air conditioning units per car mounted on the roof. Each unit is a complete system containing the evaporator, compressors, condensers, associated fans and filters. The air conditioning processor unit is mounted separately from the unit.

As part of the engineering process, a full scale train saloon model was delivered for user acceptance and technical evaluation.

The model was three quarters of the saloon of a trailer car and was considered to be made of 80% of real finishes and products. The user acceptance process engaged user groups and stakeholders to provide feedback to then validate the train design.

User and stakeholders groups included emergency services, disability groups and specialist ergonomic and disability access engineers. Representative customer groups were also engaged to complete customer surveys which also became part of the feedback to inform the train design.

2.7 TCMS & Communication System

The Train Control and Management System is a distributed control system composed of:

- Train electrical cabling and low voltage component including relays, train lines, connectors, push buttons, protections, signalling lamp, and switches;

- Main Processing Unit electronics performing the control and monitoring algorithm of the train;

- Vehicle network linking all control electronics of the TCMS and other sub-systems;

- Remote I/O modules: control electronics allowing acquisition of digital and analogue input as well as setting digital or analogue outputs; and,

- Driver display unit (DDU) console in the lead trailer car.

The train functionalities are structured following a hierarchical functional breakdown. TCMS provides the controls and the monitoring means required to run the train. It manages the various human interfaces, for
control, monitoring and first level maintenance.

The TCMS functions can be classified as:

- **Train control**: essential functions needed to drive and operate the train. A loss of one of these functions will affect the operation of the train; and,

- **Train management**: operation and maintenance assistance. These functions are not mandatory to drive the train.

According to their level of availability, safety and criticality, these train operational functions can be implemented either on a hardwired logic basis or on a programmed logic basis, carried out by the On Board Computer System.

### 2.8 Safety, Emergency, Access & Passenger Security

GoA level 4 provides the greatest level of safety in train control as it eliminates driver error. In certain degraded modes and for certain depot operations, the train is able to be driven in restricted manual mode with an upper speed limit of 25km/hr. The interior nose of the train includes a removable cover that reveals a driver machine interface to operate the train in Protected Manual mode. In this mode, the Automatic Train Protection (ATP) system is still protecting the trains from impacting into the emergency braking curve distances (refer to Section 3).

The Trains are being designed to comply with the Disability Standards for Accessible Public Transport (2002).

The CCTV has full coverage of the train saloon and is being designed to comply with the Australian National Code of Practice for CCTV Systems for the Mass Passenger Transport Sector for Counter Terrorism.

Anti-vandalism aspects have also been incorporated into the design including maintainability for maintenance, fire extinguishers included in an alarmed cabinet, and anti-vandal window film.

### 3. COMMUNICATION BASED TRAIN CONTROL (CBTC)

The Signalling and Train Control System is based on the Alstom Urbalis 400 communications based train control (CBTC) system, an internationally proven product currently in use in multiple rapid transit systems around the world, including Singapore, Switzerland and Hong Kong. The CBTC system is a predominantly on-board standalone system having minimal interfaces with the TCMS for train door and platform screen door interlocking.

The Urbalis 400 employs state-of-the-art radio CBTC technology based on moving block principles. The network based architecture uses standing interfaces that readily integrate with on board functions that connect to external systems. The data network is modular and fully redundant communications architecture. The proven, robust system features standardised engineering processes, tools and methods to optimise delivery time.

The CBTC Signalling System will comprise Signalling Interlocking, Automatic Train Control System (ATC), Automatic Train Supervision (ATS) and Data Communications.
System (DCS).

Signalling Computer Based Interlocking (CBI) type will be provided for the Depot and Mainline. The CBI system will be of a proven fail-safe design for the operation of vital signalling interlocking. It will interface with wayside equipment, the ATC system and the ATS system. The system can degrade to predefined safe conditions in the event of any fault occurring. The back-up to the system will be achieved by UPS. Power interruption will not degrade the integrity of the system nor create an unsafe condition.

When the train is following another CBTC train, train spacing is done according to moving block principle. Trains transmit their localization to the trackside ATC equipment (ZC) that elaborates an automatic protection for each CBTC train. Trackside ATC transmits to each train and point to protect (PtP by ATP) that is located at the rear end of the automatic protection of the preceding train.

The perturbation point is defined by the location where the ATO has to brake in order to respect a point to protect. In the moving block system, the perturbation point is due to the tail of the preceding train (refer to Figure 11).

3.1 Automatic Train Operation (ATO)

The rolling stock mounted ATO system provides control of train movements (particularly the regulation of speed, at or below the safety speed limit and stopping at stations) and the transfer of data between trains and wayside. The ATO system will be able to start unattended train operation mode operation anywhere on the main running line and depot departure and arrival tracks, wherever ATP transmission information is available.

3.2 Automatic Train Protection (ATP)

The rolling stock mounted ATP system will ensure safe movement of trains driven in whatever driving mode preventing the train from exceeding a safe speed permitted by the operating conditions. No system malfunction or component failure will result in an unsafe situation. The ATP system provides trains detection, safe separation of trains, safe separation between trains to fixed structures, traffic movement direction, train door control and protection, staff and passenger protection, Trains and train-borne ATC equipment remote control.

