5.4 LRT SYSTEMS & VEHICLES

In accordance with RFP Schedule 3-1 instructions, this section describes the Rideau Transit Group solution for Vehicle and LRT Systems – a solution that brings together a world class light rail vehicle manufacturer with a state of the art supplier of Communication Based Train Control.

From the outset of the OLRT bid process, the RTG team was intent on finding the "right" solution for Ottawa's unique needs. We began by canvasing the globe in an international procurement process. For more than six months, the RTG team thoroughly reviewed submissions from the world's leading suppliers of rail vehicles and systems. We measured and evaluated their products and performance against the Ottawa challenges - cold climate operations, state of the art vehicles and train control but proven in service, modern low floor convenience plus 100 km per hour capability to name just a few – with a goal of putting the "best of the best" together in one integrated package.

Our selection of Alstom Transportation's CITADIS vehicle and Thales for train control and systems will place Ottawa's new light rail system at the head of the class, meeting the industry's highest levels of safety, comfort and reliability.

Worldwide, Alstom Transportation is a global powerhouse, having earned in excess of $8 billion in Revenue in the past operating year. The company also has significant experience in the North American rolling stock business. It maintains a large manufacturing plant in Hornell N.J (one of the largest in NA) and has produced more than 7000 transit vehicles for transit authorities and rail customers. In Canada the company has Transport division offices in Ottawa, Montreal and Toronto. Alstom is very experienced in technology transfer to meet both the letter and spirit of local content regulations as discussed in **Section 5.4.2**.

The Citadis vehicle is the ONLY 100 per cent low floor vehicle operating at 100 km in the world today. Its sleek urban design is the ideal solution for Ottawa's urban environment, offering the ideal blend of form and functionality in one vehicle. Its maintenance advantages are also proven. The Ixege pivoting bogie design (which utilizes conventional axels) has been shown to have lower life cycle and maintenance costs and better performance, particularly in the snow. The Ixege bogie allows the passenger interior of the car to have all of the accessibility and convenience of a 100% low floor LRV but many of the operational and performance advantages of a 70% low floor LRV. This will prove invaluable in winter operating conditions in Ottawa.

Thales is a global technology leader in the Transportation, Aerospace, Defense and Security markets. In 2011, the company generated revenues of $17 billion with 67,000 employees in 56 countries. With its 22,500 engineers and researchers, Thales has a unique capability to design, develop and deploy equipment, systems and services that meet the most complex security requirements. Thales has an exceptional international footprint, with operations around the world working with customers as local partners.

In Canada, Thales has been operating for more than 30 years, employing 1,300 people in its Transportation, Defense & Security, and Aerospace sectors. Canada is also headquarters to Thales Centre of Excellence in Signalling with offices are in Ottawa, Toronto and Vancouver that employ over 800 people. The CBTC signalling solution was first deployed by Thales on Vancouver's driverless metro in 1986. Today, CBTC technology has become the de facto standard for urban rail systems. Since then, with more than 35 systems equipped with its SelTrac CBTC solution and over 10 million cumulative hours of operation to its credit, Thales has more experience with this solution than any other provider in the world. Successful projects in Beijing (1.2 million passengers a day on the two lines equipped by Thales), Shanghai (1.6 million passengers a day on the 5 lines equipped by Thales), Wuhan, Guangzou and Hong Kong have made Thales a market leader for transit signalling systems in mainland China. Thanks to SelTrac CBTC technology, the Docklands Light Railway – one of the busiest lines in the London transport system, with 70 million passengers a year – delivers over 98% availability – a remarkable achievement since it includes the availability of the fixed block backup system. The SelTrac CBTC installation on the Canada Line achieves over 99.95% availability (again including wayside components) even though it does not have as extensive redundancy as will be provided for the OLRT.

Thales' technologies and solutions are particularly well suited to the requirements of transit systems. Safety, reliability and cost effectiveness are fundamental to modern light rail system operations. Thales' systems control train speed and direction with great precision; this optimizes use of system assets and translates into enhanced performance and cost savings for the city. Thales' systems are in operations with major metro operators worldwide, including those of Vancouver, London, New York, Shanghai, Hong Kong and Dubai.

In addition to each company's independent success stories, Alstom and Thales have worked successfully together on several joint transit projects – the London Underground Jubilee Line and on Shanghai Metro Lines 6 and 8. The Shanghai installations employed 1500 VDC as is proposed for the OLRT. Throughout the design phase, Alstom and Thales will work closely with an engineering joint venture (EJV) comprising SNC-Lavalin Inc., MMM Group, and specialty consultants selected for their Project-specific expertise to deliver the best solution to the City.

5.4.1 LRT SYSTEMS DESIGN PROCESSES

RTG brings together the strengths, capabilities and expertise of ACS Infrastructure Canada Inc.; SNC-Lavalin Capital, a division of SNC-Lavalin Inc.; and EllisDon Inc. On announcement of Preferred Proponent these companies will form a special-purpose vehicle (Project Co) to contract with the City for the OLRT Project. Our team will use their combined experience on past projects to deliver the LRT Systems and Vehicles using the formal set of design processes explained below.

5.4.1.1 Design Methodology & Lessons Learned

Successful system integration starts with developing proper processes to validate requirements, implement them in a timely manner, and verify that the delivered system is safe and reliable. Over many years of experience on successful transit projects, RTG has developed a set of practical and results-oriented system engineering processes. These are documented in the plans and specifications defined in the following sections and incorporate the following key lessons learned:

- Perform a thorough Requirements Analysis to fully understand the City's requirements
- Use a formal engineering process through all Project phases to manage the work, track requirements and conduct comprehensive test and verification planning
- Thoroughly document interfaces and, in particular, vehicle interfaces (e.g. Train Control and wheel/rail)
- Choose proven suppliers and subsystems best suited to the City's requirements
- Emphasize off-site acceptance testing and maximize the use of simulators and test tracks
- Involve operations and maintenance staff in commissioning as early as possible

The design methodology is shown graphically in **Diagram 5.4.1 D2.1A** and the interaction with the overall Project is shown in **Diagram 5.4.1 D2.1B**.

Systems Engineering Plan

The Systems Engineering Plan described in this section will apply to each OLRT system in a manner commensurate with the safety level it is designed to provide. The Plan will ensure the tracking of system requirements and configuration through Project design, implementation and test phases to support system assurance, quality, safety management and certification and to ensure a safe and reliable Maintenance Term.

The LRT Systems and Integration Manager will prepare the Systems Engineering Plan at the conceptual design phase, based on the current internationally recognized systems engineering standard: ISO/IEC 15288, Systems Engineering – System Life Cycle Processes.

The purpose of the Systems Engineering Plan is to define an integrated set of engineering processes, thus assuring the City that good engineering practices will be followed in the systems engineering of the Works, as follows:

- Establishing and evolving a complete and consistent set of requirements that will enable delivery of a feasible and cost-effective systems solution
- Satisfying requirements within cost, schedule, and risk constraints
- Providing a system, or any portion of a system, that satisfies the City over the life of the products that make up the system
- Satisfying Sustainability requirements including safe and cost-effective disposal or retirement of a system or part thereof

The Systems Engineering Plan will specify the following elements relative to engineering of the System:

- Agreement processes (e.g. product acquisition, product supply, subcontractor management and evaluation)
- Project management processes (e.g. planning, assessment, project control, and risk management)
- Technical processes (e.g. the City's requirements definition, requirements analysis, design, implementation, integration, verification, transition, validation, operation, maintenance, and disposal)
- Proposed technical review process
- Summary of documents required by the Plan

Design Planning

The LRT Systems and Integration Manager will prepare the Design Management Plan for System design activities at the conceptual design phase. The Plan will include the following elements:

- Organization of the Design Team
- System design activities:
    - Plan and schedule for managing the requirements, analysis, definition, and validation phases
    - Design review and audit schedule
    - Document submission schedule
    - Drawing submission schedule
- System design elements:
    - Document tree, illustrating the documentation hierarchy
    - Drawing tree, illustrating the drawing hierarchy

Design Reviews

There will be three design reviews for the OLRT System:

- Conceptual Design Review (CDR)
- Preliminary Design Review (PDR)
- Final Design Review (FDR)

In addition there will be a PDR and FDR for each major sub-system within the Works.

The formality and scope of these design reviews for the System or sub-system will depend on the complexity, size, and risk associated with the System or sub-system. In the following discussion, the term system (lower case) may refer to a system, sub-system, or component.

Conceptual Design Review

Senior designers from each discipline will prepare documentation for the CDR defining the theory of operation of the overall OLRT System, including major sub-systems, sub-system interfaces, interfaces to external systems, and any requirements the system may impose on external systems or equipment. Special attention will be paid to operator interfaces.

Preliminary Design Reviews

A primary goal of each PDR will be to validate system requirements to ensure that they are the complete, necessary, and sufficient set of requirements for the system, that they are consistent with the City's intent, and that the system supplier understands them. Typical documentation submitted for each PDR will include but not be limited to the following:

- Requirements analysis and other documentation to demonstrate that the proposed system meets the specified requirements
- Functional descriptions of the system and its major sub- systems
- Equipment layout and functional architecture
- Interconnection drawings
- Finalized interface specifications
- Mock-ups of operator interfaces
- Confirmation of the following:
  - Sub-system specifications have been defined appropriately
  - Enabling products have been defined adequately to initiate enabling product development, if required
  - Approaches planned for the next design phases have been appropriately planned
  - Project risks have been identified, and mitigation plans are feasible and judged to be effective
- System Assurance documents and checklists to confirm that the design conforms to quality safety and RAMS requirements (see also **Section 5.1.5.1**)

Open items from previous design reviews for the system will be addressed and/or resolved during the PDR.

Final Design Review

For each FDR, senior designers from each discipline will prepare documentation that confirms the following:

- Specifications, drawings, and/or software development files have been appropriately defined
- The end product designs satisfy system requirements
- The system meets one of these criteria:
  - Ready for continued design and development
  - Appropriately defined for purchase of products from an external supplier
  - Ready for manufacture/fabrication
  - Adequately defined such that off-the-shelf products and/or proven products can be used to fulfill system requirements and are available
- System Assurance documents and checklists to confirm that the design conforms to quality safety and RAMS requirements (see also **Section 5.1.5.1**)

For each FDR, detailed designs and other documentation will be prepared with sufficient information to confirm a complete design and allow manufacturing/construction to proceed. Typical submittals for an FDR will include, but not be limited to, final design and installation drawings, shop drawings, calculations and analyses to demonstrate that the system will meet the specified requirements. All open items from previous design reviews for the system will be addressed and/or resolved during the FDR.

For each FDR, a System Verification Matrix (SVM) will document how each of the validated requirements will be verified, and the status of that verification. The SVM will be updated periodically to maintain the status of the requirement verification.

Other Reviews

Other types of reviews may be held on an as-appropriate and as-required basis:

- **Pre-System Definition Reviews** which, during the Project's conceptual phase, will consider all concepts analyzed and select a preferred concept for further development that has the potential for satisfying identified City requirements. In addition, this review may assess progress towards converging on a viable, traceable set of System Technical Requirements that are balanced with cost, schedule, and risk. This review will also ensure the design is optimized in terms of safety, operations reliability, availability, maintainability and lifecycle cost, service dependability, failsafe design and failure management of the system operation. OLRT system optimization is discussed in detail in **Section 5.1.5.1**.
- **Readiness Reviews** which, during the Project's integration and test phase, will demonstrate that delivered end products from lower layer systems have been validated, or that validation tests are adequately planned, and that each set of integrated products forming a composite end product is ready for end-product verification and validation, if required.
- **Audits** which, during the Project's manufacturing, integration and test phase, will demonstrate and confirm the following:
    - End products comply with their specified requirements and product verification outcomes compare favourably against configuration documentation (e.g. drawings, test procedures, authorized changes, software development files, as -built/as-coded documentation)
    - The as-built/as-coded configuration has been favourably examined against its configuration documentation (e.g. drawings, bill of materials, specifications, code lists, manuals, compliance test, compliance data)
    - Products have been built to drawings and satisfy specifications
    - The information database represents the work products of the system development
    - Required changes to previously completed specifications have been implemented
    - Enabling products for downstream associated processes are available, can be executed, and meet the City's requirements
- **Process Reviews** which, during the Project's integration and test phase, demonstrate that the development of enabling products for associated processes is on schedule, and that designs satisfy related end-product needs. Examples of Process Reviews are production readiness reviews and test readiness reviews.
- **Independent Contractor Evaluations, Reviews, and Audits** may occur as required throughout the Project

System Requirements Specification

A System Requirements Specification that captures the City's requirements and System technical requirements will be prepared by senior designers. This specification will be reviewed with the City to ensure that RTG completely understands the requirements. The Requirements Management Database will be created and maintained using the DOORS requirements management database tool.

The System Requirements Specification and Sub-System Requirements Specifications will be reviewed as part of the Preliminary Design Review.

Requirements Validation

As summarized in **Table 5.4-1**, requirements have been validated when it is determined that the subject set of requirements describes the input requirements and objectives such that the resulting system products can satisfy the requirements and objectives.

Table 5.4-1 | Requirements Validation

Stage	Objective	Methodology
General	The LRT Systems and Integration Manager will ensure that technical requirement statements are well formulated	▪ Analyzing and ensuring that each requirement statement is stated with: clarity, correctness, feasibility, focus, modifiability, removal of ambiguity, singularity, testability, and verifiability ▪ Analyzing and ensuring that technical requirement statements in pairs and as a set are stated with connectivity and without redundancy and conflicts
Requirements Validation	Defined System requirements will be reviewed against the City's needs and expectations	▪ Selecting methods and defining procedures for validating that the set of System requirements is consistent with the level of system structure, and the Validation Plan as appropriate ▪ Analyzing and comparing identified and collected requirements to the set of defined System requirements to determine upward and downward traceability ▪ Identifying and resolving variances, voids and conflicts ▪ Recording validation results
System Technical Requirements Validation	Defined System technical requirements will be reviewed against validated the City's requirements	▪ Selecting methods and defining procedures for validating that the set of System technical requirements is consistent with the level of systems structure and the Validation Plan as appropriate ▪ Analyzing and comparing identified and collected System technical requirements with the set of defined System technical requirements to determine upward and downward traceability ▪ Analyzing assumptions made with respect to defining System technical requirements to ensure they are consistent with the System being engineered ▪ Analyzing System technical requirements that have been defined as essential for the design effort where there is no parent requirement in the set of the City's requirements, to ensure they are consistent with the System being engineered ▪ Identifying and resolving variances, voids and conflicts ▪ Revalidating System technical requirements whenever a requirement change affects the City's requirements, or System technical requirements ▪ Recording validation results

Computer-Based Systems

Software

Tasks will be undertaken to ensure that System software complies fully with the following requirements:

- Operates without degradation during all date changes
- Uses a formal methodology for structured modular code design and implementation appropriate to the application and safety integrity of the System
- Uses open standards and non-proprietary protocols for all interfaces except where proprietary protocols are required to facilitate integration with legacy systems or to meet City requirements

- Ensures that configuration details are available down to the appropriate software configurable item
- Is capable of local loading and, where operationally required, remote loading

Formal documentation, change control, testing and verification processes will be appropriate to the application and safety integrity of the System for software quality control.

Software Development Management Plan

Where the System includes components of proprietary software development, a Software Development Management Plan for the System will be prepared at the conceptual design phase, to include, but not be limited to, the following:

- Organization including identification of Software Development Manager and key team members, as well as position descriptions (e.g. qualifications, training)
- Identification of subcontractors including their qualifications, how the Plan and other plans apply to them, and how they are assessed and evaluated during System development
- Software development philosophy
- Software lifecycle including phase input and output details, and phase entry and exit conditions
- Quality assurance and control activities and procedures
- Development schedule (e.g. critical activities, how key dates will be achieved, resourcing levels)
- Quality schedule including audits and reviews
- Strategies to accommodate contingencies and changes (e.g. software development schedule, resources)

The Software Development Management Plan and the software lifecycle processes documented therein will comply with internationally recognized standards.

5.4.1.2 Systems Interface Management

Interface Management Plan

At the conceptual design phase, an Interface Management Plan will systematically identify documents and provide a management tool for resolving technical interfaces between subsystems and between the System and external systems across all disciplines. This will include all System elements that have a direct or indirect interaction with systems or equipment external to the System. The Interface Management Plan will be updated as the interfaces evolve.

Interface Specifications

Each interface will be managed within a system of interface-control documentation (primarily interface specifications), which will include, but not be limited to, the following definitions:

- The organizational entities responsible for managing and engineering the interface and other entities involved
- Details of the agreed interface arrangement (e.g. physical installation, civil, power supply, signal levels, transfer characteristics, message formats, communications protocols)
- The functional, performance, reliability, maintainability and safety requirements of the individual elements forming the interface
- The proposed method and schedule for verifying interface integrity, individual element performance, and combined system performance

The interface control documentation will be reviewed in the process reviews and design reviews and will be updated as the interfaces evolve.

When interfacing to systems provided by others that are part of the Works, RTG will jointly prepare the interface control documentation with the third party.

Interface Communications

An organizational structure and corresponding procedures will be created for coordination and communication of interface data among the suppliers of systems and sub-systems within the system and interfacing to it. The City will be provided with design criteria that clearly define interface requirements between the System and systems provided by others, including any civil, structural, and fixed facilities that may interface to the System.

Configuration Data

During execution, Works suppliers will exchange configuration data (e.g. Station identification, track locations) using a structured, well-normalized record format. Project-wide configuration data guidelines will provide an overview of configuration data formats and structures specifying items such as abbreviations and Project-level identifiers.

The exact format and content of configuration data to be exchanged will be specified in configuration data control documentation (primarily Configuration Data Specifications). Such documentation will include, but not be limited to, the following:

- Detailed description of each item of configuration data, including how it is intended to be used
- Detailed description of the format of the configuration data, using examples if possible

Typically, there will be one set of configuration data control documentation for each configuration data interface with another entity (e.g. supplier, subcontractor). Subcontractors will prepare the interface-specific configuration data control documentation and comply with Project-wide configuration data guidelines.

Configuration Data Management Plan

A preliminary version of the Configuration Data Management Plan will be prepared for the System at the conceptual design phase, with the final Plan prepared at the preliminary design phase. It will include the following:

- Detailed description of the process and methods to handle configuration data
- Description of configuration data to be supplied to and by third-parties
- Description of configuration data formats to be used
- Configuration management procedures
- Change control managem ent procedures
- Configuration data schedule (e.g. when configuration data is to be delivered to, or is required from, others)

5.4.1.3 Verification & Validation Strategy

The LRT Systems and Integration Manager will coordinate system verification and validation activities with the appropriate design phase as shown in **Diagram 5.4.1 D.1C**. The System Validation process provides a comparative assessment to confirm that the City's requirements are correctly defined. By assessing services presented to the City, validation demonstrates that the correct system entity has been created. Tasks include Requirements Validation and End Products Validation.

The System Verification process will be used to ascertain the following:

- System design solution generated is consistent with its source requirements and the specified design requirements are fulfilled by the system end product
- End products at each level of the system structure implementation, from the bottom up, meet specified requirements
- Enabling system development or procurement for each associated process is properly progressing
- Required enabling systems will be ready and available when needed to perform

Test and commissioning plans will be developed, organized, and implemented to verify the adequacy of the System to meet all functional, safety, systems assurance, and performance requirements.

All materials furnished (including spare parts) and all work performed as part of the Works will be inspected and tested. If specific hardware, software, or documentation does not meet specific requirements, it will be repaired, replaced, upgraded, or added by the responsible supplier as necessary to correct deficiencies. After correction of a deficiency, all tests necessary to verify the effectiveness of the corrective action will be repeated.

Factory and site tests will be performed. Deliverables will not be shipped until all required factory inspections and tests have been completed and all deficiencies have been corrected. Site testing will ensure that the System has been properly installed, and that the System satisfies all performance, safety, reliability, and functional requirements while in actual service. Spare parts will be tested in the identical manner as other equipment.

Before testing starts, the City will have approved all test plans and procedures for the test, and all relevant prerequisite testing will have been completed. Inspection and Testing will comply with ISO-9001:2008, clauses 8.2.4 "Monitoring and Measurement of Product" and 7.6 "Control of Inspection Measuring and Test Equipment".

Test Documentation Submittals

RTG will submit test documentation to the City including the following:

- A Validation, Inspection, and Test Plan for acceptance at the Conceptual Design Review. This Plan will demonstrate that the Contractor has considered all testing requirements and made adequate schedule provisions for testing in the overall schedule.
- A System Test Plan and a Test Plan for each sub-system for acceptance at the Preliminary Design Review listing the tests required to fully verify that the System meets functional, safety, and performance requirements.
- Detailed test procedures for acceptance for each test identified in the test plans identified above, no later than 90 days before testing.
- A Commissioning Test Plan for the System for acceptance at the Preliminary Design Review. These plans will list the tests required to fully verify that the System has been properly installed and to demonstrate that the System satisfies all performance, safety, reliability, and functional requirements while communicating with a full complement of devices under actual service conditions.
- A 90-day look-ahead schedule detailing all testing activities propo sed for the period covered. The first schedule will be submitted 90 days before the first test scheduled and a revised schedule will be submitted periodically as required.
- Test Reports containing the results of all tests conducted at any factory or field location.
- Deficiency report(s), periodically or as required.

Test Documentation

Validation, Inspection, and Test Plan

The Validation, Inspection, and Test Plan will include at least the responsibilities of individuals and documentation of validation and test results and will include, but not be limited to, the following items:

- Flow diagram indicating the logical sequence of validations and tests, starting with materials receiving tests and inspections and concluding with system demonstrations tests
- Validation schedule
- Test schedule
- Responsibilities
- Record-keeping assignments, procedures, and forms
- Procedures for performing validation
- Procedures for monitoring, correcting, and re-testing deficiencies
- Procedures for controlling and documenting changes made to hardware and software after testing starts

- Coordination needed from the City

System and Sub-System Test Plan

Test plans will demonstrate that the System supplied is complete, safe and operable and will include at least the following items:

- Test schedule
- Responsibilities
- Block diagrams of the hardware test configuration including external data transmission interfaces, and detailed descriptions of test and/or simulation equipment
- Estimated duration of each test
- Coordination needed from the City
- Calibration and its traceability to known standards of hardware, software, simulation tools and test equipment to be used for testing

Commissioning Test Plan

The Commissioning Test Plan will include at least the following:

- Commissioning test schedule
- Responsibilities
- Recordkeeping assignments, procedures, and forms
- Procedures for monitoring, correcting, and re-testing deficiencies
- Procedures for controlling and documenting changes made to hardware and software after testing starts
- Coordination needed from the City

Test Procedures

Test Procedures will describe individual test cases and the steps comprising each case, with emphasis on the methods and processes to be followed:

- Objective of the test
- Requirement(s) to be demonstrated and verified
- Required setup and conditions, including descriptions of test equipment and required data
- Descriptions, listings, and instructions for test software tools and displays
- Step-by-step descriptions including inputs and user actions for each test step
- Expected results including the pass/fail criteria
- Techniques and scenarios used to simulate system field inputs and controlled equipment

Test Records

Complete certified Test Records of all factory and field acceptance test results will be maintained and delivered to the City. Test Records will be keyed to Test Procedures and will include the following:

- Reference to the corresponding Test Procedure
- Date the Test Procedure was executed
- Description of test conditions, input data, or user actions differing from that described i n the Test Procedure
- Results for each test case including a passed/failed indication
- Name of test engineer and the City's Representative (if present for execution of the Test Procedure)
- Provision for comments by the City's Representative
- Copies of any defi ciency reports generated as a result of the execution of the Test Procedure

- Copies of reports, display copies, and any other hardcopy generated by executing the Test Procedure
- Configuration data that fully describes the hardware and software that was tested, including software version and build numbers/identifiers for every software module

Failure Reporting, Analysis, and Corrective Action

Throughout the periods of System field testing, demonstration, and warranty, a closed-loop Failure Reporting, Analysis, and Corrective Action (FRACA) system will determine the cause of all test failures, unscheduled part removals, and other deficiencies. To identify failed parts and pertinent data and actions relating to each failure, failures will be classified and a cumulative summary of all failure analyses maintained. RTG will apply this process to all OLRT System and subsystem failures including performance failures.

FRACA data will regularly and systematically be evaluated to identify and monitor failure trends, no-trouble-found incidents, and new-failure effects.

End-Product Audits

During the Project's integration and test phase, end-product audits of the System will be held which, during the Project's integration and test phase, will demonstrate and confirm the following:

- End products comply with specified requirements and product verification outcomes compare favourably against configuration documentation (e.g. drawings, test procedures, authorized changes, software development files, as-built/as-coded documentation)
- As-built/as-coded configuration has been favourably examined against configuration documentation (e.g. drawings, bills of material, specifications, code lists, manuals, compliance test, compliance data)
- Products have been built to drawings and satisfy s pecifications
- The information database represents the work products of the system development
- Required changes to previously completed specifications have been implemented
- Enabling products for downstream associated processes are available, can be executed, and meet City requirements

Readiness Reviews

Readiness Reviews may be held for the System which, during the Project's integration and test phase, will demonstrate that delivered end products from lower layer systems have been validated, or that validation tests are adequately planned, and that each set of integrated products forming a composite end product is ready for end-product verification and validation, if required.

Tests on Completion

Tests on Completion will include all testing to be performed before Completion of the Works.

First Article Inspection

To ensure units are suitable in all respects for the purpose intended, a First Article Inspection (FAI) will be conducted on the first production unit of each sub-system prior to the first shipment of equipment for that sub-system from the factory. The FAI testing will include, but not be limited to, the following:

- Electrical and mechanical construction testing
- Vibration and impact resistance testing
- Temperature and humidity testing
- Functionality, performance, and timing testing
- Accelerated life testing
- EMC testing

Critical items of the System's equipment that do not have a proven history will be subject to qualification testing.

Equipment Tests

Sample units from production will be subject to routine and Quality Control inspections and testing.

Factory Acceptance Tests

Where appropriate and reasonably practicable, Factory Acceptance Tests (FATs) will be conducted on systems and sub-systems in a factory environment representative of the actual operating environment, to demonstrate that System items under test can perform in accordance with specifications, before being installed. The deliverable hardware and software will be tested. Upon completion of testing, a FAT review will confirm that the system or subsystem under test is fit to be deployed and installed.

Post Installation Checkout Tests

Post-Installation Checkout (PICO) testing will demonstrate that all system hardware (including spare parts) and software functions properly in the installed environment. The installed system will be verified against installation drawings to verify correct installation and that system equipment has not been damaged subsequent to shipment from the factory.

The field installation test will include a complete system inspection including but not limited to proper installation, grounding, cabling, conformance to plans and drawings, neatness, equipment access and installed versions of hardware and software. All cables will be tested for opens, shorts, grounds and high resistance.

Tests will be performed on each sub-system and group of sub-systems (using a bottom-up approach) to verify that they are operating correctly in the target environment. Tests will also be performed on groups of sub-systems using a bottom-up approach to verify that they are operating correctly in the target environment.

Site Acceptance Tests

After PICO Tests, Site Acceptance Testing (SAT) will be performed on installed System equipment and subsystems using the approved set of SAT procedures. These procedures will generally be a subset of those performed during FAT testing, but will also focus on requirements which could not be verified during FAT testing. SAT will be performed to verify that the System has been properly installed and to demonstrate that the System satisfies all performance, safety, reliability, and functional requirements while communicating with a full complement of devices under actual service conditions. The proper operation and performance of all System features and functions will be verified during this test.

Tests after Completion

Tests after Completion will include all testing to be performed after Completion of the Works.

Integrated System Testing

Upon successful completion of SAT on two or more related subsystems, these subsystems will be integrated to commence Integrated System Testing (IST). IST will concentrate on inter-subsystem functionality and performance under normal, abnormal, and emergency scenarios.

Trial Running

Trial Running of the System will demonstrate that the System meets specified performance criteria and is capable of safely operating in accordance with initial service plans, including specified travel times, headways, and availability.

Trial Running will exercise and confirm operating reliability of the System in simulated operating scenarios. A full regular scheduled service will be operated on the full Line using peak and off-peak schedules for an extended period. Passengers will not be carried, but appropriate dwell times will be observed. Trial Running will also include a variety of failure-management scenarios that could reasonably be expected to occur in regular revenue service.

5.4.1.4 Configuration Control Methodology

Configuration management and change control management procedures and techniques will be used in the engineering of the Works. Where appropriate (for example, in systems with software components), these procedures and techniques will comply with internationally recognized standards.

Configuration Management Plan

A Configuration Management Plan for the System will be prepared at the conceptual design phase and will include the following:

- Detailed description of the methodology and procedures to be used to control and document System configuration during the Contract period (e.g. from the preliminary configuration at the time of the proposal through the design phases to the as-delivered hardware and software configurations)
- Detailed description of configuration management processes, procedures, and techniques to be used with respect to any subcontractors
- Organizational structure with respect to configuration management

Change Control Management Plan

A Change Control Management Plan for the System will be prepared at the conceptual design phase and will include the following:

- Detailed description of methods and procedures to be used to handle change (e.g. functional changes, performance changes) during the Project Term
- Detailed description of the change lifecycle and statuses
- Detailed description of change control processes, procedures, and techniques to be used with respect to any subcontractors
- Change control organization

Configuration Control during the Maintenance Term

RTG will maintain all systems plans, maintenance reports, remedial actions, instructions and procedures in an Asset Management System. System plans include the conformed design plans reflecting as-built conditions at final acceptance of construction. Design plans, including typical installation drawings that document installation standards, will be controlled by the Maintenance Director through implementation of a configuration management process embedded in the asset management program.

A Configuration Management Committee, staffed with key personnel and chaired by the Maintenance Director, will control configuration management. All configuration changes of a system or equipment will include a request, an evaluation of the change, an approval process, and the final recording and documentation of the change. This will be managed and recorded within RTG's Asset Management System to provide traceability. Where life-limited or serialized components are changed in any equipment, the overall impact on future maintenance and lifecycle of the parent asset will be accounted for and adjusted within our Asset Management System.

Configuration Control during the Maintenance Term is described in detail in **Section 5.1.5.1**. A Regulatory Working Group is defined in **Section 5.1.6.2** to address the Safety Management System (SMS) by apply the appropriate configuration controls both prior to and during service commencement.

5.4.1.5 Systems Assurance Process & Methodology

As specified in the RFP, RAMS, including a narrative on management of the systems assurance process, is discussed in **Section 5.1.5.1**.

5.4.1.6 Climatic Performance

RTG will ensure that all systems and equipment subject to the external environment are designed for Ottawa's extreme climate by applying the following principles:

- Use suppliers with a proven track record of delivering systems in extreme climate
- Select major subsystems that are service-proven in similar climates
- Use NRC's environmental chamber for environmental qualification testing when necessary
- Verify system environmental performance during site testing.

A key factor in maintaining service during inclement weather is the proper response by both operations and maintenance and rehabilitation (M&R) personnel. RTG will address this factor as follows:

- Providing tools to manage weather extremes. For example, the CBTC System will include the ability to reduce braking and acceleration rates if low adhesion is experienced.
- Preparing maintenance procedures to deal with extremes of weather, and training M&R personnel in these procedures.
- Preparing operations procedures to deal with extremes of weather in cooperation with the City, and training operations personnel in these procedures.
- Providing snow removal equipment and procedures.

Examples of equipment and subsystems operating in similar environments are included in the cut sheets.

Methodology for Dealing with Extremes of Weather During Testing

RTG will implement the Maintenance and Storage Facility (MSF) early to provide a local test track to integrate all major subsystems. This early implementation will allow three seasons of environmental testing to experience a wide range of weather conditions. By proactive test scheduling, we will use inclement weather as a test tool.

Operations, M&R and testing and commissioning (T&C) personnel will be trained and qualified in all relevant procedures before the start of each T&C phase. A CBTC Control Operators Training Simulator will be provided to support this process.

When necessary, RTG will simulate extreme conditions (e.g. soaping rails for adhesion testing).

5.4.1.7 System Integration Methodology

To deliver an LRT system that meets or exceeds the City's performance expectations, RTG is committed to managing the Project's integration risk. System Integration is discussed in detail in **Section 5.1.5** and summarized here.

The past 30 years have seen significant improvements in Train Control System interfaces that decrease integration risk. These improvements can be seen in standardized interfaces resulting from supplier consolidation and technological advances, particularly in communication equipment and protocols. Modular hardware and software design technologies have simplified overall designs

Both Alstom and Thales are contractually required to ensure design visibility (including providing access to their key contractors) to RTG. Through this environment, RTG's LRT Systems and Integration Manager will manage the design process, ensuring that interface requirements are well understood and are properly implemented.

Processes and documentation to control interfaces will include but not be limited to the following.

- Interface specifications for each major interface
- First Article Inspections
- Qualification tests
- Factory Acceptance Tests and subsystem integration tests

- Vehicle/Train Control integration tests are planned in the MSF early in the schedule

As per lessons learned, particular attention will be paid to brake and propulsion interfaces, and the wheel/rail interface.

To ensure that proposed systems and equipment can perform as required in the Ottawa environment, RTG will carefully review supplier submissions. The process of choosing our Team's Vehicle and Train Control supplier included a detailed review of their proposed interfaces and interface management plan to verify that both suppliers understood the interface requirements and had the necessary knowledge and experience to implement them. We have chosen two experienced suppliers with demonstrated systems integration capability who have worked together and with RTG. We believe that Alstom and Thales are ideally suited to integrate the best solution for the City.

Test programs will be developed to demonstrate all aspects of the interfaces. This will include First Article Inspections, qualification tests, Factory Acceptance Tests and subsystem integration tests. Vehicle/Train Control integration tests are planned in the MSF early in the schedule. These tests will be a key milestone for ensuring that all Vehicle/Train Control interfaces have been properly addressed. On-site testing will be planned in stages that demonstrate functionality in a logical sequence and ensure that, as far as possible, only one function within one system is being tested at a time. Once multiple systems have been tested to an appropriate stage, they will be combined for integration testing (see **Drawing 5.4.1.D.1D & E**).

RTG will manage integration of other subsystems by applying the principles used for the Vehicle/Train Control interface.

Lessons Learned from Other Project Integrations

Integration of the Canada Line project was based on a similar strategy to that outlined herein, with the following lessons directly applicable to the OLRT Project:

- Agree early which parties will authorize major steps in the start-up of the OLRT Project, such as:
  - Traction Power Energization
  - First Train Movement
  - Multiple Train Movements
  - Trial Running
  - Revenue Service

  (Note that this is an example list, and not necessarily a comprehensive list for the OLRT Project.)
- Agree with each party on the list of documents and other activities required in support of their signature authorizing start-up. Document this list in a System Activation Plan.
- Agree with each party the processes and/or standards to prepare relevant documents and other activities.
- Prepare and sign certificates as early as possible.
- Combine items in one certificate where timing is similar and signatories match.
- Ensure that Revenue Service Operating procedures and training programs related to safe operations during the T&C phase (e.g. Train movements, traction power energization, hand signals) are prepared well in advance of the start of T&C.
- Ensure that sufficient operators are trained for the start of T&C.
- Ensure that System access requirements for the Driver training program are scheduled well in advance of the start of T&C and coordinated with testing activities on an ongoing basis.
- Use experts for key Project challenges and to identify latent issues based on experience on other projects.

Lessons learned are also discussed in **Section 5.4.1.1.**

5.4.1.8 Systems Branding Strategy

The OLRT System has been described as the most important infrastructure project in the City since the building of the Rideau Canal. This is the first leg of a legacy project that will shape the growth and liveability of the C ity for generations to come. Branding this iconic system creates a unique opportunity to enhance the reputation and quality of life of the City and her citizens. Systems are a key component of the new OLRT brand – the quality and performance of this 'product component' will serve to build the System's reputation for safety, reliability and efficiency. The more visible system components, including equipment that is visible to or interacts with the public (e.g. Passenger information displays, signage and announcements) take on an even greater role as the 'voice' of the brand. RTG will work closely with the City to ensure these brand elements are harmonized and consistent. The fact that Thales is a Canadian success story with key development activities taking place in Ottawa adds to the brand messaging. The Vehicle branding strategy is discussed in **Section 5.4.3.1**.

5.4.2 COMPLIANCE WITH CANADIAN CONTENT POLICY

5.4.2.1 Canadian Content Compliance Strategy

RTG is pleased to propose a Vehicle that will achieve 27% Canadian content as detailed in the Canadian Content Certificate – Attachment B. In this section we are providing supporting information to demonstrate the compliance, this includes names of potential manufacturers, equipment type and place of manufacture and contact details of manufacturer (**Table 5.4-3**). **Table 5.4-2** indicates the breakdown of the requirements calculated in accordance with the Canadian Content Policy and in the specified categories. Of the 27% Canadian Content 16% is from Ontario.

Table 5.4-2 | Local Content calculation

Project Subdivision items	Items / Total proposed price (%)	Part Localized in Canada (%)	Local Content (% proposal price)
Labour	8%	85%	7%
Sub-components and components inc. CBTC	64%	22.4%	14.3%
Project management	6%	25%	1%
Engineering	16%	5%	1%
Manual, Training, Simulators	0.5%	0%	0%
Special tools	0.3%	0%	0%
Test equipment	2%	70%	1%
Freight	0.2%	0%	0%
Warranty	3%	100%	3%
TOTAL	**100%**		**27.3%**

* *The price excludes any Canadian sales taxes (GST and others)*

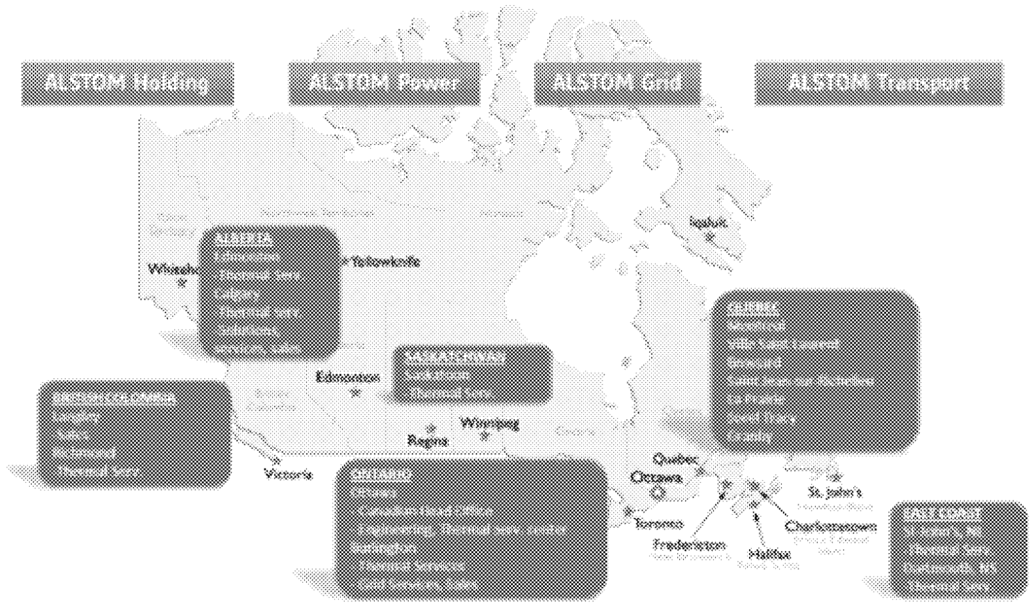
Alstom and RTG consent to the disclosure, verification and audit of the information forming the basis of their certification during the evaluation stage and any further steps taken before Commercial Close and, during and after the term of the Project Agreement. Such disclosure, verification and audit will apply to the Province of Ontario, MTO, the Auditor General of Ontario, and their designates.

70 Years of Experience in Canada

Alstom is able to exceed the required Canadian Content requirement of 25% by three means: local resources currently in place in Canada, local sourcing, and provision of final Vehicle assembly in Ottawa.

Alstom has been operating multi-specialist railway facilities in North America for more than 70 years. Alstom currently has more than 2000 employees working in Canada. Alstom Transport has available, qualified and experienced Canadian resources for the OLRT Project, including from the Center of Excellence for Passenger information, safety, communication and entertainment systems for rolling stock, station and trackside applications in Ville Saint Laurent's site in Quebec, and the Montreal railway maintenance centre (see **Figure 5.4-1**).

Figure 5.4-1 | Alstom Canadian Operations



Local Project Management

A local Project Manager will be appointed at the Project launch. Based in Ottawa, he/she will ensure that the targeted Canadian content is achieved. They will work in close cooperation with the various managers of the project who contribute to the Canadianization of the project. The team will include a Procurement Manager, Industrial Manager, Engineering Manager and Human Resources Manager for instance The Project Manager will help them to set up a localization strategy in order to satisfy and even exceed the local content. They will issue a regular internal report allowing the Authorities to check on the contractual conformity of the 25 % minimum Canadian content.

Supplier management

In order to guarantee the quality of Alstom's products, every supplier retained for the OLRT Vehicles will be qualified by Alstom's purchase quality department.

To date, Alstom already have in their qualified supplier data base a certain number of Canadian supplier such as indicated in Appendix B and **Table 5.4-3**. However Alstom will extend this Canadian supplier base and develop a specific procurement strategy for OLRT in order to deliver the objectives for sustainable procurement, including providing supply chain opportunities in the local area, especially to new and small and medium sized enterprises.

Alstom will advertise their upcoming contracts on their website, in local newspapers, procurement websites and relevant trade journals. In addition to this, they will include a list of key contacts for each current supplier contract and sub-contracted service, to encourage second and third tier potential suppliers to contact key suppliers and work in collaboration. Last but not least, Alstom will organize a Supplier Day in Ottawa to communicate the Project's main objectives and the needs in terms of purchase and schedules.

Management of the procurement process for new Canadian suppliers

A dedicated procurement team lead by the Procurement Manager will manage the procurement process, they will be supported by the various disciplines in preparation of the tender documents.

Procurement will be a key part of the design and construction progress meeting. Tender lists, procurement status, recommendations and performance against local supplier procurement targets will be discussed and monitored. If local supplier procurement targets are not being met the local Project Manager will instigate corrective actions.

Evaluation of tender submissions

A clear evaluation criteria will be established that provides a weighting in favour of local suppliers and sub-contractors.

The evaluation criteria will be a two stage process. The first stage will be a compliance check and submissions will either pass or fail. The compliance check will ensure that the suppliers/ sub-contractors have the capability to deliver the contract safely. The pass/ fail will be assessed on:

- Safety performance
- Capability (Turnover, relevant experience)

If suppliers/ sub-contractors pass the first stage then a weighted scoring criteria will be used to select a supplier/ sub-contractor. The scoring criteria will include:

- Location (Local, regional, national or international)
- Commercial competitiveness
- Programme and methodology
- Quality proposals
- Environmental control proposals
- The suppliers / sub-contractors use of local suppliers, sub-contractors, labour, plant and material
- The suppliers / sub-contractors recruitment and training opportunities for local people

The above scoring criteria with weightings will be developed at Preferred Proponent stage.

Management of suppliers/ sub-contractors

On contract award a start up meeting will be organized between RTG, Alstom and the supplier/sub-contractor. For suppliers this will be less involved, but for sub-contractors this will be an in depth meeting chaired by the relevant System or Element Project Manager. The following will be discussed and formalized:

- Management team
- Frequency and content of progress meetings
- Programme
- Quality standards and regime
- Health and safety outline (this will be followed with a Health and safety start up meeting)
- Environmental issues and control measures
- Commercial

Labour

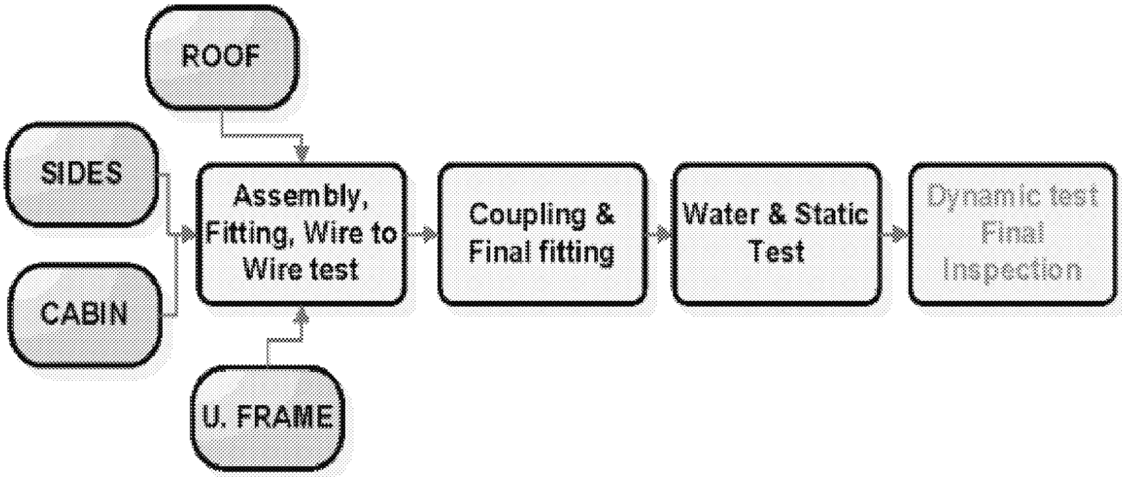
Alstom has develop a standard manufacturing process (APSYS) applicable to all rolling stock types and all manufacturing sites. This standard process will be deployed in the Ottawa MSF, where vehicles will be assembled.

A dedicated Ottawa Industrial Management Plan will be defined at the beginning of the Project. The objective of the industrialization plan is to:

- Define the manufacturing tools and process, and optimise the related investments.
- Build the Product Bill of Material (PBOM) from the Product Breakdown Structure defined by the Technical team

Final Vehicle assembly will be done using Canadian workers in the MSF in Ottawa. The modular design of Citadis Vehicles easily supports production and final assembly of the sub-assembly modules (roof, sides, cabin, and underframe) in the Canadian facility (see **Figure 5.4-2**).

Figure 5.4-2 | Modular Design Facilitates Production and Assembly



The final dynamic routine tests will take place on the OLRT System track.

Subcomponents and Components

Drawing on its supplier database, Alstom will use Canadian and Ontario suppliers for key components as shown in **Table 5.4-3**.

Subassemblies

The main subassembly frames (underframe, roof, cabin and end ring) will be produced individually including welding and painting outside the MSF building.

These frames will be delivered to the MSF where they will be pre fitted and partially tested including the cabling.

Section assembly

The pre fitted modules will be assembled to form each section based on riveting technology. After the dimensional control of the section structure, the final interior fitting and installation of roof equipment will be carried out. An assembly control (mainly electric continuity and dielectic test) is carried out before train assembly (see **Cut Sheet 5.4.1-CS-1001**).

Vehicles assembly

Each completed section is placed on bogie (s) and then coupled to the next vehicle. When the 4 cars of a train are coupled, final wiring is completed before the train is transferred to testing.

Vehicles testing

Each vehicle will be tested in static and dynamic mode according to a standard serial test program designed to test all vehicle functions.The final dynamic routine tests will take place on the OLRT System track.

Table 5.4-3 | Supplier Database Located in Canada

Supplier Name	Location	Product	Logo
Faiveley Transport Canada Inc.	1002 Rue Sherbrooke Ouest, Montréal, Québec	Brakes	Faiveley TRANSPORT
Mersen	88 Horner Ave, Etobicoke, Ontario	Electrical components	MERSEN

Supplier Name	Location	Product	Logo
Wabtec	475 Seaman St, Stoney Creek, Ontario	Passengers doors	Wabtec CORPORATION
Ceit Groupe	5650 Rue Trudeau, Saint-Hyacinthe, Québec	Interior Lining	CEIT Groupe
Knorr Bremse	675 Development Drive, Kingston, Ontario	Brakes	KNORR-BREMSE
Dimension Composite	2530, 95e Rue, Saint-Georges, Québec	GRP Front End	DIMENSION composite
I Gard	7615 Kimbel St., Unit 1, Mississauga, Ontario	Braking resistor	i GARD
Alstom Canada Inc.	1010 rue Sherbrooke, Montréal, Québec	CCTV	ALSTOM
Prelco	94 Bouleverd Cartier, Rivière du Loup, Quebec	Windows & Windshield	Prelco

Other Items

- **Project management** - Alstom's Project Core Team will be based in Ottawa. This team will be in charge of all OLRT rolling stock requirements from the start of the Project until the end of warranty
- **Engineering** - Alstom's Field Engineer will be in charge of the warranty, reliability and maintainability growth phase. Work will be performed locally by Canadian engineers.
- **Test equipment** - Serial tests on each Vehicle will be performed on OLRT System track by Canadian Engineers. NRC's climatic chamber in Ottawa may be used for specific climatic-type tests.
- **Freight** - Canadian freight companies will be used to transport vehicles and goods.
- **Warranty** - During the warranty period, Canadian engineers will ensure Vehicle reliability and availability.

Technology Transfers

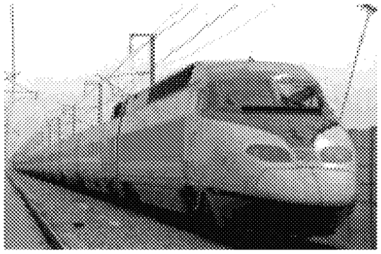
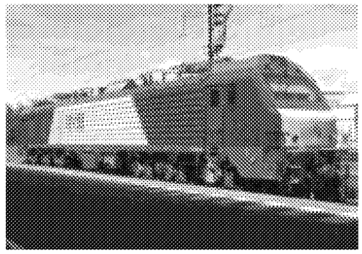
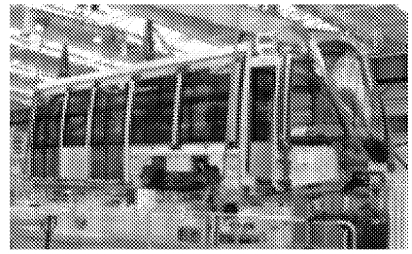
Alstom Transport has more than three decades of experience in technology transfer. In response to a diverse range of local content requirements Alstom Transport has implemented numerous partial and total technology transfers around the world. **Table 5.4-4** shows some of Alstom's main projects with a local content requirement.

Table 5.4-4 | Examples of successful Technology Transfer

Header	Header
34 Korea - KTX (Korean High Speed Train)	Full transfer from France to Korean partners
500 China CoCo Electric locomotives	Full transfer from France to Chinese partners
Montreal Metro (Bogies)	Transfer from Alstom Le Creusot to Alstom Sorel Tracy (Quebec)
70 Madrid LRV	Transfer from La Rochelle (France) to Barcelona(Spain)
37 Istanbul LRV 20 Acela Express trains	Transfer from Valenciennes (France) to Katowice (Poland)

Header	Header
20 Acela Express trains	Traction cubicle: Transfer from Tarbes (France) to Hornell (USA) Trucks: Transfer from Le Creusot (France) to Bombardier (USA)

Figure 5.4-3 | Examples of Successful Technology Transfer

Korean High Speed Train	China Locomotives	Istanbul LRV
		

Once the two first OLRT Trains have been fully validated by Alstom's Center of Excellence in Valenciennes, France, Alstom will complete a technology transfer to Canada. This process ensures that the entire Train will be assembled in the Ottawa facility described below. Major components of the technology transfer process include the following:

- Preparing the manufacturing plant
- Installing and testing of validated tools for pre -assembly
- Preparing documentation, training and support for local staff

Manufacturing Facility at the MSF

Two main functional areas are required to produce the Citadis vehicle:

- A manufacturing building (4000 m² approx. + additional warehouse)
- A static test building to perform water tightness and functional static test – (2500 m² approx.)