3.3 Computer Based Interlocking (CBI)

The centralised architecture of CBI will include two systems one for Mainline and one for the depot. Input / output modules (SMIO) will be installed in signalling equipment rooms at stations and at the depot maintenance building.

3.4 Data Communications System (DCS)

5GHz frequency band in the Radiocommunications Class Licence (Low Interference Potential Devices) has been identified as the range for the implementation of radio connections for CBTC DCS system and in-saloon CCTV system.

Figure 11: Moving Block – end of authority anticipation
4. OPERATIONS AND MAINTENANCE

The Sydney Metro operator Metro Trains Sydney (MTS) will operate and maintain the railway for 15 years after project completion. During this stage, MTS will be the rolling stock operator (RS) responsible for engineering and operational standards and safe working on Sydney Metro Northwest.

The journey time from Chatswood to Cudgegong road will be completed in 37 minutes with a 3 minute turnaround time at terminus. In the AM and PM peak there will be 15 trains per hour. Consequently, customers won’t need a timetable – they’ll just turn up and go.

On Sydney Metro Northwest, customer service attendants will move through the trains during the day and night as well as at all stations. Train service performance is targeted to achieve 98% punctuality and 99.5% service delivery of trains scheduled for service as per timetable.

It is proposed that the system will be fully capable of resuming normal operations within one round trip after an incident has been declared ‘all-clear’. Maintenance time for assets will be optimised to reduce the amount and duration of possessions required.

The overall performance of the railway is assessed & payments made on the basis of achieving various key performance indicators (KPIs). These include:

- Train and station cleanliness, condition and graffiti;
- Public area and rail corridor cleanliness, condition and graffiti;
- Customer information during service disruption
- Gate management;
- Customer satisfaction survey;
- Complaints management;
- On-train and station environment;
- Lift and escalator access
- Other assets availability (CCTV, Help Points, and Induction loops)

5. SYDNEY METRO TRAINS FACILITY (THE DEPOT)

The Sydney Metro Trains Facility (SMTF) at Tallawong Road provides:

- Stabling of trains which is fully automated and protected by a interlocked key entry system;
- Rolling stock maintenance including cleaning and stores
- Support of infrastructure maintenance;
- Housing the Operations Control Centre and Depot Control Centre;
- Housing the network administration, training and meeting accommodation;
- Tandem under floor wheel profiling;
- Automated train wash;
- Cleaning and train wash facilities;
- Automatic wheel, brake and pantograph monitoring;
- Bulk power supply substation;
- Engineering vehicles for the maintenance of railway infrastructure;
- Traction and distribution substation; and
- Future proofing to ensure capacity is provided for any increased patronage.

The maintenance shed includes the following features:

- Bogie exchange lifting road with retractable overhead wiring;
- Service roads;
- Heavy cleaning roads with roof and platform level access;
- Overhead crane functionality for component change out; and,
- Location for parts/materials and sufficient area for the efficient logistic movements

In addition to the maintenance of the trains, the depot includes the Operations Control Centre (OCC) which remotely manages the day to day operations of the railway.
6. TESTING, COMMISSIONING AND OPERATIONAL READINESS

The Sydney Metro contractor will undertake a robust testing, commissioning and operational readiness regime prior to service commencement.

The trains will undertake an integrated factory acceptance test (IFAT) for the initial deliveries, on a dedicated test track fitted with sufficient signalling and communications equipment to allow representative testing of the trains in grade of automation (GoA) level 4. These tests will be undertaken prior to delivery to site.

Once the trains have been fully tested and delivered to site, the following site tests on the greenfield railway will be undertaken:

- Static installation and operation checks on all installed assets, or groupings thereof, forming part of the works to ensure that they function correctly and meet the design requirements in a standalone manner after installation;
- System integration tests on "integrated" systems forming part of the works which have already been subjected to and passed the necessary site acceptance tests; and,
- Site tests, including dynamic braking performance testing, electromagnetic compatibility signalling compatibility with other assets, ride stability and comfort, exterior and interior noise and vibration, CBTC signalling system functionality and platform screen door interfacing.

Once the greenfield railway (from Cudgegong to Epping) has been fully tested, the existing heavy rail network (ECRL) will be shut down and handed over to Sydney Metro. At this stage the upgrade works and subsequent testing and commissioning of the complete integrated railway will be undertaken.
7. CONCLUSION

Sydney Metro is Australia's largest public transport project that will deliver more trains and faster services across Sydney. The standalone system includes single deck trains that include automation of the highest level ensuring safety, reliability and ride comfort.

The project has a number of Australian firsts and improvements on typical train services including:

- Fully automated trains through the CBTC signalling system;
- Platform screen doors;
- Metro style service requirements including all-stops running, reliable and frequent service; and,
- Fully integrated procurement, construction and operation of a standalone railway.

The new technology coupled with Stage 2 - extending beyond Chatswood - place this project uniquely for expansion as a new mode of transport for Sydney into the future.