The two MSF tracks designated for heavy maintenance will be used for final vehicle assembly. The MSF will be available for manufacturing equipment installation in early 2015. The vehicle wash facility area will be used to perform the water tightness test. The planned layout is shown in **Cut Sheet 5.4.1-CS-1001**.

Hiring Plan and Skills Development

Alstom intends to hire more than 100 people locally to manufacture the OLRT Vehicles. These workers can be transferred to maintenance activity on conclusion of manufacturing. The personnel breakdown will be approximately 80% workers and 20% management. In addition, the hiring plan will consider other personnel for the Project management team and local engineering team.

Alstom's recruitment strategy will be based on two search modes: active and passive.

Active Candidate Sourcing

- Posting the jobs on niche sites to reach a national audience within specific technical disciplines
- Utilization of "Banners" on the main page of niche sites to highlight Alstom jobs in comparison to competitors

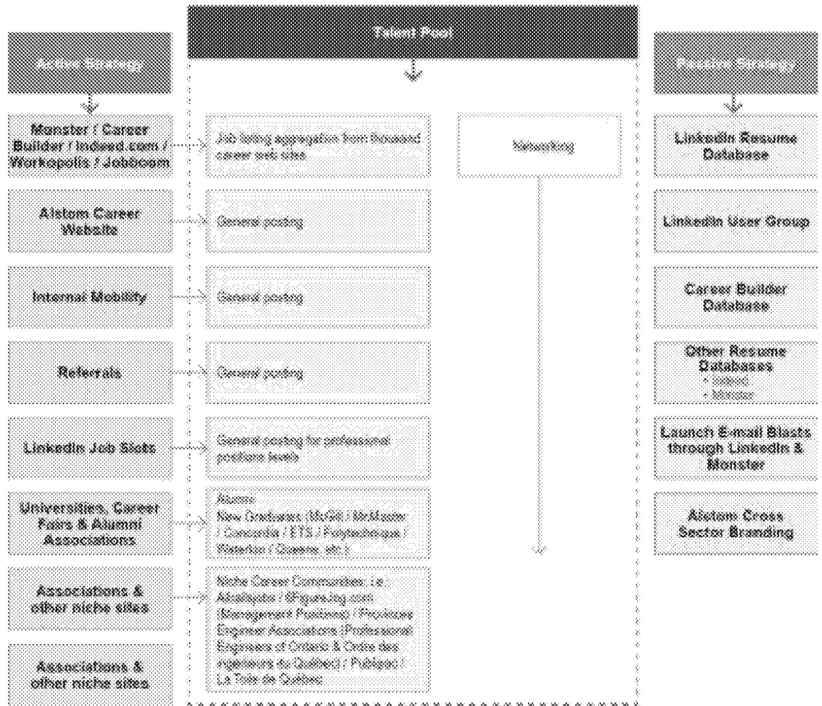
- Utilization of "e-mail blasts" to send Alstom job announcements to candidates who are registered viewers of these various niche sites

Passive Candidate Sourcing

- Using Social Media/Business networking tools
- "Mining" third party applicant databases containing résumés

These two sourcing methods are performed simultaneously and therefore have several benefits:

- Branding and visibility reinforcement
- Multiple sources of applications = multiple sources of advertisements
- Supporting the search for key technical talent: useful niche sites for technical experts
- Being able to compete wi th strong competitors using well advanced Social Media strategies
- Methodology is applicable to all other disciplines (Key Management positions, etc).



This strategy will be applied to all type of positions:

- Internships
- Technical Experts
- Production employees
- Senior Management
- Professionals

The standard recruitment process is as follows:

- The first selection of resumes is managed by the Human Resources Department
- The selected resumes are sent to the Managers for their review
- The relevant Manager and his/her team review the resumes and communicate the preferred selection to the Human Resources Department
- The HR Department phones the selected candidates with selected questions and send feedback to the relevant Manager
- The Manager, the HR Manager & his/her team interview the candidates face to face and make the final decision
- A background check is implemented on the final candidate. Some psychological tests could be added to the selection process

In accordance with the strategies discussed in this section, RTG is confident that the 25% Canadian Content can be achieved.

5.4.3 LIGHT RAIL VEHICLES

Passenger Vehicles are the dynamic linking element of any LRT system and contribute significantly to the customer's experience. The OLRT Vehicles must consistently address a wide range of factors including safety, comfort, availability and local conditions. For these reasons and more, the proposed OLRT vehicle is a Citadis 100% low-floor LRV. Since production of Citadis vehicles began in 1997, more than 1,500 Citadis LRVs have been sold worldwide. More than 40 cities have purchased the Citadis LRV, thereafter accumulating more than 245 million kilometres for this service-proven vehicle.

Citadis vehicles deliver a wealth of advantages in support of Passenger comfort, and system capacity, aesthetics, availability and safety. This superbly engineered vehicle is easily customizable, easily accessible and easier on the environment. Citadis is also the only 100% low-floor LRV in the world running in daily operation at 100 km/h. Key advantages of the proposed Citadis vehicle include the following:

- **Customer Comfort – Best in class**
  - Design focused on Passenger comfort and safety
  - Modular design allows multi -purpose areas
  - Large windows provide bright, attractive riding experience
  - Two-level suspension truck provides ultra -smooth trip and high comfort levels
- **System Capacity - 100% Low-floor Vehicle**
  - Vehicle interior is configured with no steps, allowing for safer, quicker and smoother Passenger flow and reduced dwell times
  - More efficient standing capacity compared to a 70% low -floor LRT
  - Improved access for Passengers with mobility restrictions
- **System Aesthetics – Visual appeal**
  - Sleek, lower profile Vehicle integrates beautifully into the urban environment
  - Iconic addition to the Ottawa landscape
- **System Availability – State-of-the-art systems; global expertise**
  - Citadis benefits from Alstom's global expertise as a Train maintainer
  - State-of–the-art on-board monitoring system for remote diagnosis and troubleshooting
  - Braking equipment, gear-box, traction motor and wheels are directly accessible for inspection and replacement from the side of the Train without truck removal
  - Exclusive rapid-mounting system replaces side window in 30 minutes
- **System Safety – Safety enhancements**
  - Designed according to the latest safety standards (EN 50126)
  - Safety is considered through the entire lifecycle of the Vehicle: from concept to O&M
  - Compliant with ASME-RT1 requirement for structure and crashworthiness
- **Easily Customizable – Modular design**
  - Designed to be easily customized to accommodate Ottawa's specific requirements
  - All Citadis Vehicles are based on the same proven-design sub-systems for improved availability
- **Increased accessibility – Mobility for all**
  - 100% low-floor allows ease of use for all Passengers
  - Leveling system ensures perfect alignment between platform and the LRV
  - Large corridors and gangway

- **Environmentally Sensitive – Reduced footprint and impacts**
  - Vehicle is recyclable at 95%
  - Reduced energy consumption
    - LRV features regenerative braking
    - Citadis is fitted with a single -stage gearbox for better efficiency
    - Interior lighting is based on low -consumption LED
  - Vehicle design reduces noise levels inside and outside the Train

5.4.3.1 Branding Strategy & Approach

Best or Leading Practices

The OLRT system has been described as the most important infrastructure project in the City since the building of the Rideau Canal. This is the first leg of a legacy project that will shape the growth and liveability of the C ity for generations to come. Branding this iconic system creates a unique opportunity to enhance the reputation and quality of life of the City and her citizens.

Station and urban design are critical components in developing a 'complete brand approach', but the Vehicles are the dynamic linking element and ultimately become the 'face' of the brand. Too often, Vehicle livery has been largely regarded as an extension of the agency, a "uniform" for vehicles. This ignores the potential to capture and communicate the brand promise with each passing view of, or travel experience onboard, an OLRT V ehicle.

As a member of RTG, Alstom is committed to working with the City to integrate the Vehicle brand with the overall brand of the System. We will work with the City during its System branding process to develop a full understanding of the complete identity for the OLRT. More specifically, the Vehicle brand will encompass the Vehicle front styling, interior and exterior colour schemes, window tinting and livery.

Brand Building

To develop a compelling and positive Vehicle brand, the branding strategy should incorporate the following elements.

- **A long-term vision** - An explicit definition of what the brand is to represent in the eyes of its target audience.
- **A better product** - Product quality is an ideal branding variable. Working within the budget envelope, RTG will assist the City in delivering a better product across Vehicles.
- **An analytical edge** - RTG will help the City use research and consultation for a clear understanding of transit users (current and prospective) and their needs.
- **An exercise of creativity** - Vehicle branding requires creative thinking, planning and execution through every element of the Vehicle.

RTG Approach – Fully Integrated Branding

RTG understand that branding goes beyond Vehicles and must have a 'complete design approach' to be successful. Our partnership approach with the City, our expertise, and our lessons learned will benefit the citizens of Ottawa and create a world-class LRT identity.

Alstom enjoys a long-established global reputation for expertise and innovation in transportation solutions. One reason for this is the Design & Styling (D&S) department created in 2005, and which is unique in the railway industry. The department comprises 20 top designers, each dedicated to creating designs that harmonize with the general configuration of the Vehicle - and ensure that Vehicle branding adds a compelling and exciting element to the overall System brand.

The D&S department's cross-functional organization is particularly well suited to meeting the specific needs of envisioning and incorporating key branding elements:

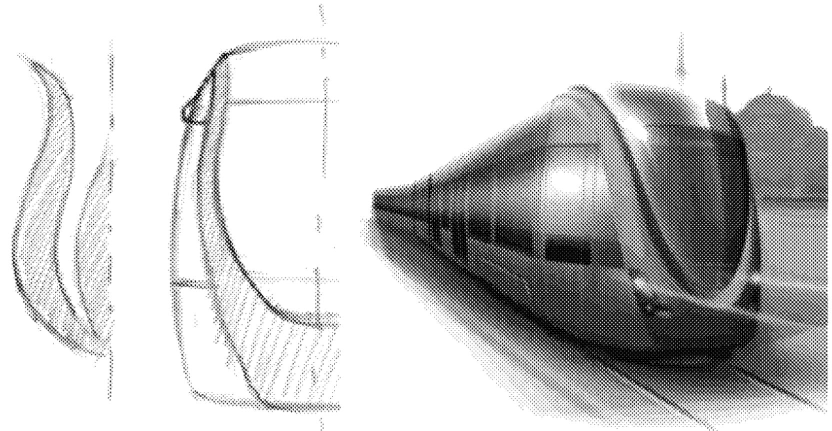
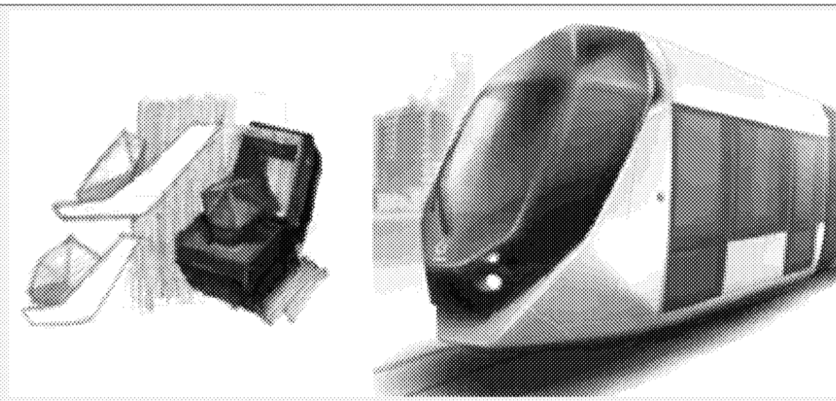
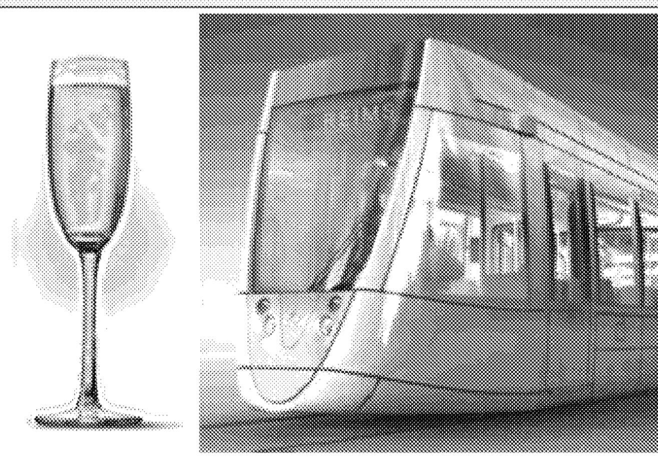
- Consolidating competencies in terms of design, digital modelling, colours, materials, and lighting
- Producing designs suited to each client's cultural context
- Stimulating creativity

For the OLRT Project, Alstom will follow its normal practice and use a highly collaborative approach to branding with active and ongoing involvement of the City and key Stakeholders. A multi-disciplinary team, including graphic designers, architects, planners, engineers, branding specialists, and Stakeholders is involved in strategy and ideation. Working with the City's branding process, the D&S department will analyze the cultural, economic, political and geographical context of the Project. This is summarized through photo reports and keywords. The objective is to define the artistic theme which will be used as a connecting thread for creation throughout the Project.

A unique competitive advantage of our modular product configuration is that the front end and interior arrangement can be customized and become a critical component of the brand. The D&S department will propose various versions of shapes for the interior and exterior, colours and trims in support of the final branding approach.

Branding is completely integrated into the industrial design process for the Vehicle. See **Section 5.4.3.7** for a complete description of the industrial design process. **Table 5.4-5** shows three examples of how Vehicle design becomes a key brand element.

Table 5.4-5 | Vehicle Design

City and Theme	Vehicle Design
LRV Istanbul – Theme: Tulip	
LRV Dubai – Theme: Diamond	
LRV Reims – Theme: Champagne Flute	

Branding by Design

The Alstom D&S department follows a multi-step iterative process that ensures Vehicle design delivers maximum branding value and quality results.

Design, Step-By-Step

The design process is divided into six steps: preliminary meeting, pre-choice meeting, choice meeting, freeze meeting, working mock-up and representative mock-up.

Round-The-Clock Dialogue

Teamwork is part of a methodology that has been proven over time. Face-to-face meetings will establish a rapport with the client that makes the choice process simple and straightforward. Once the design principles are agreed upon, they are integrated into product design. In addition, the Design & Styling department can work directly with external designers or local partners.

A Committed Team

The dialogue takes place over several months. An Alstom project manager first proposes a work schedule and this sets off a feedback loop involving designers, modellers and colours and materials experts. These in turn consult with engineers and suppliers who speak a common language.

A Proven Methodology

Listening to client needs is built into the team-based approach. It is imperative to ask the right questions to fully grasp the nature of each project. Only this kind of quality interaction gives rise to previously unexpressed needs.

Feasibility

All elements proposed during the selection process are feasible. The design team works with software that is compatible with the one used by railway engineers. Adjustments can be made at any stage of the process, from the rough sketch to the 3D model. A five-axis milling machine then renders the design into a volumetric model.

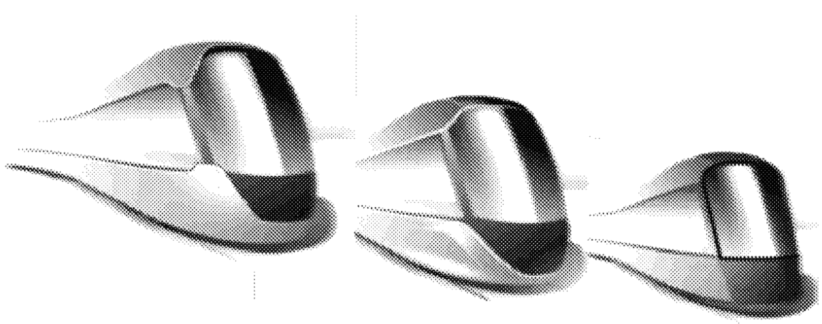
Design Manual

At the freeze meeting, customers are handed a Design Manual detailing the specifications of their proprietary train design. The Manual lists up to 80% of the shape characteristics of a Train, both interior and exterior. It also includes a graphic line, colour preferences, seating configuration, lighting options and materials. The signing of the Design Manual serves as a contractual agreement between Alstom and its clients.

OLRT Treatment Exploration – Positioning Led Design

Figure 5.4-4 shows examples of branding schemes are provided only as examples, to demonstrate how different positioning choices could inform final branding.

Figure 5.4-4 | Preliminary studies of three front end shapes proposed for OLRT



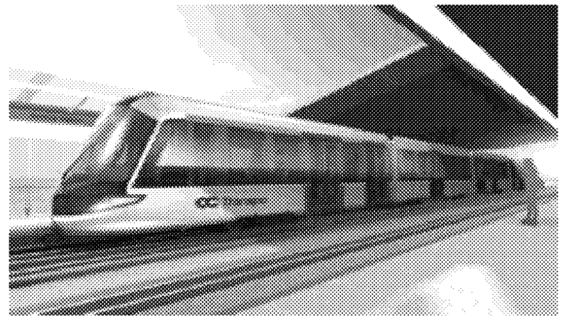
To demonstrate the scope and flexibility of our branding process the Alstom D&S department and RTG have created three preliminary design alternatives for exterior design and interior design. Following a review of what is building the City today, and what the City is building for tomorrow, these alternatives have been specifically created for Ottawa. Starting with the identification of key elements that could form the basis of a strong OLRT brand foundation, we have shown how we translate these into shapes, graphics and colours in the vehicle design.

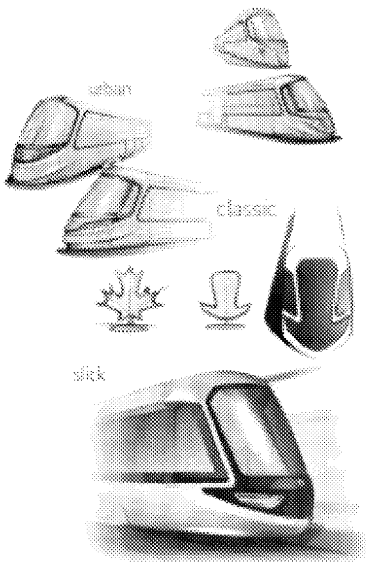
The Citadis product is a technically proven design, but the platform has been purposely designed such that it can easily be customized for each of our clients. This creates flexibility and possibility from the outset. The alternatives included here are intended to demonstrate the degree of differentiation possible – and are the starting point for a collaborative branding process with the city.

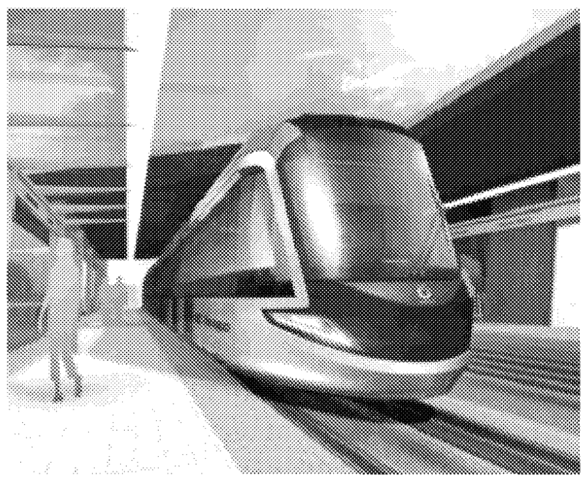
Exterior Design

Theme A: Strong and Free

This design incorporates a strong graphic shape on the front end. It retains the essential lines of the maple leaf to create a design that recalls the national symbol without being literal and obvious. The graphic and form create a style that is contemporary today, and will become a classic in the future. It is strong, solid and present. The surface treatment is both detailed and sleek, conveying a sense of quality and pride befitting the stature of Canada's capital city.

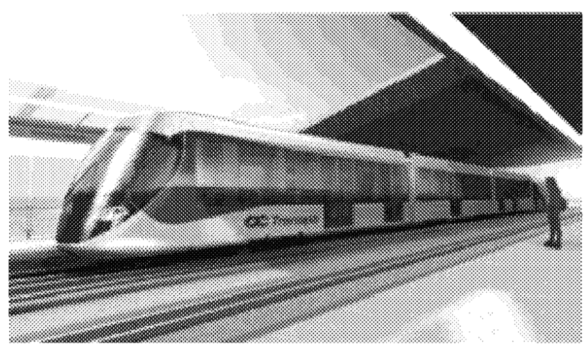


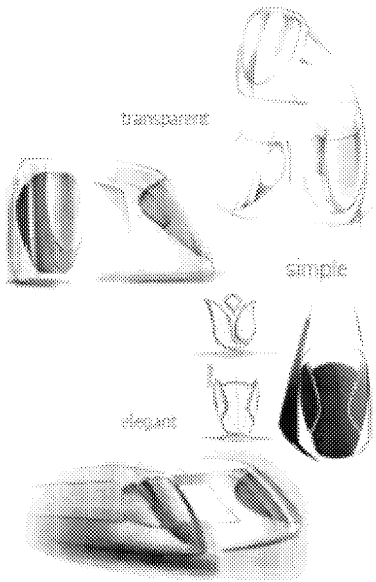


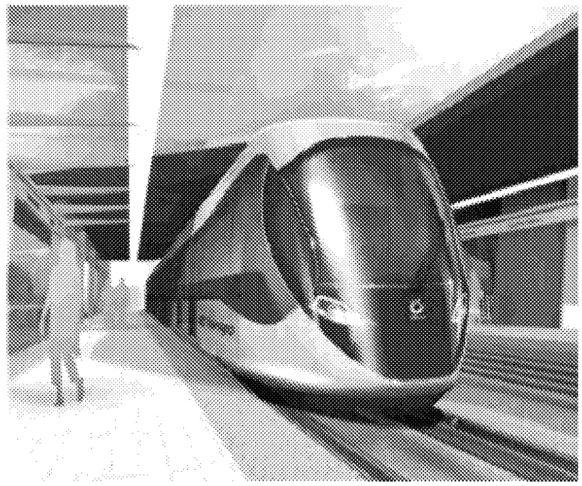


Theme B: Quiet Strength

Ottawa is home to the world's largest tulip festival. This theme takes inspiration from the tulip petal and is well balanced and softly curved. The result is highly aesthetic and elegant, and conveys a sense of quiet strength. The large windscreen with integrated headlights creates a heightened sense of transparency and expansiveness. A comparison of this treatment to that of the Istanbul LRV is a strong example of how we take the essence of a city and transform it into a unique brand element. Although both cities claim the tulip as an iconic element, the OLRT expression is uniquely Canadian.

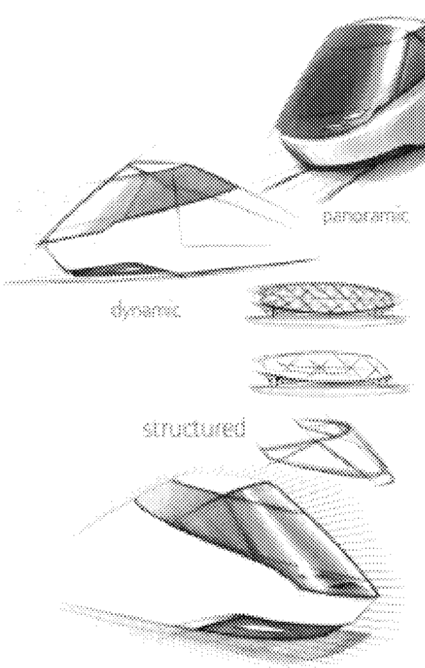


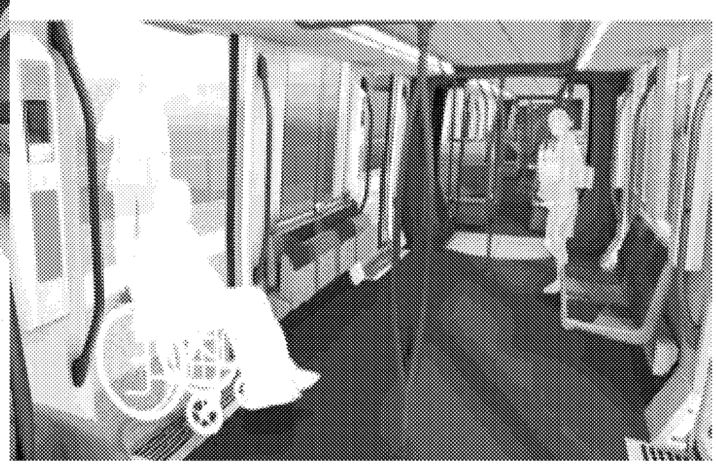




Theme C: Fast Forward

This theme takes its inspiration from some of the most advanced architectural features in the City. The design conveys a strong sense of purpose and motion; at once dynamic and panoramic. The sleek continuous front end is futuristic and powerful – with just a touch of attitude. The design makes a strong statement that the City has arrived.





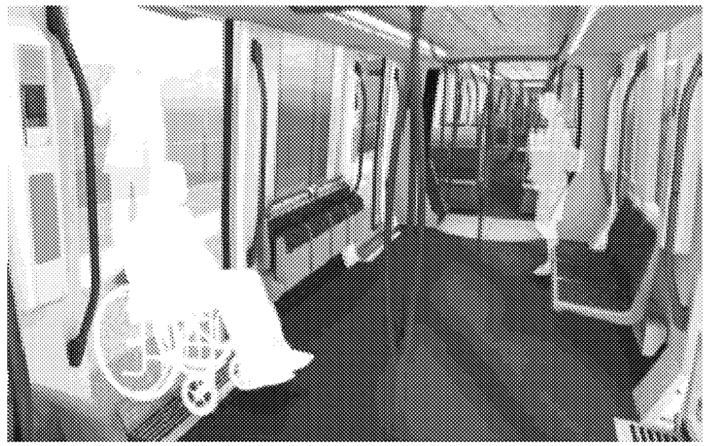
Interior Design

Theme 1: Geometry

Geometry is the basis of all strong composition. With a starting point of straight lines and geometric shapes this design theme shows how intriguing the basics can be when skillfully combined. In this simple but bold choice, a sense of animation is created by combining strong contrasting colours with neutral elements. The result is strong, contemporary and distinctive.

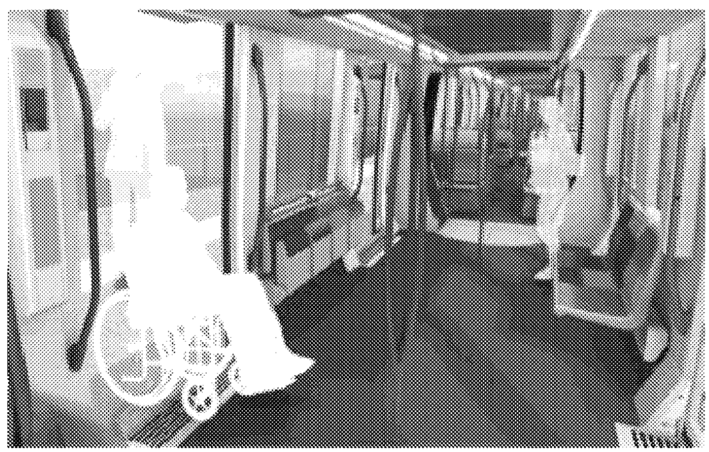
Theme 2: Facets

In this design it appears that facets of light from passing buildings are reflecting within the Passenger car. The diamond grid pattern on the ceiling gives the impression of light reflecting off the water - creating a bright, animated ambiance. The classic colour scheme produces a sense of calm and comfort. The use of red creates an additional feeling of warmth.



Theme 3: Tulip

This innovative interior design dramatically separates the ceiling from the rest of the interior. Nature images and landscapes in the ceiling panels give the impression of a contemporary photograph exhibition. These pictures are filtered using plain colours and low contrasts, creating a calm, contemplative atmosphere. The images are a subtle reminder of the simple pleasure of taking time each day to really look at our surroundings.



All of the elements shown in the three external and three internal design options are interchangeable. These design options demonstrate how character and interest can be added to the Vehicle branding process by integrating elements that reflect on local history, aspirations, culture, and unique aspects of the surrounding landscape.

5.4.3.2 Proposed Vehicle

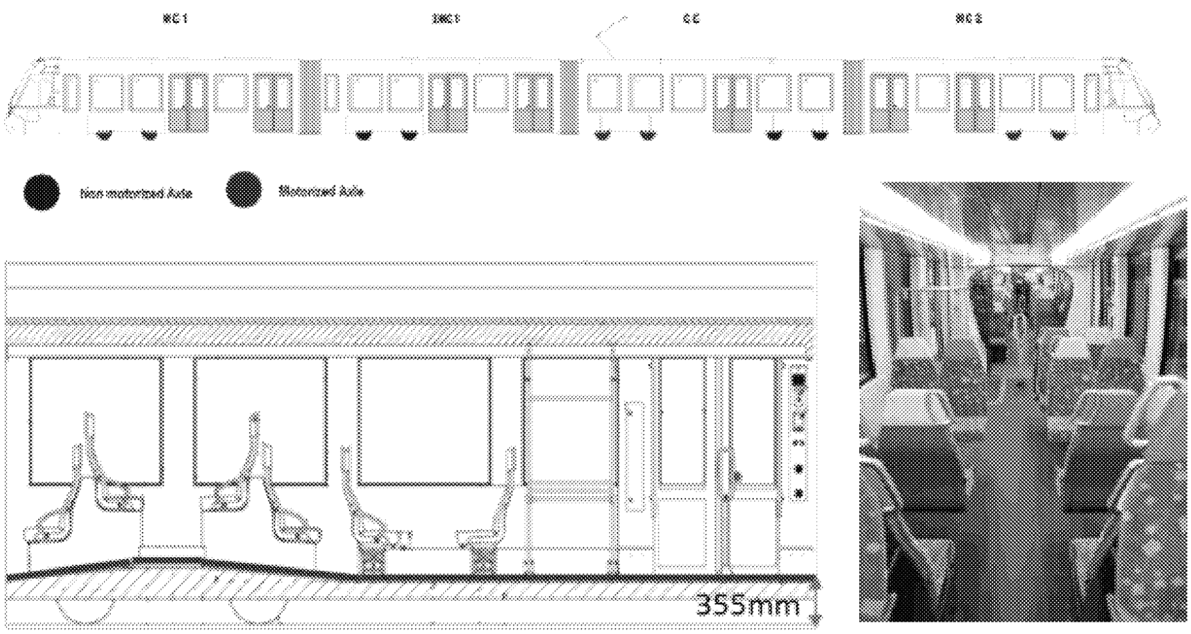
General Arrangement and Performance Level

The proposed Vehicle for the OLRT Project is part of the Citadis product range. As shown in **Figure 5.4-5**, each Vehicle is composed of the articulating sections.

- 1 extremity section with Driver's cabin and motor truck (MC1)
- 1 intermediate section with one trailer truck (IMC1)
- 1 centre car with one trailer truck and one motor truck (CC)

- 1 extremity section with Driver's cabin and motor truck (MC2)

Figure 5.4-5 | Articulating Sections and Low-Floor Arrangement



The Vehicle features 100% low-floor in the Passenger area for an improved ride experience:

- **Optimized Passenger Flow** - Safer, quicker and smoother Passenger flow inside the Vehicle to reduce dwell time.
- **Improved Comfort** - The flat floor provides Passengers with an increased sense of comfort.
- **Improved Safety** - No step means no trip-hazard in the Train.
- **Improved accessibility** - All Passengers, including those with restricted mobility, strollers or luggage can move easily within the Passenger area.
- **Optimized Capacity** - In partial low-floor vehicles, standing Passengers remain in the low-floor sections; in a 100% low-floor Train, they have full access to all available space within the Vehicle.
- **Improved aesthetics and urban integration** - 100% low-floor vehicles are lower than partial low-floor Vehicles resulting in smoother vehicle profiles and reduced visual impact.

Other key Vehicle features include the following:

- Maximum operating speed of 100 km/h for high-capacity line.
- Large windows in the Passenger compartment create a feeling of spaciousness.
- Seven dual-leaf sliding-plug Passenger doors are evenly distributed throughout the Train for reduced dwell time. The Passenger-exchange length over useful Vehicle length (i.e. not including the Driver's cabin) is higher than 20 percent.
- An HVAC unit located in each car ensures optimum thermal comfort in the Passenger cars.
- The proposed width and length combination optimizes capacity while ensuring a high level of Passenger comfort.
- Major sub-systems, such as HVAC, traction cubicle or air compressor, are roof-mounted and concealed by lateral roof fairing profiles presenting a pleasing, uniform appearance when seen from road level.
- Vehicle can be operated in multiple units of two vehicles.
- Bi-plan side walls produce a more aesthetic vehicle with a large Passenger compartment while reducing the vehicle dynamic envelop.
- The Vehicle's modular design enables large use of pre-assembly, making it easy to assemble and maintain.

The Vehicle layout is shown in **Drawing 5.4.1-SW-101**. **Table 5.4-6** summarizes the other main characteristics.

Table 5.4-6 | Vehicle Characteristics

Characteristics	Dimension/Performance
Length over coupler face	49 metres
Vehicle width	2,650 mm
Vehicle tare weight	78 tonnes
Number of sections	4
Number of trucks	5
Number of motor trucks	3
Seated Passengers	104 seats + 16 flip-ups
Standing Passengers with 3.33 pass/m²	180 Passengers
Total Train capacity at 3.33 pass/m²	300 Passengers
Comfort rate with 3.33 pass/m²	40%
Wheelchair areas	4
Double doors	7

Performance Reliability and Safety of Proposed Vehicle

The proposed Vehicle is an evolution of Citadis based on Istanbul Citadis and SNCF Nantes Citadis to fulfil OLRT requirements (**Section 5.4.3.3** provides more details). The main modifications to the Citadis Nantes are the following:

- Replacement of the 25 kV/750 Volts dual-voltage traction package by a 1500 Volts traction package
- Lengthen car body to provide Passenger capacity in line with O LRT System performances
- Addition of one door on MC1, MC2 and IMC1 to manage Passenger flow and reduce dwell
- Removal of the handicapped toilet in MC1
- Replace SNCF signaling system with Thales CBTC system
- Implementation of design solutions to comply with climatic conditions in OLRT environment
- Modifications to comply with standards and regulations specific to OLRT environment and Canadian content (for example: addition of service proven pneumatic secondary suspension to comply with ADA/AODA)
- Modifications to comply with Transport Canada regulations, only to the extent that the regulations are appropriate for LRV vehicles. For example RTG does not plan to provide onboard washrooms.

Performance

Table 5.4-7 | Performance of Proposed Vehicle

Parameter	Performance
Maximum Speed	100 km/h
Acceleration: Initial maximum vehicle acceleration (OCS voltage>1500 V, AW2 Loading) up to 32 km/h	1.34 m/s² +/-5%
Full service electric brake rate at AW3 loading from 64 km/h to 5 km/h	1.34m/s²
Full service blended (electric/friction) at AW3 from 80 km/h to standstill	1.34m/s²
Maximum service blended (electric/friction) + track brake up to AW3 from 88 km/h to standstill	2m/s²

Parameter	Performance
Full service friction brake rate at AW3 loading from 80 km/h to standstill	1.34m/s² +/-10%
Emergency Brake at AW3 load from 48 km/h to standstill	≥2.24 m/s²
Friction only at loads up to AW3 load from 80 km/h to standstill	1.78 m/s² +20%/-10%
Parking brake holds an AW3 Train on a 6% grade indefinitely	Yes
Jerk rate	From 0.44 to 1.34m/s3

Reliability

As with every product developed by Alstom, the Citadis range and Ottawa's Vehicle are designed to deliver a high level of reliability and to allow for easy maintenance operations. **Table 5.4-8** shows figures applicable for the proposed OLRT Vehicle.

Table 5.4-8 | Vehicle Reliability

Parameter	Performance
Mean distance between Service-Disrupting Failures over a 12-month period (per LRV)	52000 km
Mean Time To Repair failures (MTTR)	1.5 hour
Maintenance periods	12500 km 25000 km 75000 km 100000 km 300000 km 400000 km 600000 km 900000 km 1200000 km
Failure recovery achievable within "x" minutes of two Trains converging (i.e. time to couple to an immobilized Train, reconfigure the consist, and start moving it off the line)	30 min

Safety

Safety is at the core of every Alstom product. During development of the Citadis product range, close attention was paid to all safety-related aspects and items to make Citadis one of the safest Trains on the market. For the OLRT Project, a complete safety study will be part of product development. This study will take into account the tremendous amount of in-service experience on the Citadis product range as well as all the requirements, environmental and operational, specific to the OLRT. Safety studies will be conducted in accordance with the EN 50126 standard and the Safety Assurance process outlined in **Section 5.1.5.1**. For each hazard identified in the PHA (Preliminary Hazard Analysis), Alstom will submit proof that the Ottawa Vehicle complies with the safety target.

Safety Analyses

The subsystems or equipment liable to create events identified in the PHA will undergo detailed analyses, conducted in accordance with at least one of the following methods:

- **Fault Tree Analysis taking into consideration the different events -** A deductive method starting from a single and well identified event, leading to basic events that are each independent and amenable to calculation of their probabilities (e.g. breakdowns, human mistakes, external conditions).

- **FMECA (Failure Mode Effects and Criticality Analysis)** - An inductive method whereby, starting from the exact definition of the functions of a device or assembly, one can systematically seek out the failure modes and their consequences or effects on the Citadis set.

These analyses will demonstrate that the steps taken to deal with risks are or will be set up to reduce the probabilities of occurrence related to the events in categories of gravity 3 and 4 to a negligible level. These analyses will be entered in the "rolling stock safety level justification file". The steps needed to deal with risks may consist of the following:

- Structural provisions
- Functional provisions
- Provisions related to the detection of the failures
- Provisions related to standards
- Calculations
- Tests
- Quality procedures
- Maintenance procedures
- Operating rules

Corrective action will be taken if results do not meet objectives. Examples of safety hazards considered are as follows:

- Loss of command of Emergency Brake
- Insufficient Emergency braking effort
- Propulsion fails to cease when Emergency Brake is requested
- Train moves in wrong direction
- Door opens spontaneously when not commanded
- Door opens on wrong side of car
- Excessive currents or overheated equipment cause fire hazard
- Train moving when doors are not closed and locked
- Cars in Train separate when not commanded
- Indication of uncoupled when not uncoupled

Synthesis of Safety Analyses

Safety-Critical Item List

The safety level concerns all equipment which requires safety analysis during the Project by the Alstom RAMS team. The Engineering Department is in charge of designing these assemblies and validating them by using calculations or design principles (in accordance with the normative documents). Safety analyses are performed to verify the design.

Safety levels are attributed during the design phase by the safety department for the equipment being considered. The safety level of an assembly corresponds to the consequences of the rupture of a single component of the assembly in relation to its effects on people, the equipment and the environment. The classification of safety levels used for the design, whether screwed or welded assembly, is as follows:

- **Level 1 – High:** The rupture of the assembly leads to physical injury and global failure of the assembled system. => Disastrous level
- **Level 2 – Moderate:** The rupture of the assembly affects global operation of the system or may have consequences involving physical injury. => Critical and significant level
- **Level 3 – Low:** The rupture of the assembly does not directly affect the global operation. Consequences involving physical injury are highly improbable. => Minimal level

Safety Synthesis File Justifying the Safety Level of the Rolling Stock

The file justifying the safety level of the rolling stock consists of all safety notes relating to analysis of the events included in categories of gravity 1, as follows:

- An overall description of the event and the associated subsystems
- A qualitative and/or quantitative analysis of the event grouping together the structural provisions, the quality links, the operational surveillance systems and the requirements during operation and maintenance

Requirements for Safety during Operation (Line and Maintenance)

"Requirements for safety in operation" is the outcome of the safety analyses, bringing together all the customary maintenance and operating requirements needed for preserving safety. This document takes into consideration the conditions affecting safety and requiring application of one or several logistics actions to preserve safety.

Analysis of Test Plans

The objective of this task is to check that the requirements and recommendations resulting from safety analyses concerning the tests to be performed have been taken into consideration.

Analysis of Procedure for Application of Modifications

Following an encoded modification in design, a procedure is set up for applying these modifications. The objective of safety is to check that the proposed modifications in accordance with this procedure comply with safety requirements.

Safety File

The safety file consists of all documents describing the steps taken to deal with risks and/or those demonstrating for a given subject that the risk studied has been eliminated or controlled.

Winterization Measures

Due to Ottawa's extreme climate, some winterization solutions will be implemented on the OLRT Vehicle. Adaptation will be concentrated in two main areas:

- Ensure Passenger and Driver safety and comfort
- Ensure proper operation of rolling stock

The solutions implemented on the OLRT will be based on the following:

- Alstom's extensive experience in manufacturing vehicles for environments with heavy snow and extreme cold conditions (e.g. Citadis for Grenoble, X40 Train for Sweden, Helsinki-Saint Petersburg high-speed tilting Train, Moscow tramway, EP 20 and 2ES5 locomotives for Russia, KZ8A and KZ4AT locomotives for Kazakhstan)
- The future European Norm PrEN16251 - Railway Application – Environmental conditions - design and test of rolling stock under severe conditions

The extreme cold climate related issues are the following:

- **Extreme cold temperature** - This will affect material mechanical characteristics; reliability of electronic, pneumatic and hydraulic equipment; thermal comfort, and cold surfaces in Passenger area.
- **Snow** – This will impact filtration at air intake, roof and underframe accumulation, presence on track, and visibility.
- **Ice formation** - Main issues linked to ice formation are improper operation of unprotected moving parts such as doors or pantograph; risk of impact of ice blocks on underframe equipment wiring; and slippery conditions for Passengers.

- **Ice/snow removal** - Presence of salt, glycol or other products used to deal with snow on roads, walkways or rolling stock in the environment will be taken into account in the design of the LRV (risk of corrosion or chemical attack).
- **Condensation** - Condensation will impact interior comfort conditions, visibility, increase risk of corrosion, affect proper operation of electronic component and affect equipment's life expectancy. Particular care will be taken to deal with the 58°C thermal shock.

Winterization will be addressed at the Train level. Product adaptation linked with winterization will be validated by specific tests, at Train and sub-system level, as suggested by the PrEN16251 - Railway Application – Environmental conditions - design and test of rolling stock under severe conditions.

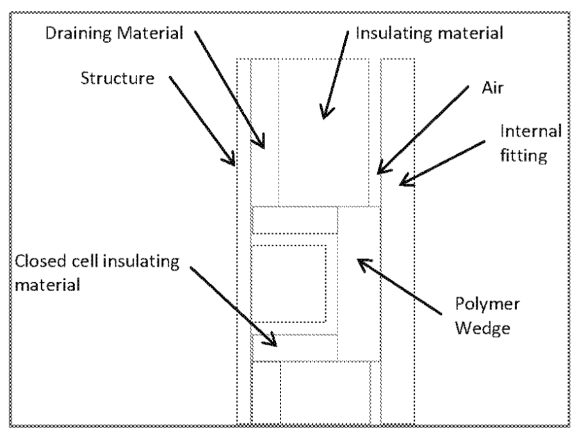
Based on operational experience from the Edmonton and Toronto LRT systems, during periods of extreme cold temperature (below -25°C), Trains will be parked either in a heated area (MSF), outside under catenary power, or outside without catenary power. Vehicle winterization measures will support each of these operational strategies.

Solutions to Ensure Passenger Safety and Comfort

Thermal insulation of Passenger compartment and Driver's cab. To ensure that temperature remains comfortable and homogeneous inside the Train in the most extreme conditions (hot or cold), thermal insulation is key. It serves three main purposes:

- Ensuring homogeneous temperature through the Passenger compartment
- Preventing Passengers from contacting cold and/or wet surfaces
- Reducing the energy needed to heat-up or cool down the Vehicle

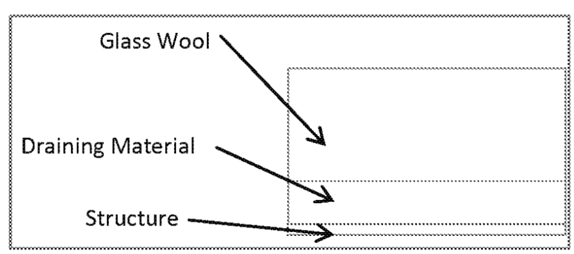
Insulating material will be used on walls, ceiling and floor of the Passenger compartment and the thermal coefficient will be increased to meet OLRT specifications for thermal comfort. The wall and roof insulation will consist of the following:



- A multilayer acetate celluloid insulating material to drain condensation water
- A layer of self-adhesive insulation material

In areas where structure could come in contact with the internal fitting wall, particular care is taken to prevent thermal bridges between the structure and the material accessible to Passengers, by using a combination of the following:

- A thermal and water vapour barrier made of a closed-cell insulating material
- Polymer wedges between steel structure and interior paneling



Floor insulation will be achieved by superposition of the following:

- A multilayer acetate celluloid insulating material to drain condensation water
- A layer of glass wool with a protective skin

Most floor insulation will be incorporated in the floor structure.

Safety of Passenger access. To reduce risk of slipping, heating will be located at floor level to prevent snow or ice accumulation. Door thresholds will be heated to prevent ice and snow accumulation in this sensitive area.

Passenger compartment heating. To provide thermal comfort performance required by the ORLT specification, heating will be provided by the roof-mounted HVAC unit, and heated air will be provided to the Passenger compartment through an air diffuser located on the ceiling and at floor level. Where required, heaters and a heating floor will provide additional heating.

Door adaptation to cold climate. Freezing rain in the Ottawa region will cause the formation of an ice layer on the Train car-body. To ensure proper operation of the doors in extreme cold conditions, the power of the motor actuators will be reinforced, thus allowing the actuator to open the door in case of ice formation around the door area on the Vehicle side. Additionally, the following door-operating mode will be proposed to the City for extreme cold conditions:

- **For an outside stop -** Door will only open when requested by a Passenger through a push button located inside or outside the door. This will prevent cold air from entering the Vehicle if no Passenger needs to get in or out of the Vehicle, thus increasing overall Passenger comfort.
- **For a stop in tunnel** - All platform side doors will open to ensure every door on the Train is open at least three times per round trip, thus preventing significant accretion of freezing rain on the door.

Door-edge elastomeric gasket will be adapted to -38°C operation.

Ensure proper braking performances of the Train. The Vehicle will be equipped with a state-of-the-art wheel slip/slide protection system as described in the braking equipment section of this section of the Response. Sanders and sand-boxes will be heated to prevent ice clogging the sand ejector circuit, thus ensuring functionality in cold weather and snowy conditions.

Solutions to Ensure Proper Vehicle Operation

Door adaptation to cold climate. The following measures will be taken to mitigate the effects of condensation on Vehicle components:

- Structural elements will be hermetically sealed or will contain drainage holes of at least 20 mm located to prevent condensation water from accumulating and freezing inside the structure. Drainage holes will be located to prevent water projection on sensitive equipment.
- External equipment will contain provisions (e.g. insulation, drainage holes) to reduce thermal shock and/or evacuate condensation water .
- A global draining frame will be located inside the T rain to evacuate condensation water .
- Humidity resistance of electrical and electronic apparatus will be reinforced (e.g. use of specific varnish on electronic boards).

Material selection. All material used on the Train (including oil, grease, rubbers, plastics) will be selected and tested to ensure performance in Ottawa's extreme cold conditions. Particular care will be taken for subsystems located outside the car body such as the flange lubrication system, lubrication of truck components (bearings, gear-box), and rubber mounts.

Particular care will also be taken during design in locations when different materials will be used (for example steel/aluminium interface). In these areas, differential contraction values will be taken into consideration during the design process. Properties of all materials used in the Vehicle design will be validated by test at -38°C, including glues and joints. For all external components, material will be selected to ensure mechanical and chemical resistance to de-icing method used by the operator (glycol, steam). The salt used on regular roadways will also be taken into account as necessary.

Solutions to deal with snow accumulation. External panels and components will be designed to reduce snow accumulation on the roof. Particular care will be taken to prevent snow accumulation and/or to allow proper snow evacuation around the pantograph. The design will allow for evacuation of water coming from melted snow or ice. Air outlets will be designed to reduce the risk of "melting then freezing" around sensitive devices (pantograph). The full low-floor architecture does not allow sufficient room for significant snow accumulation in the truck area.

Protection against ice impacts. When necessary, screens and covers will be used to protect under-frame equipment, wiring and connectors from ice impacts. Components will be located to minimize exposure. In areas where protection screens cannot be installed (area around truck), the frame will be protected against impact by a protective coating.

Removal of snow on track. A snow plough will be mounted under the cabin and designed according to the operating principle used on the ORLT network (removal of major snow accumulation by use of dedicated vehicle or by revenue service vehicles).

Optimization of air inlet and outlet. The air inlet will be positioned and sized so that snow accumulation in any part of the Vehicle cannot obstruct an air intake. As much as possible, the air intake will be located as high as practically feasible in regards of the surface where snow can accumulate, and its shape will be designed to minimize the risk of complete obstruction (i.e. air inlet will be shaped to favour height over width).

Adapt pantograph to deal with snow accumulation on catenary. Pantograph raising and lowering will be done electrically. To ensure a good electrical contact between the pantograph and the catenary, the proposed pantograph will be fitted with an ice scraper that will remove ice from the catenary.

Adapt coupler to presence of snow and ice. Heated coupler faces will be used to prevent accumulation of ice and snow. When folded, the coupler will be protected from external pollution such as snow, ice, dust and salt.

Validation

All the proposed solutions, whether they are at the component or Train level, will be revalidated in the OLRT context. At sub-system level:

- Validation will be run at component level with our internal and external suppliers
- When required, specific mock-up will be built to reflect the actual OLRT environment

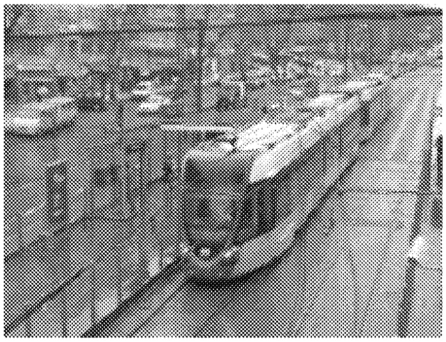
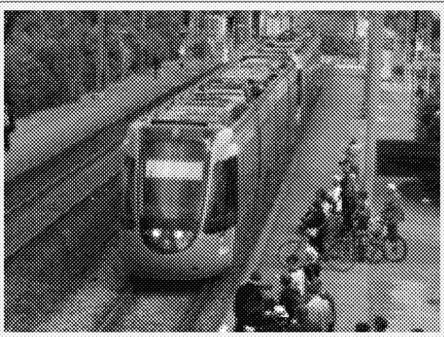
At the Vehicle level:

- Design adaptations linked with Vehicle winterization will be validated on the Train. When applicable, test procedures will be based on the recommendations of the PrEN16251.
- Train-level performance will be validated under the severe conditions described in the OLRT specification. Depending on the test, it can be run in one of the following climatic chambers:
  - In North America: in the Alstom facility in Hornell, NY or in the NRC facility in Ottawa
  - In Europe: in the Alstom facility in La Rochelle (France) and Vienna (Austria)

5.4.3.3 Service History of Proposed Vehicle

As described in **Table 5.4-9**, the existing Vehicles are substantially compliant with the four parts of the PA Schedule 15-1 definition of a *Service Proven Vehicle.*

Table 5.4-9 | Service History

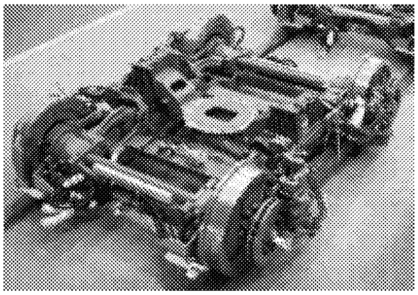
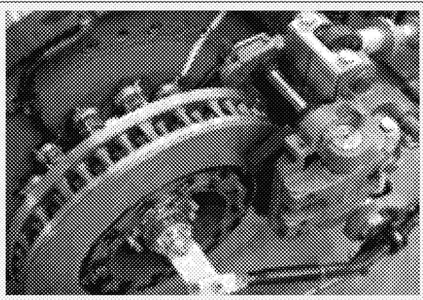
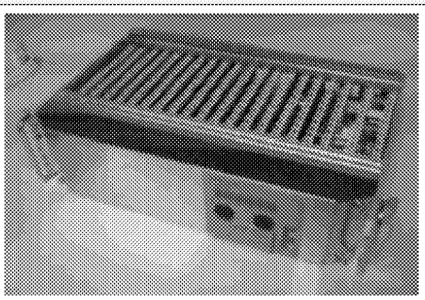
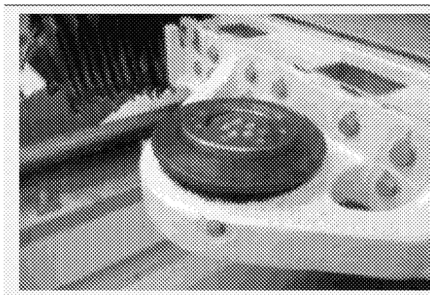
Vehicle	Service History
	**Istanbul Citadis** ■ 37 vehicles in service ■ System opened December 2010 ■ Operating Speed: 70 km/h ■ Operation in multiple unit of two vehicles ■ 120s minimum headway ■ 19.5 km line ■ 14,000 PPHPD at peak hour
	**SNCF Nantes Citadis** ■ 7 vehicles with 12 months of service ■ Operating Speed: 100 km/h ■ Operation in single and multiple units of up to three vehicles ■ Operated as a suburban Train ■ 26.5 km line ■ Only Full low-floor LRT running at 100km/h

As summarized in **Table 5.4-9**, all OLRT Vehicle subsystems are service-proven on both Istanbul and SNCF Citadis.

The Citadis vehicle has been operating worldwide since 1997 with more than 1500 LRVs in service. Alstom's experience in cold climates has been described in **Section 5.4.3.2**. Many of the Vehicles, including Istanbul, are operating in hot climates. The in-service MDBF of the Istanbul is as follows, with failures being defined as malfunctions causing Revenue Service delays of 4 minutes or more:

- Target MDBTD on Istanbul = 130,000 km
- Achieved MDBTD after 14 month = 575,000 km
- Target MDBTD on Ottawa LRT = 50,000 km

Table 5.4-10 | Vehicle Subsystems

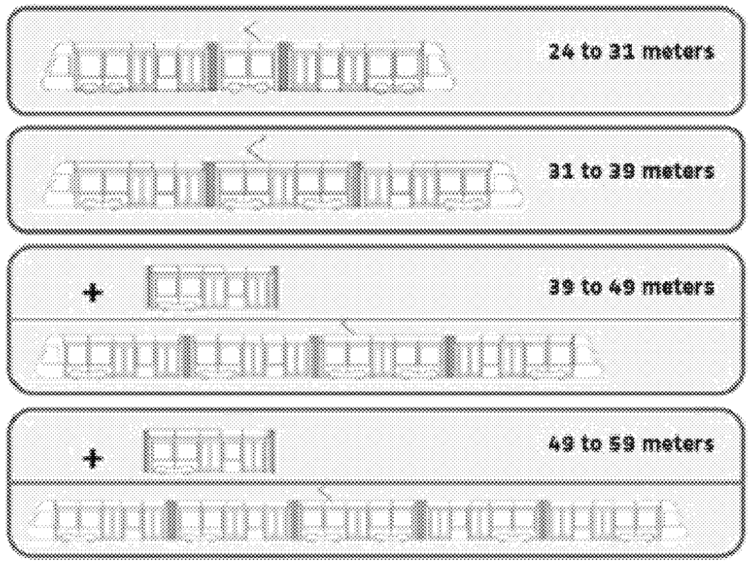
Vehicle Component	Service History
	**IXEGE Truck** ■ Most recent Citadis truck generation specially designed for high comfort, 100% low-floor and 100 kph operation ■ This truck is pivoting and fitted with solid axle ■ Truck layout drawing is provided in **Cut Sheet 5.4.1-CS-208**
	**Hydraulic braking system** ■ Alstom has developed two alternative and interchangeable solutions for the Citadis family: - Faiveley system is mounted on Istanbul - Knorr system is mounted on SNCF Nantes ■ Drawings for Nantes brake system are provided in **Cut Sheets 5.4.1-CS-201 to 5.4.1-CS-207**
	**ONIX Propulsion system** ■ Alstom ONIX IGTB technology + Alstom AGATE control unit is the standard Alstom traction system ■ Equip all Citadis LRV
	**Articulation joint** ■ Standard and proven-design Citadis solution is installed on both Istanbul and SNCF Citadis

5.4.3.4 Experience with Consist Arrangements

Citadis is a modular product. The Citadis range is based on service-proven modules and subsystems assembled together to meet the client need precisely. Alstom has experience with coupling long consists and will design the OLRT Vehicles to account for the requirements for structural strength, pushing and towing, coupler structural strength, resistance losses for instance, as further described in **Section 5.4.3.21**.

Figure 5.4-6 illustrates the Vehicle consist modularity principle of the Citadis range fitted with pivoting trucks. Ottawa's Vehicle will be an evolution of SNCF Nantes Citadis and specific design modifications are, therefore, not required.

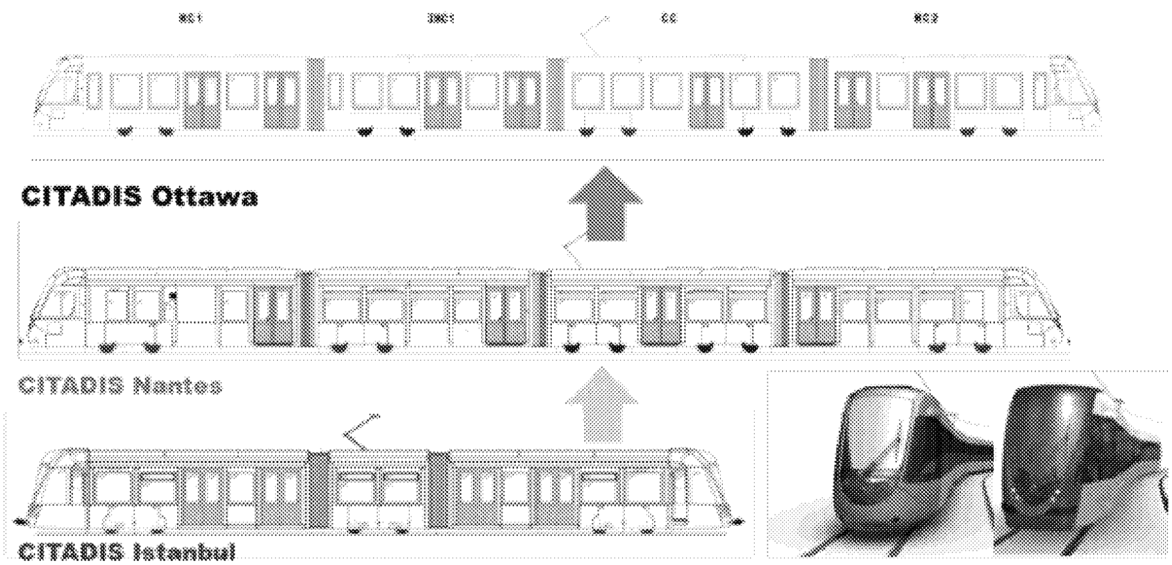
Figure 5.4-6 | Vehicle Consist Modularity



Train consist and architecture is similar but the carbody shells are slightly extended for Ottawa, to comply with ridership and door arrangement expectations. Particular attention has been paid to comply with truck axle weight limitation and minimum radius curves.

The Citadis Nantes is operated daily in multiple units of 2 or 3 Vehicles for a maximum Train length of 126m. As shown in **Figure 5.4-7**, the typical proposed OLRT Train will be a multiple unit of two 49 m Vehicles for a maximum Train length of 98 m. Based on our experience with long Train consists, the maximum Train length in normal operation (2-Vehicle Train) as well as during rescue missions (one 2-Vehicle Train towing another) is taken into account in the design of the Train (e.g. structural strength car-body and coupler, Train line design for losses due to Train length and coupler passage).

Figure 5.4-7 | Train Consists



5.4.3.5 Testing

List of Tests

Serial Tests

The serial tests are tests performed on each Vehicle to confirm, by simplified tests, that the main performance levels checked by the type test are effectively reproduced. The serial tests, performed on the series sub- assemblies and parts of the Vehicles, are aimed at verifying the main characteristics of the concerned sub-assemblies and parts; these can be systematic or statistical.

Static Serial Tests

All tests necessary to prove proper functionality of the Vehicle will be performed:

- Current return circuits and protection circuits tests
- Dielectric strength and insulation of all 1500 V and low voltage circuits
- LV functional tests (e.g. exterior signaling and lighting circuits, Driver's cab)
- HV static tests including auxiliary supply
- Door functional tests
- Ventilation and heating tests
- Traction – braking static tests
- Brake system and hydraulic circuits tests
- Passenger information and CCTV tests
- Interface with Train control system tests.

Dynamic Serial Tests

For each Vehicle, the dynamic performance will be tested to prove that the City's requirements are fulfilled:

- Geometric checks
- Weighing of Vehicles
- Water tightness check of complete Vehicle
- Wheel flange lubrication and sanding system tests
- Safety devices tests
- Door functional tests
- Traction functional check
- Braking functional and performance tests

Type Tests

To ensure the City's complete satisfaction, Alstom will set up a Validation Type Test plan, to demonstrate compliance with the technical specification as well as the legal requirements.

The validation strategy will cover the full range of activities from component validation, through Vehicle integration testing, functional static and dynamic type tests, as well as dynamic performance type tests to Vehicle integration testing in Ottawa. Type tests are performed on new items, or new sub-systems. A type test proves that the specified contractual performance and functional requirement has been achieved. Validation activities will be structured in the following sequences:

- Design Phase
- Component Validation
- Integration Testing
- Functional and Performance static Validation
- Dynamic Performance Validation
- On-site Integration tests

Alstom has incorporated in its quality system the requirements set forth in the EN 17025 "General Requirements for the Competence of Testing and Calibration Laboratories. For the main system integration, accredited test laboratories will be used.

Design Phase

During the design phase the Validation team will prepare the Validation Plan, identifying the main verification and test activities of the Vehicle and the Train, and draft the test procedures. The main input for the validation plan will be the IEC 61133 "Railway applications – Rolling stock - Testing of Rolling stock on completion of construction and before entry into service" and the technical specification requirements that need a test to demonstrate Vehicle and Train compliance.

On the basis of a gap analyses with the reference solution, a FMECA-based critical risk analysis will define the depth of the validation activity – need for specific design reviews, simulations, mock ups or test. The Validation Plan will be refined throughout the design reviews of the specific subsystems.

Component Validation

During the testing phase the Validation team will work with the different subsystem suppliers and internal subsystem experts, to prepare component type tests, and participate in testing critical systems, i.e. doors, traction, brake, bogies, and Train Control and Monitoring System (TCMS).

A significant component validation test will be the static car-shell structure test, performed at Alstom's Valenciennes site. During this test, the car body will be outfitted with strain gauges and all the main structural tests, as defined in EN 12663, will be performed.

Integration Testing

Integration of the different equipment and subsystems will be tested with their suppliers during the initial integration of the first Vehicle. To prepare this phase, a functional integration test bench will be used to validate the functional design including vehicle low voltage, TCMS logic and subsystem control logics. The functional integration test bench will incorporate at least one electronic unit of each type under test while the others, as well as their environment, may be simulated. The test bench will be used for functional validation in single mode Vehicle use as well as multiple-unit Train.

Functional and Performance Static Validation

Complementary to the functional integration test bench, static functional test will be performed in Vehicle (single unit) and Train (multiple unit) configuration. Static performances such as battery autonomy, lighting levels, and acoustic levels will be measured. ODA compliance will also be tested at this stage.

To demonstrate Vehicle performance under winter conditions, tests will be performed under extreme temperatures, and under winter conditions, in a climate chamber. During this test the important systems such as the brake system, air supply, and door system will be tested.

Dynamic Performance Validation

Dynamic traction and braking performances will be tuned and tested on a test track in France, prior to testing on-site in Ottawa. The program will focus on the different braking modes in nominal and degraded mode in several load cases as well as testing with degraded adhesion. The dynamic performances will be performed in Vehicle (single unit) mode. The Train (multiple unit) configuration testing will demonstrate a smooth operation without performing braking performance tests. During this phase, the ability to rescue a Train with another Train will also be tested.

On-Site Integration Tests

The on-site Integration test will focus on tests requiring either the final interfaces or localizations. This testing will include: dynamic gauge, bogie stability and comfort, EMC, dynamic noise, the correct localization of Passenger announcements, radio and Vehicle/ground communication.

Test Results from Equivalent Vehicles

Even though most components are service proven, most type tests at Train level will need to be performed for the specific Ottawa Train configuration and operation interfaces. However, the component type tests performed for existing Citadis will be used as a reference and will be supplied.

Available applicable Test Result reports from Nantes Citadis (**Reports 5.4.1.A-TR-101 to 5.4.1.A-TR-119)** are listed in **Table 5.4-11A** below. Please see applicable test reports.

**Please Note: Due to the length of test results, the following reports have been submitted in electronic format only.*

Table 5.4-11A | Available Test Reports

Reference Number	Type	Report Name	Entitled Report Title
5.4.1.A-TR-101	Testing	TEST REPORT TRAM-TRAIN NEW GENERATION WINDSHIELD	RAPPORT D'ESSAIS Tram-Train Nouvelle Génération ■ Pare Brise
5.4.1.A-TR-102	Testing	TYPE TEST REPORT CDRL 7-08 AUXILIARY CONVERTER FOR CITADIS OPTIONS 7, 9, 11, 12, 13, AND 16	
5.4.1.A-TR-103	Testing	TEST REPORT TRAM-TRAIN NEW GENERATION ALSTOM BRAKING PERFORMANCE ON FRENCH NATIONAL RAILWAYS	RAPPORT D'ESSAI TRAM-TRAIN NOUVELLE GENERATION ALSTOM PERFORMANCES DE FREINAGE SUR RFN
5.4.1.A-TR-104	Testing	TYPE TEST PROJECT TTNG SWIVELLING AND SLIDING DOOR WITH 2 PANELS AND STEP	Essai de type – projet TTNG Porte louvoyante coulissante à 2 vantaux & marche
5.4.1.A-TR-105	Testing	TEST REPORT ACOUSTIC SPECIFICATIONS	EXIGENCES ACOUSTIQUES AU CAHIER DES CHARGES
5.4.1.A-TR-106	Testing	CITADIS 35 kW TTNG PROJECT QULIFICATION TESTS	
5.4.1.A-TR-107	Testing	TYPE TEST REPORT MEASURES OF ILLUMINATION/LIGHTING	Measures de l'éclairement
5.4.1.A-TR-108	Testing	■ TYPE TEST REPORT ■ SANDING	■ Sablage
5.4.1.A-TR-109	Testing	■ TYPE TEST REPORT ■ NVR, CAMERA AND EMB	

Reference Number	Type	Report Name	Entitled Report Title
5.4.1.A-TR-110	Testing	■ TYPE TEST REPORT ■ VEHICLE MEDIA CONTROLLER – 4T	
5.4.1.A-TR-111	Testing	■ TYPE TEST REPORT ■ INTERNAL LED DISPLAY	
5.4.1.A-TR-112	Testing	■ TYPE TEST REPORT ■ INTERNET ONBOARD SYSTEM	Système Internet on bord Rapport d'essais de type
5.4.1.A-TR-113	Testing	■ TYPE TEST REPORT ■ 6U PA PACK	
5.4.1.A-TR-114	Testing	■ TYPE TEST REPORT ■ SURVEILLANCE CAMERA (IP)	Caméra IP Rapport d'essais de type
5.4.1.A-TR-115	Testing	■ TYPE TEST REPORT ■ RACK CCTV ■ NVR/EBM/WIFI	Rack CCTV - NVR / EBM / WIFI Rapport d'essais de type
5.4.1.A-TR-116	Testing	■ TYPE TEST REPORT ■ BREAKER	■ Disjoncteur Arc 1520 M
5.4.1.A-TR-117	Testing	■ TYPE TEST REPORT ■ BRAKING RESISTANCE ■ AIR COOLED	■ Rapport d'essais de type ■ Résistance de freinage à ventilation naturelle ■ TTNG
5.4.1.A-TR-118	Testing	■ IMPACT SIMULATION FOR ALSTOM ■ PROJECT TTNG/FRANCE ■ AUTOMATIC COUPLER ■ TYPE SD330	
5.4.1.A-TR-119	Testing	■ STATIC TESTS ■ EXTRACT FROM STANDARD NF F 31-119 ■ RAILWAY ROLLING STOCK ■ BEHAVIOUR OF ROLLING STOCK'S SEATS AT STATICS STRESS, ■ FATIGUE STRESS, VIBRATIONS STRESS AND SHOCKS STRESS	■ Extrait de la norme NF F 31-119
5.4.1.A-TR-201	Car Body	■ STATIC RESISTANCE TEST OF ■ CAR BODY STRUCTURE ■ TTNG	■ Essais Statiques De Resistance De Structure ■ Sur Chaudrons De Caisses TTNG De Fabrication ■ Alstom

Reference Number	Type	Report Name	Entitled Report Title
5.4.1.A-TR-202	Car Body	■ DESIGN NOTES ■ CAR BODY STATIC AND FATIGUE DESIGN ■ CALCULATIONS ■ CEx WITH 2 DOORS PER SIDE	■ CALCULS EN STATIQUE DE LA ■ STRUCTURE DE CAISSE CEx ■ AVEC 2 PORTES PAR FACE
5.4.1.A-TR-203	Car Body	■ DESIGN NOTES ■ CAR BODY STATIC AND FATIGUE DESIGN ■ CALCULATIONS – CX	■ CALCULS EN STATIQUE ET EN ■ FATIGUE DE LA STRUCTURE DE ■ CAISSE Cx
5.4.1.A-TR-204	Car Body	■ DESIGN NOTES ■ CAR BODY STATIC AND FATIGUE DESIGN ■ CALCULATIONS – C2B	■ CALCULS EN STATIQUE ET EN ■ FATIGUE DE LA STRUCTURE DE ■ CAISSE C2B
5.4.1.A-TR-301	Crash	■ DESIGN NOTES ■ CRASH TESTS REFERENCE SIMULATIONS	■ Simulations des collisions de référence
5.4.1.A-TR-302	Crash	■ REGISTRATION OF CRASH TEST	■ Recalage de l'essai collision cabine
5.4.1.A-TR-303	Crash	■ TEST REPORT ■ CRASH TEST LEVEL 1 ON CABIN	■ Essais de collision échelle 1 ■ sur la cabine TTNG ■ RAPPORT ■ D'ESSAI
5.4.1.A-TR-401	Thermal Load	■ CITADIS OTTAWA ■ HVAC THERMAL LOAD CALCULATION	

Table 5.4-11B lists component-type tests and Train-type tests.

Table 5.4-11B | Component Type Tests and Train Type Tests

Validation Activity	Test on Equivalent Vehicle	Test on Proposed Vehicle
Component Type Test		
Windscreen Performances	●	
Bogie System	●	●
Winterization/Climatic Adaptation	●	●
Aux: Auxiliary Supply	●	
Brakes	●	
Doors	●	
Horn	●	

Validation Activity	Test on Equivalent Vehicle	Test on Proposed Vehicle
HVAC	●	
Internal Lighting	●	
Sanding	●	
PA/PIS	●	
Signaling Interface		●
TCMS	●	
Main Circuit Breaker	●	
Traction Converter		●
Braking Resistor	●	
Motor		●
Carbody Shell	●	●
Automatic Coupler	●	
Seats	●	
Interiors		●
Smoke Detector		●
Train Type Test		
Resistance to Motion		●
Dimensional and Gauge		●
EMC: Electromagnetic Compatibility		●
Acoustics/Noise		●
Railway Dynamics		●
Weight Management and Allocations		●
Winterization/Climatic Adaptation		●
Aux: Auxiliary Supply		●
Break		●
Doors		●
Horn and End Lights		●
HVAC		●
Internal Lighting		●
Sanding		●
PA/PIS		●
Signaling Interface		●

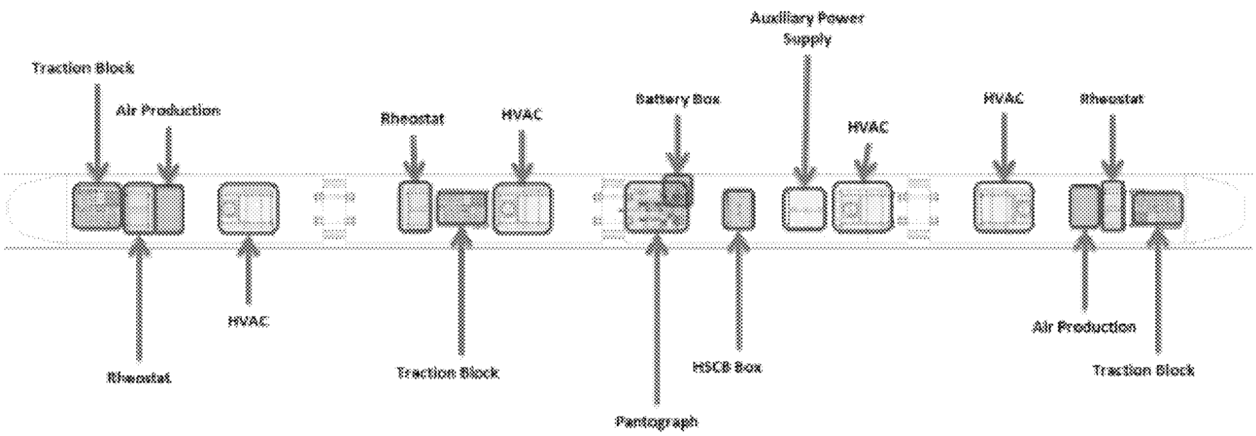
Validation Activity	Test on Equivalent Vehicle	Test on Proposed Vehicle
TCMS		●
Traction		●
Safety Earthing (grounding)		●
Fire Protection System		●
Train: Journey Time		●

5.4.3.6 Preliminary Drawings & Electrical Subsystem Schematics

Roof Equipment

Figure 5.4-8 shows our proposed distribution of roof equipment on the proposed OLRT Vehicle.

Figure 5.4-8 | Roof Equipment



The Vehicle's high-voltage architecture is shown in the Traction Block Diagram (**Cut Sheet 5.4.1-CS-901**):

- The power supply (see 1 on the diagram) collected by the bi-directional pantograph
- The lightning arrester (2), protecting the high -voltage equipment against over-voltages
- The circuit-breaker box containing:
  - The ultra-fast circuit-breaker (3) protecting and isolating the traction chain
  - The HV presence indicator
  - The auxiliary protection fuse

All equipment listed above is located on the CC car (see **Figure 5.4-8**).

The power is then distributed to the various power blocks located on the MC1, IMC1 and MC2 cars and the Auxiliary power supply located on the CC car.

Traction Block Control Unit

The traction block contains the following apparatus (see **Cut Sheet 5.4.1-CS-901**):

- Pre-charge circuit (6 and 7)
- Line inductor (8)
- Rheostatic chopper (12)
- Filter capacitor (11)
- A traction inverter (14) driving the two associated three-phase induction motors (18.1 and 18.2) located on the motor truck
- Associated current sensors (17)
- The rheostatic grids (13) are located on the roof next to the traction box

Return Current

The return current scheme has been designed to provide redundant paths to return current safely to the rail in a manner that protects bearings while reducing interference to wayside equipment. Resilient wheels are provided with four shunt straps between the wheel hub and the rim.

Auxiliary Power

The redundant auxiliary converters (see architecture and layout drawing in **Cut Sheets 5.4.1-CS-401 to 5.4.1-CS-405**) deliver different types of power output to operate the various on-board systems and devices:

- 28.5 Volts dc that supplies all LV equipment (on-board CBTC, Train lights, rear facing cameras, Passenger saloons' normal and emergency lighting, Train Control and Monitoring System, track brakes, door motors, windscreen wiper, battery charger)
- 480 V 60 Hz, three-phase, fixed frequency that supplies the Driver's cabin heater, saloon heaters and air compressors
- 480 V 60 Hz three-phase with variable frequency from 45 Hz to 60 Hz (U/f constant) that supplies the compartment HVAC units

Alstom's auxiliary power design complies with the redundancy requirements of the PA. In the case of failure of one auxiliary converters all loads and limited battery charging shall be maintained. Upon complete failure of auxiliary converters or loss of the OHL voltage, the two 28.5 Vdc batteries provide back-up power supply to critical loads for up to 90 minutes. In normal operation the battery chargers charge the batteries to ensure that they are kept at full load all the time.

All auxiliary loads (ac and dc) are circuit breaker protected. All circuit breakers are available from the cab compartment.

Batteries

The nickel-cadmium batteries, charged by the static converters deliver the following:

- Energy for low-voltage circuits (e.g. track brakes)
- Emergency loads
- Various devices (e.g. pantograph motor, windshield wiper motor)

The battery capacity was calculated taking the following design criteria into account:

- Restart the LRV after 48 hours in the stabling yard with the parking lights turned on
- Supply essential loads in operation following a loss of power for 90 minutes
- Supply energy in stabling for at least 3 hours

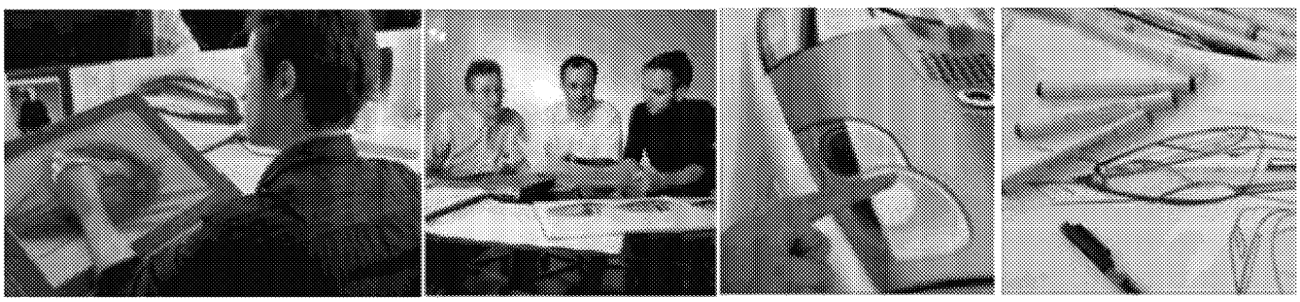
Depot Supply Sockets

When the batteries are discharged, they can be recharged by an external source through dedicated sockets. These sockets are located on the low-voltage control box on the MC2 section roof near the battery box.

This operation must be carried out when the Train is in sleep mode and the battery isolated from the 28.5 V Train network. The battery is isolated from the Train by means of the battery isolation switch and is then connected directly to the socket. Connection of this socket to an external charger then enables the battery to be recharged. Note that it is not possible to power Train equipment via this charging socket.

5.4.3.7 Industrial Design Representations

Alstom has long established a global reputation for know-how in transportation solutions. Unique for the railway industry, the Design & Styling department was created in 2005 to meet the needs of today's railway customers and guarantees quality results.



With a dual role in the engineering and manufacturing of rail vehicles and infrastructure, Alstom has established its own dedicated Design & Styling (D&S) department, comprising 20 designers dedicated to the full spectrum of railway products, from streetcars to very high-speed Trains. This multi-disciplinary approach allows us to create innovative designs that meet clients' aesthetic and performance expectations, while respecting the general configuration of the vehicle under development.

The department's cross-functional organization is adapted to meet the specific needs of rail transport markets:

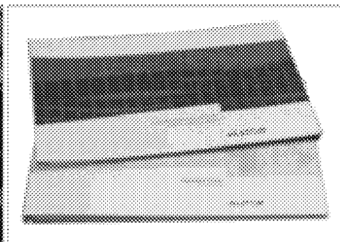
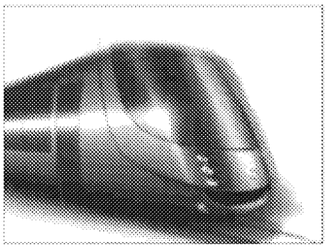
- Consolidating competencies in design, digital modelling, colours, materials, and lighting
- Benefiting from the knowledge of a network of industrial design experts in different regions
- Stimulating the creative process and producing designs suited to each client's cultural context
- Meeting design expectations for the entire range of Alstom Passenger Trains, from urban to main line Trains

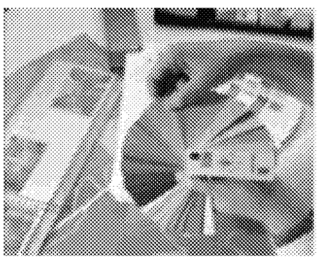
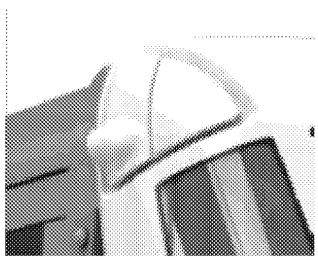
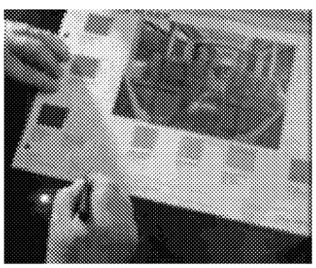
With more than 100 successful projects completed, the process encourages customer input, creates a common vision and identifies and integrates the efforts of potential project partners. In the past, D&S has worked with civil contractors including Systra, Impresa Pizzarotti, Isolux Corsan; and international architects including Dubus Richez, BillingsJacksonDesign,RKD architects, Cepezed.

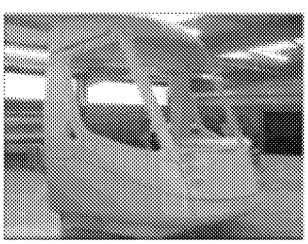
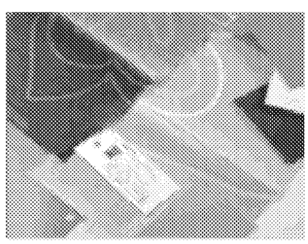
Our highly collaborative approach to design actively involves the client and key stakeholders. Working with each city's branding process, the D&S department analyzes the cultural, economic, political and geographical context of the project. This is summarized through photo reports and keywords. The objective is to define the artistic theme which will be used as a connecting thread for creation throughout the project.

A unique competitive advantage of our modular product configuration is that the front end and interior arrangement can be customized and become a critical component of the brand. The D&S department will propose various versions of shapes for the interior and exterior, colours and trims in support of the final branding approach.

Alstom has laid out a collaborative design process that guarantees quality results. The objective of this process is to develop a product that fully satisfies all stakeholders and results in production of a full scale mock-up. As soon as the mock-up is accepted by the City, it will be sent to Ottawa and made available for community and Stakeholder programs.

Preliminary Meeting

After the notice to proceed, Alstom meets with city representatives to gather input regarding requirements.

Pre-Choice Meeting

New proposals based on information collected through preliminary meeting are presented. Selection of these proposals serves as a departure point for shape definition, colour schemes, graphic lines and materials.

Choice meeting

The shape, colour and graphic line of a Train car is further determined with 3D software. Virtual images allow customers to get a feel of the object from different angles. It is also a way to confirm the details and options agreed upon previously.

Freeze of options

Customers sign off to 80% of their preferences. This marks the beginning of the manufacturing phase for products related to styling and design. The shapes, colours and materials chosen are specified at this stage. Alstom then submits a life-size impression of the graphic line for approval by the client.

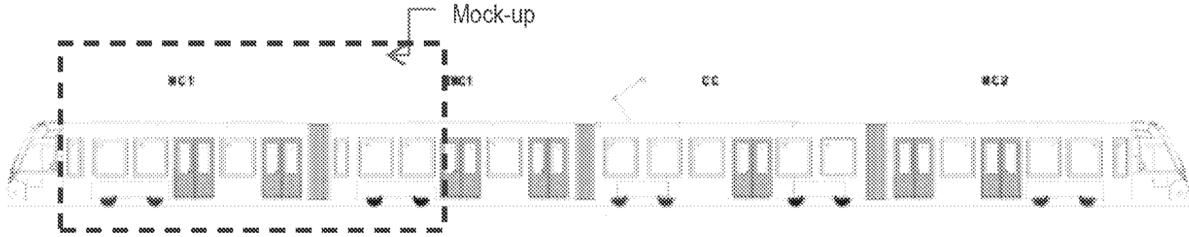
Working mock-up

Customers can see working mock-ups of components such as the front-end cab or seating, among others. The mock-ups represent 90% of the design choices made. This step is optional, but highly recommended. Clients see factory samples to check for colours, patterns and trims.

Representative Mock-up

The representative mock-up is an accurate model of the future Vehicle unit. All specifications may be reflected in the mock-up, from front-end cab design to the colours and trimmings inside. The mock-up proposed for OLRT will consist of a section as shown in **Figure 5.4-9**.

Figure 5.4-9 | OLRT Vehicle Mock-Up



Constructions, surfaces and finishes will be as close as practicably possible to the final product specification. Volume and location of interior components will be representative to the serial product to ensure representative spacing between components. The mock-up will not be functional and will not be equipped with trucks but will be fitted with lighting and Passenger Information Display Systems (PIDS). It will be connected to the 110 V, 60 Hz network to provide energy to the functional equipment. **Figure 5.4-10** illustrates the concept, showing the exterior and interior of the Reims LRV mock-up.

Figure 5.4-10 | Reims Vehicle Mock-Up

5.4.3.8 Vehicle Dynamic Modelling and Simulation results

Traction Performance

Except where otherwise specified, the traction system performances and curves are defined with the following parameters:

- Maximal load 4 pass/m^2
- Power supply voltage: 1500 V
- Inverter filter voltage: 1800 V in braking modes
- Half worn wheels
- Jerk limitation to 1.3 m/s^3

The values specified in the curves and text below, are to be assigned with a tolerance of ±5%. The specified values take into account of the following:

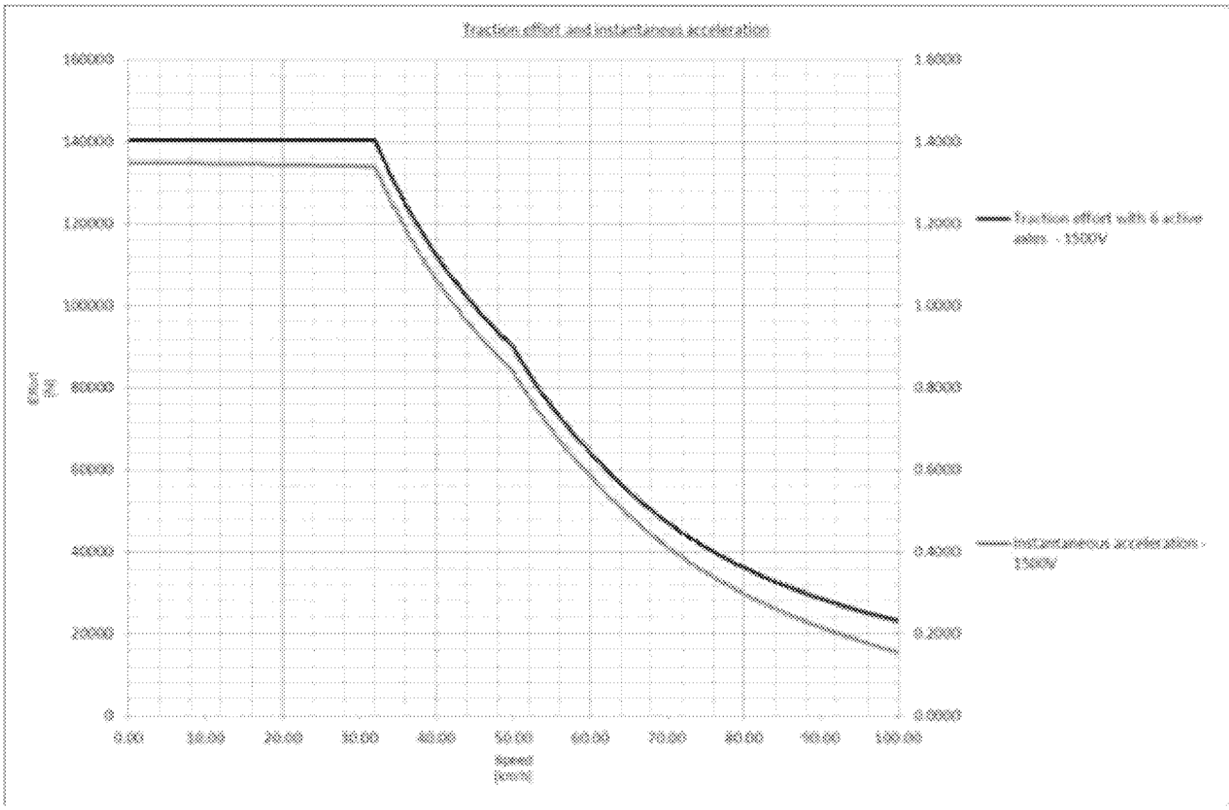
- Acceleration of flywheel masses

- Resistance to forward motion calculated with Davies formula (R)
- Starting resistance
- Resistance due to slopes (where specified)

Traction Characteristics on Flat Track

Figure 5.4-11 presents the traction Train level curves of the Citadis in single unit. The propulsion system will provide initial maximum vehicle acceleration of 1.34 m/s² +/-5% (OCS voltage>1500 V, AW2 Loading) up to 32 km/h as required by the PA.

Figure 5.4-11 | Single Unit Nominal Traction Characteristic



Train Simulation Results

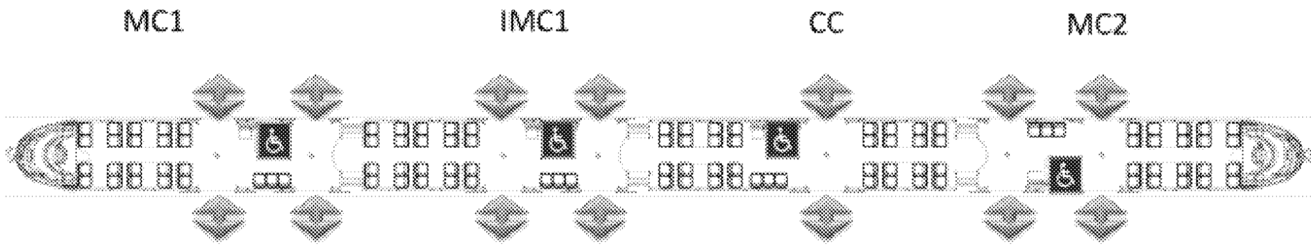
The Vehicle dynamic modelling and simulation results are presented in **Section 10.0** and summarized in **Section 5.4.5**.

5.4.3.9 Accessibility

Approach to Vehicle Accessibility

The Vehicle interior is designed with full low-floor Passenger area and seat arrangement (longitudinal and transversal) to provide full accessibility in compliance with AODA/ADA requirements. Transport Canada requirements will be complied with only to the extent that they are applicable to LRVs. The Vehicle is equipped with seven dual leaf Passenger access doors per side to optimize Passenger accessibility and reduce exchange time at stations (see **Figure 5.4-12**).

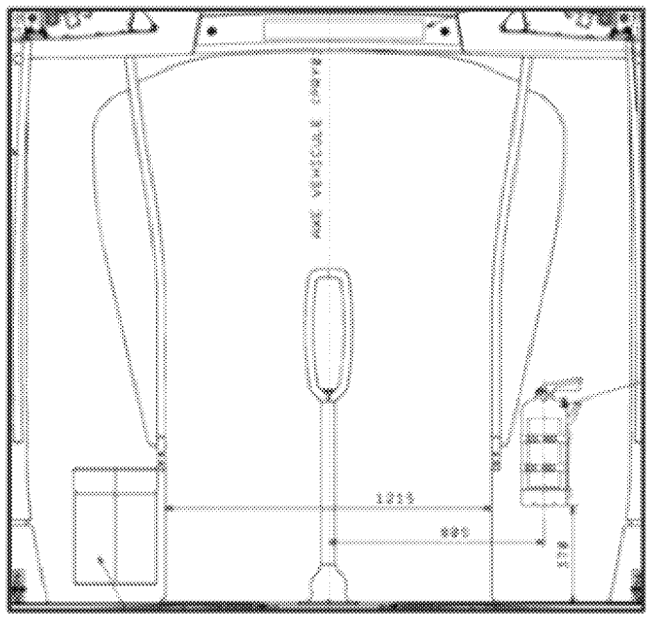
Figure 5.4-12 | Door Placement

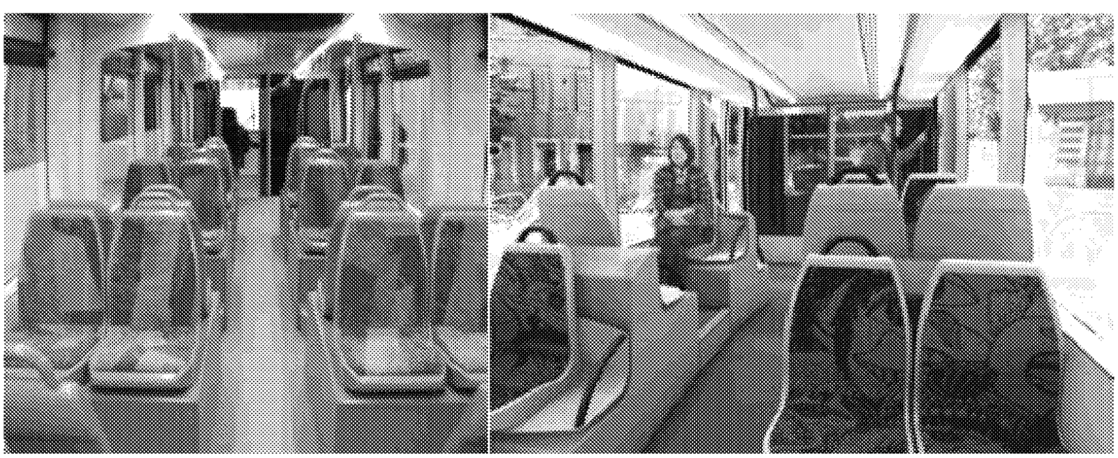


In addition:

- The Ottawa Vehicle, part of the service-proven Citadis product range, guarantees a continuous unobstructed path connecting all accessible elements and spaces of the Vehicle with a low-floor which includes slopes (less than 8 percent in accordance with TSI Requirements)
- The accessible space between seats, handrails matches with the ADA requirement (600 mm)
- Proposed Vehicle accommodates the needs of individuals with or without restricted mobility
- All thresholds are equipped with a colour band running along the full width which contrasts with the step tread and is adjacent to the floor
- Vehicle access points are located to facilitate entry and to maximize passenger flow. The proposed Vehicle doors provide a width of 1300 mm when opened, facilitating access for people with restricted mobility.
- For boarding, the proposed Vehicles are equipped with a leveling system (air suspension) which ensures a gap of plus or minus 15.8 mm between the height of the Vehicle floor and the platform. The maximum horizontal gap between the Vehicle at rest and the platform is 76 mm.
- The gangway walkway links two sections and includes a floating tread plate. The width in the gangway is 1215 mm.

Figure 5.4-13 | Vehicle Cross-section





Accommodation of AODA and ADA Requirements

The proposed Vehicles comply with subparts A and D (Light Rail Vehicles and Systems) of the Americans with Disabilities Act (ADA) reference 49 CFR 38 for Transportation Vehicles. During design, manufacturing construction, and revision of Trains, Alstom covers the ADA requirement by taking into account anthropometric dimensions.

Wheelchair Access

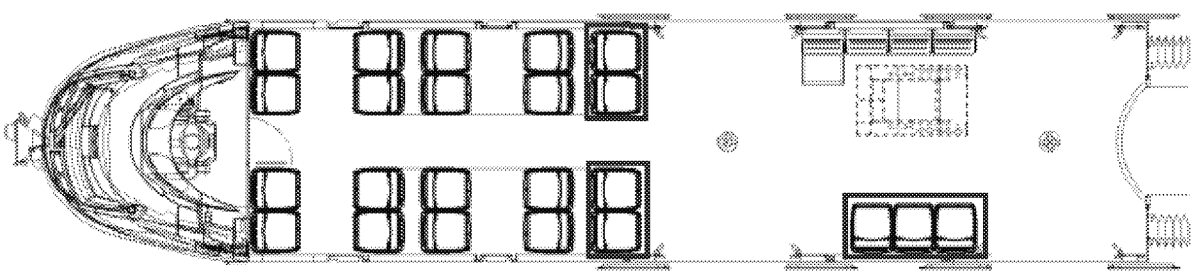
At each entrance, the dual-leaf doors providing an access width of 1300 mm, to allow passage of one wheelchair or mobility aid users. A 1220 mm by 760 mm wheelchair spot is conveniently located next to each door area and allows smooth Passenger flow around the area. Priority seats are located next to the wheelchair area.

Information Displays

Signage

All signs are bonded on the Train with International Symbol of Accessibility and are displayed on the exterior of each operating Vehicle. The doors use auditory and visual warning signals to alert Passengers when doors are closing. Each Vehicle contains signs which indicate that certain seats are priority seats for persons with disabilities (see **Figure 5.4-14**; seats in front of display and close to the doors-as outlined in red).

Figure 5.4-14 | Signage



OLRT Vehicles will accommodate persons using wheelchairs or other mobility aids. In these areas, signs indicate the location and advise other Passengers of the need to permit wheelchair and mobility aid users to occupy them (see **Figure 5.4-15)**. Signage dimensions will meet ADA/AODA requirements.

Figure 5.4-15 | Example of Accessibility Signs

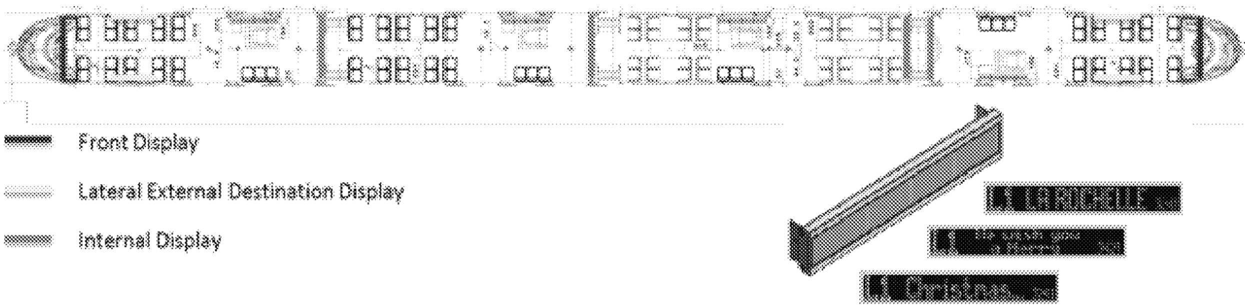
Passenger Information Displays

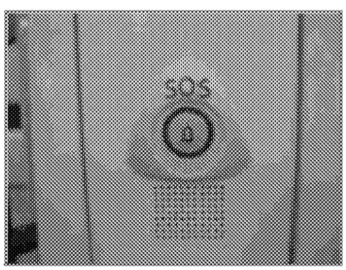
Proposed Vehicles are equipped with displays which inform Passengers of the route (see **Figure 5.4-16**). The system is designed to provide synchronized audio and visual Passenger information announcements including destination, station stops, time, and emergency announcements according to Train route. The displays will meet these standards:

- Visible from the platform
- Located on the face to be visible (two per face of the Vehicle)
- Integrated behind the window and have a glare-free surface, and a consistent shape. Text letters are yellow, contrasted with the black serigraphy of the window which permits a clear view.

The Ottawa LRT information system is also equipped with an interior public address system operated by OLRT personnel, or digitized human speech messages to announce Stations and provide other Passenger information.

Figure 5.4-16 | PIDs

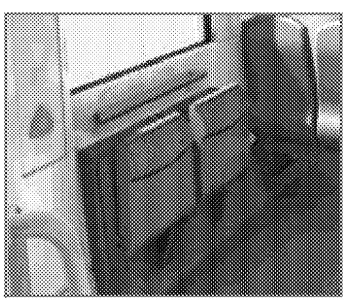




Pushbuttons

All Passengers have access to push buttons for access-door opening request or to communicate with the Driver in an emergency. Provisions are made to integrate these push buttons according to ADA/AODA requirements:

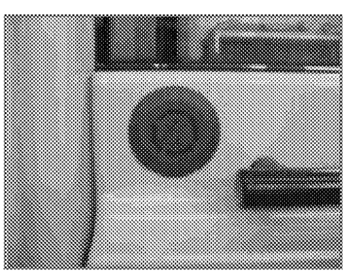
- Located to be accessible by Passenger in wheelchairs
- Contrast with internal fitting on which they are mounted



In wheelchair areas, a push button allows Passengers to request the automatic opening of the adjacent Passenger door at the next Station. This allows Passengers in wheelchairs to request door opening before arriving at a Station, allowing time to go out of the Train comfortably.

Interior – Handrail and Stanchions

The handrails in Ottawa's Vehicle are sufficient to permit safe boarding, onboard circulation, seating and standing assistance, and alighting by persons with disabilities. The proposed Vehicle also fulfills the TSI requirements so it is possible to grab the handrails everywhere in the Train. The OLRT Vehicle is equipped with grab bars, handholds, handrails or stanchions located as follows:



- In appropriate locations
- By each priority seating area intended for use by persons with disabilities
- At each side of any entrance or exit used by persons with disabilities

- In location at any entrance or exit used by a person with a disability. The bars are accessible from ground level and are mounted inside the Vehicle when the doors are closed.
- At appropriate locations throughout the Vehicle to support independent and safe boarding, on-board circulation, seating and standing assistance and de-boarding for persons with disabilities.

The grab bars, handholds, handrails or stanchions do not interfere with the turning and manoeuvring space required for mobility aids to reach the allocated space from the entrance. They are contrasted (K>3 as TSI requirement) with their background to assist with visual recognition. Every grab bar, handhold, handrail or stanchion will have these characteristics:

- Rounded and free of any sharp or abrasive element
- With an exterior diameter of 35 mm that permits easy grasping by the full range of Passengers and sufficient clearance from the surface to which it is attached
- Designed to prevent catching or snagging of clothes or personal items
- Equipped with a slip resistant surface

Grab bars, handholds, handrails and floor-to-ceiling stanchions have a smooth curve. Their precise shape will be finalized during the design phase.

5.4.3.10 Train Systems & Safety Critical Items

During development of the Citadis product range, safety analyses have defined critical items and assemblies. Safety-critical equipment is equipment whose failure might induce a safety hazard; for example, structural elements, braking system, traction systems, doors and signaling equipment. A preliminary list, provided in **Cut Sheet 5.4.1.B-7**, is based on Alstom's experience and will be updated for OLRT in the design phase. A brief description of the main sub-systems is provided in this Section, with a summary of the associated safety approach where relevant.

Doors

The Vehicle is equipped with seven dual-leaf sliding plug doors on each side of the Train. Doors are largely glazed. The electric type actuator (one per dual leaf door) is in the upper part of the door. The door leaves are made up of an exterior glazing of the laminated glass type, bonded onto the structure and covering the door-leaf surface area. The panes include black silkscreen printing all around the edges, to round off their aesthetic appearance and protect bonded areas from UV radiation. The door leaves' leading edges are fitted with elastomeric joints to ensure safety when closing, and tightness. Tightness all around the door edges is ensured by an elastomeric sealing joint on the door leaf itself and the frame, concealed for aesthetic reasons and mechanical strength. The doors are equipped with a fixed threshold to reduce the gap between Train and platform. Doors' main characteristics are provided in **Cut Sheet 5.4.1.B-2**.

Our approach to access safety has the following elements:

- **Train-speed criteria** - The doors (except emergency working) can only be opened if a zero-speed threshold information signal is present. The door's closed-and-locked status is interlocked with propulsion.
- **Closing control** - Doors are fitted with special safety devices that allow each door to be locked after its closure and which authorize Train start-up once all doors are closed and locked.
- **Obstacle detection on door closure** - An obstacle-detection device inhibits the closure of the relevant door as long as a Passenger is detected between the door posts.

Truck

The proposed truck is a truck from the IXEGE family used on Citadis LRTs. For the OLRT, this truck will be fitted with a pneumatic secondary suspension to meet the levelling requirement specific to the OLRT Project. This truck benefits from all validation tests completed for the IXEGE truck. The main truck characteristics (see **Cut Sheet 5.4.1.B-5**) include:

- Achieves simultaneously the goals of having a pivoting motor truck for a low floor with a conventional truck configuration with primary suspension, secondary suspension and axle drive.
- Allows negotiation of tight curves, even without transition, while reducing wheel /rail contact forces and the resulting wear, due to pivoting trucks in the lead Vehicle position.
- Provides optimum accessibility for wheels, brakes and traction equipment. Wheels can be removed without separating the truck from the Vehicle, or removing the axle from the truck.

Braking System

Detailed information about the braking system is given in **Cut Sheet 5.4.1.B-1**. The safety approach related to the braking function is as follows:

- **Safety Brake** - Safety brake command is reversed logic, which means safety brake is applied when the safety braking trainline is not energized. This safety braking trainline is galvanically insulated to ensure that a single-point failure cannot lead to the non-application of the safety brake. Magnetic track brakes are applied independently.
- **Mechanical Brake** - Brake actuators are also reversed logic, so if no voltage is applied on the line, sufficient braking is applied to stop the Train and hold it still.

Traction System

The traction system is described in **Section 5.4.3.6**.

Safety Approach

Driving direction is distributed to traction equipment through two independent trainlines. These trainlines are powered by a stable multiple-position commutator. If a driving selection occurs when the Train is running, it will not be taken into consideration. Traction power application depends on activation of the dead-man system by the Driver. Traction is inhibited by trainlines when brakes are applied and the main circuit breaker is open upon safety braking.

Traction motor

The 4 LCA 1651 traction motor is a closed, self-ventilated, three-phase induction motor. Its nominal power is 150 kW. Additional information is given in the traction motor **Cut Sheet 5.4.1.B-4**.

Train Control/Monitoring System

The Train Control/Monitoring System (TCMS) is based on the latest generation of Alstom computerized processing software. The basic architecture for the Citadis is designed for operation in both single and multiple units without requiring reconfiguration.

The philosophy for the Citadis is to enable the TCMS to process a maximum of functions, both vital and non-vital ones. This is accomplished largely by using data-processing techniques (digital computers, software and communication by local information networks) with the aim of decreasing the number/lengths of hard-wired circuits needed, while increasing the service level, focusing on providing assistance in driving and maintenance.

Control Electronics are dedicated to performing a given Train function (e.g. the door function) that is linked with the TCMS. The TCMS inputs/outputs and the data network are used to exchange information between all electronics units of the Train. In all cases, the MPU performs the main control/command and monitoring functions, with other equipment performing its own local functions. Following this principle, data sent by the MPU to one or several electronic equipment is called "commands"; data sent by electronic equipment to the MPU or others devices is called "controls" or "monitoring".

The software programs concerned are not designed to accomplish safety-critical functions. Vital functions will be achieved by hardware logic. The software has been developed in compliance with the EN50128 software development standard.

Architecture of the Train Control/Monitoring System (TCMS)

The main architecture deployed is based on the following:

- Trainlines to perform Train safety command functions (e.g. traction/braking, doors opening/closing authorization) and controls (e.g. all doors closed status), at Train and unit level
- A redundant MVB network allowing communication between all electronic equipment inside the same unit (e.g. Traction Unit, Brake Control Unit)
- A WTB network linked (via the unit coupling cable) with the MVB network of each unit via a Gateway WTB/MVB, and allowing communication between Train units (when in multiple unit mode)
- An Ethernet network interfaced with major sub-systems for collection of maintenance and diagnosis data, at Train unit level (when in multiple unit mode)

Cut Sheet 5.4.1-CS-903 provides the preliminary TCMS architecture for the OLRT Vehicle. This architecture is given for information and may be subject to change during the design stage. It indicates the various types of equipment connected to the networks but does not represent an exhaustive quantitative list.

5.4.3.11 Spin/Slide Control system

Each truck type is equipped with an anti-slide device. Slide is detected axle per axle on the motor trucks and wheel per wheel on the trailer truck. Brake release during vehicle slide is performed truck per truck (both on the motor truck and trailer truck). The anti-slide module automatically activates the release of sand.

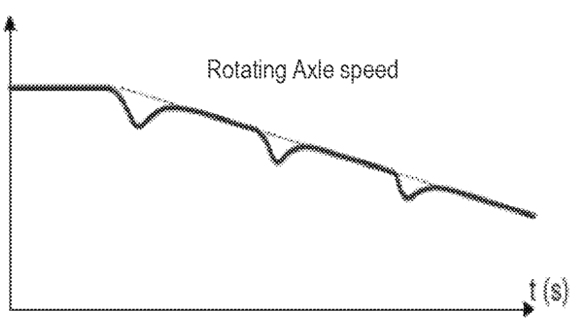


Figure 5.4-17 | Rotating axle speed regulation on a sliding wheel (trailer truck)/axle (motor truck) during service brake

In the event of a slide, in service brake, the control system quickly reduces the effort (Kill the slide) on the truck that has slid. The effort setting is reduced to adapt the effort to the adhesion available. The effort correction is calculated to match the wheel (trailer truck)/axle (motor truck) deceleration and the difference between the speeds of the wheel (trailer truck)/axle (motor truck) and the reference speed as shown in **Figure 5.4-17**. This type of regulation (Kill the slide) allows for quick and stable slide deletion.

In a slide during emergency brake, the control system reduces the effort on the truck that has slid to maintain a certain controlled level of slide (15-20%) to stay as close as possible to the maximum effort request (Keep the slide). This type of regulation (Keep the slide) allows for high efficiency in high-adhesion level braking (**Figure 5.4-18**).

In a skid, the effort rapidly regresses. The gradient and amplitude of this regression depends on the acceleration of the axle (motor truck) and the difference in the axle (motor truck) speed compared to the reference speed. When there is no more spin, the traction effort is gradually applied again (**Figure 5.4-19**).

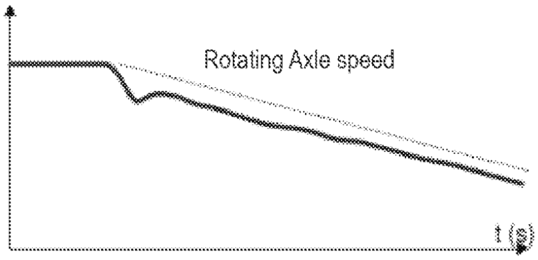


Figure 5.4-18 | Rotating axle speed regulation on a sliding wheel or axle during emergency brake

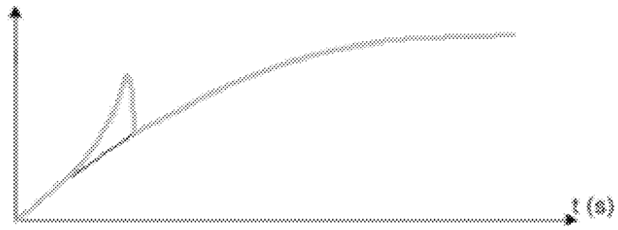


Figure 5.4-19 | Rotating axle speed regulation on a skidding axle (motor truck) during traction phase

5.4.3.12 Vehicle Delivery & Partial Assembly

The Vehicle will be shipped separately in two sections from France to the MSF in Ottawa.

5.4.3.13 Vehicle & Wayside Subsystems

Communication between Vehicle and wayside is managed by the Train Control/Monitoring System (TCMS). The proposed TCMS for the OLRT Vehicle is part of the service-proven standard Citadis product range.

Communication Based Train Control

The on-board and wayside portions of the CBTC system are described in **Section 5.4.4**.

On Board Communications Network

All Train-wide voice communications, control of destination signs and Passenger information signs and transmission of video within the Train will take place over a dedicated Ethernet network (see **Cut Sheet 5.4.1-CS-903**).

The vehicle will communicate with the wayside via a Wi-Fi system with transceivers at Stations and the MSF. This link will be used for non-vital information such as video, Automatic Passenger Counting (APC)

Radio

On-board Train Radio will be specified as defined in PA Schedule 15-2 Part 4 to fulfil related interface requirements with the planned City Radio System.

Closed Circuit Television

Exterior Surveillance

In each Station, video cameras will monitor boarding platforms. Video will be streamed to the TCMS via Wi-Fi communication and displayed to the Driver. Cameras will also be installed aboard the Trains, enabling the Driver to monitor the sides of the Train when not in a Station.

Interior Surveillance

The video-surveillance system is based on a complete digital technology system. The CCTV function is integrated with the Ethernet backbone. Electronics cards which ensure "supply, network communication and recordings" functionalities needed by this system are located in the same shelf (called Universal Mobile Controller) as Public Address.

This CCTV system consists of the following elements:

- Cameras to monitor the Passenger compartment
- Cameras to monitor the view out of the cab front and rear window
- One recorder with a hard disk(s) integrated in the UMC racks

Automatic Passenger Counting (APC)

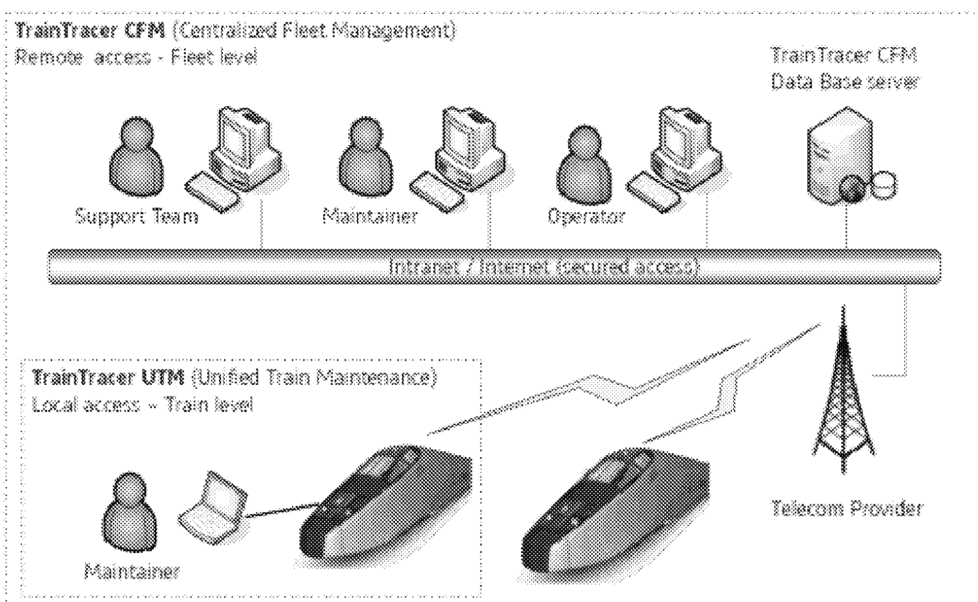
The APC system will provide an accurate count of passenger traffic and report the data to the Performance Monitoring System in real time.

Remote Diagnosis - Train Tracer

TrainTracer is the Alstom solution to facilitate Train diagnostics, interfacing Train on-board equipment with the M&R Team. Besides the usual access to Train data using a laptop PC directly connected to the Train, TrainTracer offers remote access to full fleet data through intranet and internet. Health data is automatically monitored on board each Train in operation and moves to back-office Web server through cost-effective wireless communications (see **Figure 5.4-20**).

Using a web-based server enables technicians to access Train data anytime and from anywhere there is intranet or internet access. Data will be available to the M&R Team, as well as for a remote support team or maintenance manager. As an option, access to TrainTracer could be made available to the Operator. This approach provides unprecedented visibility into the real-time operation and health of each Train. It expedites corrective maintenance, supports the Train crew and prevents some failures. TrainTracer reduces maintenance cost and simultaneously improves Train availability. This section describes the technical aspects of TrainTracer solution proposed by Alstom Transport as the maintenance assistance system for rolling stock.

Figure 5.4-20 | TrainTracer



TrainTracer Application Overview

To assist the Train maintainers, two TrainTracer applications will be available:

- **TrainTracer CFM (Centralized Fleet Management)** - A centralized application, managing data at fleet level, accessible using a thin client through a secured intranet or internet access
- **TrainTracer UTM (Unified Train Maintenance)** - A local application, managing data at Train level through a laptop PC. The connection to the Train is direct.

Main faults generated by the Trains are automatically sent to TrainTracer CFM server and recorded:

- Alarms related to failures affecting current commercial service
- Faults to be fixed at depot

Other faults and detailed information are accessible through a laptop in the MSF using TrainTracer UTM and other servers using open protocols. They are used for deeper investigation of faulty equipment.

These two applications may collaborate since CFM imports maintenance data that has been recovered by UTM. This solution enables us to manage the case where a remote connection is unavailable and a direct local maintenance operation has been necessary.

Catenary System

Interface with catenary system is described in **Section 5.4.3.14**.

Wheel Rail Interface

Information on wheel rail interface is given in the truck **Cut Sheet 5.4.1.B-5**.

5.4.3.14 Power System

The OLRT Vehicle complies with the EN50163 standard, concerning the supply voltages for traction systems. **Table 5.4-12** summarizes the lowest, highest and nominal voltages.

Table 5.4-12 | Voltages

Lowest non-permanent voltage	Lowest permanent voltage	Nominal voltage	Highest permanent voltage	Highest non-permanent voltage
U_{min2} [V]	U_{min1} [V]	U_n [V]	U_{max1} [V]	U_{max2} [V]
1000	1000	1500	1800	1950

Table 5.4-13 shows the estimated power balance on the catenary power supplied for nominal catenary voltage.

Table 5.4-13 | Estimated Power Balance

Parameter	Performance
Maximum Power for auxiliaries	325 kW (including 4*75 kW for heating)
Maximum Power for low voltage network and equipment	16 kW
Maximum Power for Traction	1050 kW
Maximum Power required on Catenary Power Supply	< 1400 kW (estimation)

5.4.3.15 Carbody Strength

To ensure maximum safety for Passengers, the carbody will exceed requirements of ASME-RT1. Cars are composed of the following equipped modules:

- Underframe (version depending on Vehicle)
- Driver's cabins (in head Vehicle only)
- Roof
- Sidewalls (symmetrical left and right)

Final assembly between the sub-assemblies will be performed either by welding, riveting or fastening, as required by structural, manufacturability and maintenance requirements. Several lifting and jacking points are present in each Vehicle , designed and calculated to ensure correct performance for re-railing and maintenance operations. The exact position and design of the support surfaces shall be developed to ensure compatibility with existing and service-proven elements.

See **Test Reports 5.4.1.A-TR-201 to 5.4.1.A-TR-204** for the car-body strength calculation results of the Citadis Nantes.

5.4.3.16 Vehicle Weights and Axle Loads

Table 5.4-14 shows Vehicle weights and axle loads under different configurations.

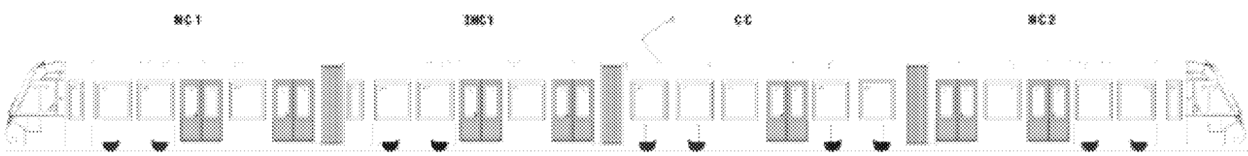


Table 5.4-14 | Vehicle Axle Loads

Tonnes	MC1		IMC1		CC				MC2		
Condition	Axle 1	Axle 2	Axle 3	Axle 4	Axle 5	Axle 6	Axle 7	Axle 8	Axle 9	Axle10	Total
Tare Load	8,341	8,341	6,945	6,945	7,271	7,271	7,998	7,998	8,276	8,276	77.6T
3.33p/m^2	10,229	10,229	10,267	10,267	9,227	9,227	10,731	10,731	10,164	10,164	101.2T
4 p/m^2	10,797	10,797	11,589	11,589	9,933	9,933	11,851	11,851	10,732	10,732	109.8T
8 p/m^2	11,365	11,365	12,910	12,910	10,369	10,369	12,970	12,970	11,301	11,301	118.4T

5.4.3.17 Crashworthiness

The end cabins provide appropriate protection to both Driver and Passengers. The design integrates ASME RT-1 required elements. It includes crash-energy absorption devices designed to deform in a preprogrammed fashion and located as shown in **Figure 5.4-21**.

Using a modular concept allows for a quick re-entry into revenue service of any Train involved in one of the considered crash scenarios. In the event of low speed crashes, impacted elements (central absorber and/or coupler assembly) are designed to be easily replaced. In the event of a higher-speed collision, end cabins are bolted on the end of the frame and can be easily and quickly replaced.

From the structural point of view, the Driver's cabin can be divided into two main elements:

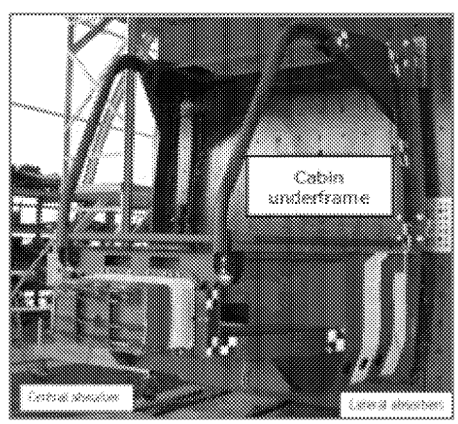
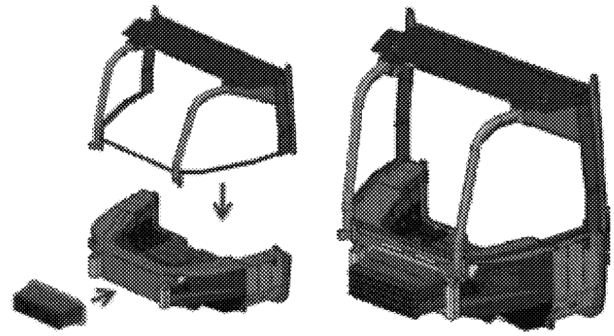


Figure 5.4-21 | Crash-Energy Absorption Devices

- A top frame composed of corner posts and a top structural shelf as specified in ASME RT-1
- An underframe integrating the crash absorption elements, the driver's survival cell, full-width anti-climber, collision posts and the interfaces with the top frame and all required equipment supports to comply with ASME RT-1



Detailed design will be finalized in conformance with the client's aesthetical design requirements. See **Test Reports 5.4.1.A-TR-301 to 5.4.1.A-TR-303** for the preliminary crash calculations.

5.4.3.18 Development, Production, Testing and Commissioning Schedule

See **Section 5.4.1.E** for the preliminary schedule. **Section 5.4.3.5** details the Testing and Commissioning Strategy.

5.4.3.19 Compliance Matrix

See **Section 5.4.1.F** for the compliance matrix.

5.4.3.20 Heating and Cooling

The Passenger compartment air conditioning is ensured by a roof-mounted fully unitized air conditioning unit on each car. All units can be maintained from the roof.

Equipment Description

The HVAC unit is a fully unitized roof-mounted unit developed to achieve heating and cooling performances while minimizing noise. The cooling circuit is hermetically sealed and uses homologated refrigerant liquid (R407C) in accordance with current European Standards and the Montreal protocol, and complies with Canadian laws and regulations. Drawings of the proposed HVAC are provided in **Cut Sheets 5.4.1-CS-501 and 5.4.1-CS-502**, with further details of the HVAC unit in **Cut Sheet 5.4.1.B-3**.

The HVAC unit has been designed to provide 8 m^3/hr of fresh air per Passenger in AW2 loading conditions. The fresh air damper can be closed by the Driver for faster warm-up and cool down of the Passenger compartment. If over temperature is detected, thermostatic and electrical protection is provided. An emergency shutdown switch is also provided in the Driver's cabin.

System Capacity

HVAC capacity has been designed for optimal comfort. The proposed unit offers 35 kW of cooling power and 30 kW of heating power. To ensure system capacity in terms of temperature stratification, treated air will be distributed to Passenger compartment by air outlets located on the ceiling and at floor level. Thermal load calculations used to define the heating and cooling capacity required are provided in **Test Report 5.4.1.A-TR-401**.

Controller

The controller regulates temperature in the Vehicle through multiple operating modes. These operating modes are determined by system configuration, analogue input values, digital input states, and the system set point. The following functions are provided by the controller:

- Safety and shutdown protection
- Diagnostics
- Fault monitoring and annunciation to MPU
- Self-health check

- Sequential starting of motors
- Includes a +/-2°C set point adjustment for all switching points

Cabin Equipment

The ventilation, heating and cooling functions for the Driver are ensured as follows:

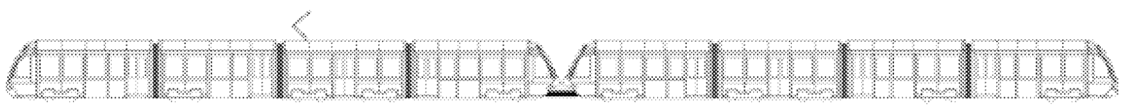
- An overhead air diffuser with volume and directional adjustability fed from the main HVAC unit
- Two thermostatically controlled cab heaters
- Side window defrost
- Electrically heated windshield

5.4.3.21 Approach to Pushing/Towing, Fire Safety and Ride Quality

Pushing/Towing

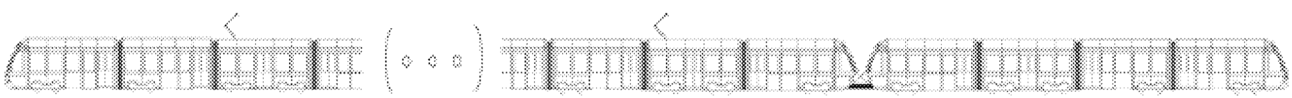
Alstom Citadis products are service-proven on diverse railway networks and are designed to rescue and to be rescued. The proposed OLRT Vehicle is designed for the following towing/pushing operations:

- A single Vehicle rescues another single one



Rescuing single Vehicle *Rescued single Vehicle*

- A multiple Vehicle rescues a single unit



Rescuing multiple Vehicle *Rescued single Vehicle*

- A multiple unit rescues another identical multiple unit

Rescuing multiple Vehicle *Rescued multiple Vehicle*

In rescue operation, the allowed operating speed is limited to 30km/h.

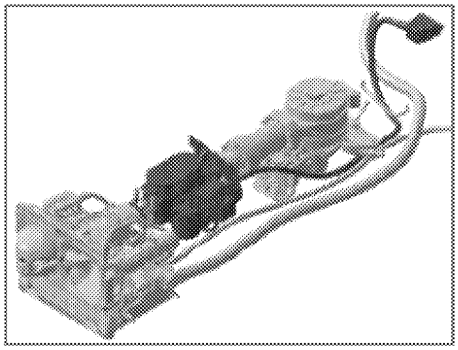


Figure 5.4-22 | Automatic Coupler

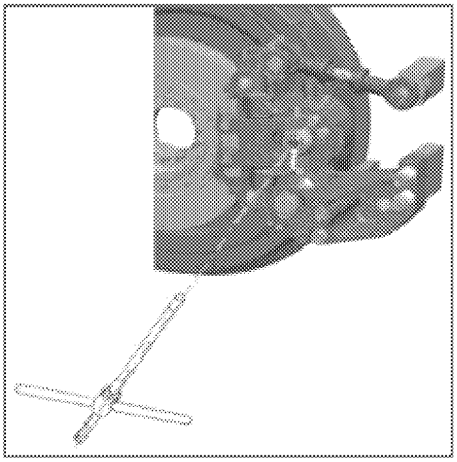


Figure 5.4-23 | Brake Release

Coupling

In normal rescued condition, the automatic coupler is used (see **Figure 5.4-21**), which contains all necessary trainlines for rescue mode. It can be manually deployed in cases of low battery or motor breakdown.

Rescue Mode Description

The rescuing Train provides low-voltage energy for all necessary functions. Mechanical brakes are released with the auxiliary hydraulic pump thanks to shared low-voltage energy.

In an emergency stop button or an unwanted uncoupling, all rescued mechanical brakes are actuating to stop the Vehicle, preventing all cases of unbraked Trains.

In the exceptional case of non-brake release through auxiliary hydraulic pump, the Driver can release the brake mechanically (**Figure 5.4-23**). Brake application will be possible only when hydraulic pumps are activated again.

In addition, the following functions are available in the rescued Vehicle (the rescuing one is fully operational):

- Emergency stop buttons (in both cabins)
- Windshield wiper
- Exterior lighting
- Cabin lighting
- Train radio

Fire Safety

All non-metallic components used on the Vehicle are smoke-, flame- and toxicity-tested to NFPA 130, 49 CFR part 238 and BSS 7239. Equipment will meet NFPA 130 requirements. All materials used on the Vehicle, as well as their weight, location and their fire/smoke/toxicity test report will be recorded in a database and maintained through the Vehicle lifecycle. **Table 5.4-15** summarizes the fire loading values.

The underframe and roof are made of steel to ensure sufficient fire resistance. Design will be validated by performing tests in accordance with ASTM E119, NFPA 130 and 49 CFR part 238. Smoke detectors are located in fresh air intake sections of each car. If smoke is detected, fresh air intake will be automatically closed to prevent external smoke from entering the Vehicle. Two additional smoke detectors will be installed in the vehicle's interior to alert both the driver and the Control Operators in the TSCC of a possible onboard fire. To ensure proper Vehicle evacuation in case of fire, all doors are equipped with an external and an internal manual door release. Two fire extinguishers will be located in each Driver cab.

Table 5.4-15 | Fire Loading

Item	Value
Estimated fire loading for MC section (MC1 & MC2)	43 GJoules
Estimated fire loading for IMC section	36 GJoules
Estimated fire loading for CC section	39 GJoules

Item	Value
Estimated fire loading for an entire Vehicle	**161 GJoules**

Ride Quality

Thanks to its unique truck architecture, the proposed Vehicle features comfort levels in line with international standards for Passenger comfort:

- ISO 2631 associated with UIC 513 (Measurements will be performed as per UIC 518
- ISO 2631-1985: Evaluation of reduced comfort boundary for urban application

5.4.4 TRAIN CONTROL

RTG is pleased to offer the SelTrac Communication Based Train Control (CBTC) System from Thales Canada for the OLRT Project. SelTrac's proven CBTC architecture provides comprehensive Train Control functionality with the highest levels of performance, reliability, availability and safety. The SelTrac CBTC System provides the 21st century urban transit system operational capabilities required for the OLRT:

- Fully protected bidirectional operation over the entire alignment
- Moving block Train protection to maximize Passenger throughput
- Flexible Control Operator interface that supports fully automatic scheduled operation while providing tools to manage incidents
- Proven safety record – the longest in the CBTC industry
- Proven performance in severe climatic conditions
- A fully automatic maintenance yard with unattended coupling and uncoupling to promote Project sustainability

Thales has operated in Canada for more than 30 years employing 1,300 employees in Transportation, Defence & Security, and Aerospace sectors. Thales' centre of excellence for signalling is located in Toronto, with offices in Vancouver and Ottawa employing more than 800 people. These Canadian offices pioneered the development of CBTC Systems for the world market in the 1980s and continue to be leaders in delivering CBTC systems that exceed client performance expectations, and in defining CBTC industry standards (IEEE 1474). Thales' Software Defined Radio, which will provide network communications for the OLRT CBTC System, was developed in their Ottawa office.

Thales has 31 lines in revenue service totaling 900 line kilometres, with a total of 1100 line kilometres contracted, and has installed CBTC solutions around the world for more than 26 years. There are currently more than 900 transit track kilometres signalled with Thales SelTrac CBTC solution in over 35 cities including major transit centres such as London, New York, Hong Kong, Shanghai, and Beijing. Thales has never failed to successfully deliver a SelTrac CBTC project and, once delivered, the system has never been replaced. (See **Cut Sheets 5.4.1.C-1 & 2** for the full project list) RTG and Thales are excited to work with the City to bring this unique Canadian success story to the nation's capital.

5.4.4.1 Modelling & Results of Expected Systems Performance & Applicability to the OLRT

As the most experienced CBTC provider using the globally proven free-space radio technology, Thales' SelTrac CBTC System exceeds the City's operational and headway requirements, ensuring Passenger comfort and optimum travel times. All features specified by the City are either included as generic SelTrac functions or have been previously implemented as a site-specific function in another system. This section provides an overview of how the SelTrac CBTC System will be applied to the OLRT and describes the modelling that was performed to validate the CBTC System design as integrated with the chosen Vehicle and alignment.

Applicability to the OLRT

The SelTrac CBTC System proposed for the OLRT consists of the following major subsystems which are distributed as shown on **Diagram 5.4.1.D-SK-202**:

- The Automatic Train Supervision (ATS) system which provides the high level OLRT control functions such as Train schedule regulation, Control Operator interface and the interface to other OLRT systems (e.g. SCADA, Passenger Information, City systems)
- Zone Controllers (ZC) that ensure safe Train separation and provide the interlocking function on a section of guideway
- Vehicle Onboard Controllers (VOBC) that ensure Trains are operated at a safe speed and within the Movement Authority commanded by the Zone Controller
- The Data Communication System (DCS) which provides the fibre-optic backbone for communication between the fixed subsystems as well as the high-speed wireless data network for communication with the VOBCs
- Track Circuits that provide broken rail protection and tracking of maintenance equipment and non-communicating Trains[1]
- Track-mounted equipment including wireless Access Points, switch machines, signals at interlockings, Train location norming transponders, intrusion detection at tunnel portals and Stations, proximity detectors at Stations, and signage

RTG will also provide a training simulator to assist in the delivery of Control Operator training and certification programs. This system will be entirely independent of the revenue service equipment listed above.

All these subsystems will be supplied and integrated by Thales and are described in more detail in **Section 5.4.4.6** and **Cut Sheets 5.4.1.C-3 to 5.4.1.C-18**. The system configuration is based on the highly successful Canada Line in Vancouver, including a fully automatic storage yard. Unlike Canada Line, all major OLRT CBTC subsystems[2] will be fully redundant, thus providing even higher CBTC system availability.

Operating and maintenance procedures and training are an important factor in achieving high system performance. Canada Line operations personnel will coordinate the development of OLRT operating procedures with the City and will participate in developing and delivering operations training programs. Similarly Canada Line maintenance personnel have participated in the design of the CBTC System and will oversee the associated maintenance procedures, training, and participate in the testing and commissioning of the OLRT. This strategy will ensure that the CBTC System design is supported by well-trained personnel, thus ensuring high system performance.

Simulation Modelling Results

Thales simulated the performance of the CBTC System on the OLRT alignment using a simulator that has been validated against actual performance of Trains in other systems. The simulation used conservative values of braking and acceleration derived from actual Train performance characteristics provided by Alstom. Actual guideway civil speeds and CBTC System tolerances and processing delays were used. The Thales CBTC System uses a proven safety distance algorithm that applies a conservative safety distance based on the worst-case braking distance calculated for actual Train speed, which allows the System to safely maximize throughput.

The simulations confirm that RTG's proposed system for the OLRT meets or exceeds all of the City's operational requirements by achieving the following:

- [redacted]

[1] RTG has chosen to provide track circuits because, although they are not required by the SelTrac CBTC System, we believe that they are the City's preferred option. We are open to exploring other options which may improve system availability at the Conceptual Design Review.

[2] Canada Line Interlockings are not redundant.

- [redacted]
- System capacity for all operating scenarios

Simulation results are summarized in **Section 5.4.5** and details are presented in the Operation Performance Simulation. A narrative can be found in **Section 10.0.4**.

5.4.4.2 Interaction of the Train Control System with Vehicles

Revenue Vehicles

Using proven interfaces, the VOBC will control and monitor major Vehicle subsystems including propulsion, brakes, and doors. In general these interfaces will be Ethernet, MVB and discrete trainlines for safety critical functions. Vehicle networks and CBTC networks will be independent, and the CBTC Ethernet network will be redundant. The functional description of the VOBC can be found in **Section 5.4.4.6**.

Thales has successfully installed their system on Trains built by all major manufacturers. They have worked with Alstom on the London Underground Jubilee Line and on Shanghai Metro Lines 6 and 8. The Shanghai installations employed 1500 Vdc as is proposed for the OLRT. The preliminary Train network design prepared jointly by Alstom and Thales is shown in **Drawing 5.4.1.D-SK-201**.

Non-Revenue Vehicles

SelTrac protects non-communicating Trains (NCT - either failed Trains or unequipped vehicles such as maintenance equipment) with a Manual Route Reservation (MRR, which sets and locks a route from an origin to destination for an NCT move) and tracks the NCT using track circuit status.

The Zone Controller interfaces with the track circuits and monitors their status to determine block occupancy, which is reported to the ATS. The Zone Controller will use block occupancy to determine the location of the NCT and will release the route behind the Train based on a check-in/check-out algorithm using block occupancy status.

NCT tracking is performed automatically by the ATS function. The ATS operator can use the Occupancy Train Correlation command to manually associate an NCT with a block occupancy. The ATS Line Overview graphically shows all Trains in CBTC territory – equipped, unequipped, and non-communicating.

5.4.4.3 Interaction of the Train Control System with Operators

Train Driver

The Train Operator Display (TOD) in the Driver's cab of the Vehicles provides status and commands to the Driver in a clear and easily understood format. The TOD is ergonomically designed to present data in a clear and concise display. The VOBC will provide data to the TOD via an Ethernet interface (see **Figure 5.4-24**):

- Speed (Maximum permitted speed, Actual speed, and New target speed)
- Train operating mode (UTO, ATO, ATP, Coupling, Non-CBTC Territory, Manual Release, ATP Cut-out)
- Indicates direction of travel, distance to go (to the next stopping point, to a new target speed, and to the movement authority limit)

Figure 5.4-24 | Typical TOD Operation Screen

- Dwell countdown timer, Faults, Alignment at the Station
- CBTC Available modes
- Side of doors that open, o verspeed indication
- Train doors status
- Train identification number
- Current Station
- Next Station
- Train destination/Headcode
- Ready-to-depart indicator (audio/visual)
- Local Time
- Station Overrun Message
- Indication of Station hold at (next) platform
- Indication of Station skip
- Open/Close Train Doors command
- Train operator ID, Rolling Stock ID
- Travel Direction, Emergency Brake Status

Mainline Operators

The mainline Control Operators (COs) are the command level of authority for the OLRT. The SelTrac ATS function provides COs with an interface where they normally run the railway in accordance with a prearranged schedule with minimal intervention, but which provides powerful tools to intervene as required to manage special circumstances such as Passenger emergencies, large crowds, system failures or severe weather. ATS workstations and overview displays provide real-time status of, and alarms for, the full rail network. Operational procedures will be developed in cooperation with the City to define the appropriate response to alarms and delays. ATS functions and screens are described in detail in **Section 5.4.4.6**.

COs are assigned a command Level of Authority (LOA) based on their training and certification. They are also assigned a Region of Authority (ROA) based on the portion of the railway they have been assigned to control. ATS command level authorization and territory control are controlled through the User Administration ATS function. ATS operators are required to log in with a defined user account to access ATS functions. Each user account is associated with one or more LOA user groups, which determine what commands are accessible to that user.

For those commands which perform a function in a specific territory of the railway, the logged-in ATS operator must acquire control of the ROA that includes that area before being able to issue the command. Only one CO may have control of an ROA at a given time. The user account specifies for what ROAs the operator is authorized to request control. Assigning ROA and LOA groups is restricted to authorized personnel.

All commands executed by an operator are logged in the archive server with the user account and workstation from which the command was issued.

Maintenance & Storage Facility (MSF) Yard Control Functions

The MSF Yard ATS workstations provide similar capabilities as the mainline, plus certain yard-specific functions such as the Train Wake-Up Command and a Train Park Command. The ROA function ensures that the yard Control Operator (YCO) cannot execute commands that affect the mainline. The yard control functions are described in **Section 5.4.4.7**.

5.4.4.4 Train Control System

The SelTrac CBTC Subsystems outlined in **Section 5.4.4.1** are further described here. Equipment location and interconnections are shown in high level architecture **Diagram 5.4.1.D-SK-202**. System hardware is described in **Cut Sheets 5.4.1.C-3 to 5.4.1.C-18**. System software, including development life cycle and configuration control are discussed below.

The CBTC product offered by Thales has an optimized architecture built around the integrated Zone Controller (ZC), which implements both CBTC and Computer-based Interlocking System (CIS) functionality.

The vital components of the system are the Vehicle On-board Controller (VOBC) on the Train and the Zone Controller (ZC) on the wayside. Together they provide the Automatic Train Protection functions of the SelTrac CBTC. The non-vital ATS provides the operator with a high-level set of operation management functions for Automatic Train Supervision. The Data Communication System (DCS) provides the communication means for all components to exchange data. A wayside Train detection system is implemented to track non-communicating Trains using track circuits.

Automatic Train Supervision (ATS) is the top-level system management and supervision component of the SelTrac CBTC, providing the ATS functionality:

- Schedule and headway automatic regulation, including energy -saving features
- Automatic and manual routing
- System status (e.g. status of Trains, switches, emergency-stop system) monitoring and display
- Operator control functions and user interface
- Data logging and report generation
- Interface with external systems, including Passenger information systems

The function of the ATS Server is to perform predictions, routing, schedule regulation, and to maintain the system status and alarm database. The ATS Server will write all log information (i.e. events, alarms) into the clustered database in the MSF. The Database Storage Unit (DSU) is the repository of the system databases. It is used to securely distribute application data to the system components remotely. The ATS is non-vital and performs no safety critical functions.

ATS Servers are redundant and implemented in a hot standby configuration. Redundancy of ATS workstations is achieved by providing multiple workstations in each control room and allowing any workstation to be configured for any function.

The **Zone Controller (ZC)** is the core Automatic Train Protection (ATP) component of the wayside vital Train control, which integrates the Limit of Movement Authority calculation with interlocking functionality. Each Zone Controller manages a section of the railway (zone) in accordance with various operation and configuration requests from the ATS. The ZC controls and monitors the following:

- All track-mounted equipment in its zone
- All Trains in its zone via continuous communication with the VOBC
- Trains entering or leaving its zone via continuous communication with the neighbouring Zone Controller(s)

The ZC is a vital subsystem and is configured as a 2 X 2oo2 (see **Section 5.4.4.9**) subsystem to achieve high safety and availability. Each ZC is equipped with a local ATS workstation to maintain basic ATS functionality in the unlikely event of loss of communication to the central ATS Servers. In case of complete loss of the ZC CBTC System process, the ZC will function as a conventional interlocking in a standalone fashion.

The **Vehicle On-Board Controller (VOBC)** is the core onboard train control system component which provides driver controlled operation (ATP Only mode), driver supervised operation (ATO mode), and driverless operation (UTO mode), by implementing Automatic Train Protection and Automatic Train Operation functionality, including safe automatic or manually driven Train movement, including Driverless turnback and accurate Station stopping, automatic door operation and protection.

The VOBC performs ATP and ATO functions in accordance with ZC and ATS commands, with which it maintains continuous communication over the CBTC wireless network. The ZC provides the Limit of Movement Authority (LMA) used by the VOBC to safely operate the Train in accordance with the maximum speed profile. The VOBC, using its sophisticated safe-braking model, calculates in real-time its safe braking curve, allowing the Train to stop very close to the end of its LMA, thus reducing the required overlap distance. The VOBC reports the position, speed and status of the controlled Train to the ZC.

The VOBC is a vital ATP component of the SelTrac CBTC system and is designed and built redundantly for high safety and availability. Each 48.5 m Vehicle is equipped with a safety redundant (2oo3) VOBC (see **Section 5.4.4.9**). In addition to on-board tachometers and accelerometers, the VOBC uses transponders to maintain Train position and proximity plates which support accurate Station stopping in ATO mode.

The **Data Communications System (DCS)** is the SelTrac CBTC communication component. Its main function is to enable fast, bidirectional, secure and dependable communication between all subsystems (see **Figure 5.4-25**).

Figure 5.4-25 | Data Communication System Context

[redacted]

The radio component of the DCS is based on IEEE 802.11 successfully deployed over more than 300 line kilometres. The radio layout provides geographical redundancy (zones have overlapping coverage) and on-board redundancy (with a pair of antennae installed at each end of the Train to provide diversity).

DCS security devices ensure that communication between the wayside trusted network and the wireless trackside and on-board network is secure.

The modular system architecture provides built-in expandability to support line extensions and/or fleet expansions to realize the full capacity of the OLRT. The system architecture of the Train control system is supported by trackside equipment and three classes of software.

Trackside Equipment

The following equipment will be installed at the trackside:

[redacted]

- [redacted]

Software Classification

The software for this Project falls into three classifications:

- **Vital Software –** Software which, if implemented incorrectly, may reduce System safety. The development and modification of vital software is subject to rigorous reviews and procedures (e.g. ZC and VOBC software).
- **System-Critical Software –** Software which, if implemented incorrectly, may reduce System day-to-day operational capability. The development and modification of system-critical software, although not required to meet the same standards as vital software, is subject to a complete design/review/test program to ensure that the functional requirements are met (e.g. ATS software).
- **System Support Software –** Software which, if implemented incorrectly, will not have an immediate effect on the level of System service but which is required to meet the overall System specification. The development and modification of System support software is designed with a less rigorous method, compatible with ensuring specified functionality (e.g. Training Simulator software).

Software Development Lifecycle

This section describes the software development process for producing software to meet functional requirements.

Software V-Model Life Cycle

The V-Model for the software development process is used to manage the relationship between each phase of the development cycle and testing, as indicated in **Diagram 5.4.1.D2.3A**. The model deploys a well-defined structure, in which each phase is implemented in accordance with the outputs from the previous phase. System requirements are input to the model.

Software Configuration and Control Management

Software configuration and all associated documentation will be controlled and managed according to Thales' proven Software Configuration Management work instruction. The software system will be segmented into Computer Software Configured Items (CSCIs) that will be version managed by use of the software tool ClearCase. Defects to these CSCIs will be managed through the accompanying software tool ClearQuest.

During the development, software configured items include the following:

- Software Requirements Specification (ClearCase)
- Software Design Documentation(ClearCase)
- Software Source Code (ClearCase)
- Software Test Plans (ClearCase)
- Software Test Specifications (ClearQuest/ClearCase)
- Software Test Source Code (ClearCase)
- Software Test Scripts (ClearCase)
- Software Test Results (ClearQuest)

When an anomaly is detected, a Software Change Report (SCR) report is submitted to the defect tracking system. This report is handled as per Thales' Change Control Process. Closure of this report will follow the documented development process complete with all reviews and checkpoints. Thales's Change Control Process ensures the following:

- Any perceived hardware, software or document fault is reported, recorded and resolved.
- Change instructions are represented in a clearly stated, structured and consistent manner .
- Proposed changes are fully evaluated (in a defined way, by all relevant parties), and are properly resolved .

- There is visibility on the status of all changes.
- All communication paths are well defined.

Hardware Configuration Control

All Line Replaceable Units (LRUs) that are identified as hardware configuration items are serialized during manufacturing. As part of final inspection, the configuration of each LRU will be verified and recorded.

Where items are procured from a subcontractor, the subcontractor will record the configuration and submit the configuration log with the item in accordance with the purchase order requirement. The configuration log will be verified as part of Thales' inspection procedures.

5.4.4.5 Key Functions and Modes

This section is divided into two major tables. **Table 5.4-16** defines key functions for both normal and abnormal conditions. Abnormal conditions are defined to be failure conditions or extreme weather. **Table 5.4-17** defines the interaction of operational modes and identifies how Drivers interact with the system.

Key Functions

Table 5.4-16 | CBTC System Key Functions

Key Function	CBTC System Condition	
	Normal	Abnormal
[redacted]		

Key Function	CBTC System Condition	
	Normal	Abnormal
[redacted]		
Automatic Train Operation		
[redacted]		

CBTC System - Operations Mode Interaction

Because of its large installation base, the Thales CBTC System supports all the features of each operating mode specified in the PA, generally as part of the generic product and in a few cases as site-specific functions implemented on previous projects. **Table 5.4-17** shows how the subsystems interact to manage the operations modes. Vehicle modes are further described in the **State Transition Diagram 5.4.1.D2.6**.

Table 5.4-17 | CBTC System Operations Mode Interactions

Mode	Description	CBTC Interaction (Key Functions)				Driver Interaction
Train Modes		ATS	ATP - ZC	ATP – VOBC	ATO	
[redacted]						

Mode	Description	CBTC Interaction (Key Functions)	Driver Interaction
[redacted]			

Mode	Description	CBTC Interaction (Key Functions)				Driver Interaction
		uncoupling	Supervision			
ATS Modes						

[redacted]

5.4.4.6 Train Control System Functional Description

The functional description is organized by the classic categories (i.e. ATS, ATP and ATO), summarized as follows:

- ATS performs all s ignalling and c ontrol functions but has no responsibility for safety
- ATP is responsible for safe Train separation and routing in accordance with control requests from the ATS
- ATO is responsible for automatic operation of the Train in accordance with commands from the ATS and under the supervision of ATP

Automatic Train Supervision (ATS)

ATS for OLRT can be divided into two major modes: ATS Automatic Mode and ATS Manual Operation Mode. Both modes operate with minimal intervention and provide the CO with powerful tools to intervene as required to manage special circumstances such as Passenger emergencies, large crowds, system failures or severe weather. Any automatic operation can be manually overridden by the CO. A preliminary list of commands is shown in **Table 5.4-17**.

ATS Automatic Mode

This is the normal mode in which the OLRT will run. The CO loads a timetable at the beginning of the day. The timetable defines a set of runs for each level of service (LOS) and each run defines the schedule of operation for a Train in that LOS. ATS will wake up each Train at the required time, send it to a Driver pick-up platform, route it to the mainline, and assign it to a run. Trains are routed from Station to Station according to their assigned timetable run. Once the run is no longer required, ATS routes the Train back to the yard.

Automatic Train Regulation

This function regulates Train movements to either a schedule or defined headway. Schedule regulation minimizes deviations between the operating timetable and actual Train movements. Headway regulation ensures that the time between Trains is consistent.

ATS will modify a Train's acceleration rate, maximum speed and/or Station dwell time to address a difference (late or early) between its actual Station arrival time versus the target arrival time according to the active regulation strategy. ATS can also apply the following regulation functions in real time to provide significant energy savings:

- **Adaptive Slow Running** – Modify a Train's driving profile to reduce acceleration rate and limit speed to avoid stopping between Stations due to the preceding Train being behind schedule .
- **Arrival/Departure Coordination** – Coordinate braking and acceleration of nearby Trains to reuse energy from regenerative braking.
- **Constrain Peak Demand** - Limit the number of Trains departing simultaneously to reduce power spikes.

The timetable compilation tool provides Energy Efficient Planning capabilities similar to these three to optimize a timetable for energy efficiency.

Automatic Train Routing

[redacted]

ATS Manual Operation Mode (Interlockings)

ATS Manual Operation Mode allows the CO to control the interlocking process of the ZC from an ATS workstation (either central or local). This mode may be useful in case of loss of CBTC Train-to-wayside communication or during the maintenance window when operating with unequipped vehicles. The ZC will operate as a conventional interlocking performing all the functions specified in the PA including allowing the CO to do the following:

- Set up routes by selecting entrances and exits or by selecting switch position for each switch
- Block and unblock switches
- Call, cancel and fleet signals
- Set the interlocking to operate in an automatic turnback mode

ATS CO Interface

The ATS provides the human-machine interface (HMI) to the CO. The SelTrac HMI is powerful and flexible, again due to Thales' experience and large installation base. The CO uses the ATS workstation to issue commands and to monitor the state of the system. The ATS Line Overview provides a complete visual representation of the OLRT state including of the location of Trains, their routes and Movement Authority, the state of wayside devices, system alarms, and Traction Power status. **Cut Sheet 5.4.1.D2.2** shows typical ATS screens, and the NetTrac MT **Cut Sheet 5.4.1.C-4** provides further information. **Table 5.4-18** provides a preliminary list of ATC commands. The details of the ATS HMI interface will be developed at the CDR and will fully support the operating procedures that RTG will prepare in cooperation with the City.

Table 5.4-18 | Typical ATC Commands

Typical ATC Commands		
ATS Level		
Online timetable updates	Run assignment	Re-determination
Line assignments	Regulation mode	System hold
Train hold	Train stop / proceed	Shuttle operation
Platform hold	Platform skip	Server switchover
Train reset	UTO Train park	UTO Train wake-up
point to point Train routing	Region & Level of Authority	Occupancy Train Correlation
ATP Level		
Temporary speed restriction	Set/clear work zone	Emergency brake set/reset
Manual switch control	Interlocking mode control	Manual route reservation
Open/close track	Route blocking	Platform close
Signal block	Authorize UTO mode	UTO Train couple/uncouple
Switch block		
ATO Level		
Speed adjustments	Dwell adjustments	Door control
Acceleration rate adjustment	Brake rate adjustment	

Automatic Train Protection (ATP)

The heart of the ATP function is the ZC: it determines the Limit of Movement Authority (LMA) and provides route locking while supporting full bidirectional operation. The VOBC is responsible for enforcing the LMA and accurately reporting Train position. The ZC reserves a block (section of guideway) for the Train up to the end of the route (typically the next Station) unless there is an obstruction along the way (e. g. preceding Train). As the Train moves within this block the VOBC reports the Train's new position allowing the ZC to release that part of the block now behind the Train. If the LMA is restricted by a preceding Train, the ZC will advance the front end of the block as the preceding Train moves ahead, hence the CBTC term "moving block." These functions are described below.

Safe Train Separation and Interlocking

[redacted]

[redacted]

Train Tracking

Using position reports from the Train and its known length, the CBTC system safely and accurately determines the location of both the front and rear of the communicating Train. The VOBC vitally determines Train length, using Vehicle length and coupler status. Vehicle length is defined by the Vehicle ID plug, and coupler status is used to determine if the Train is a single Vehicle or a coupled consist. Train position is maintained as described below.

[redacted]

Tracking Communicating Trains

The ZC uses the position reported by the VOBC to track communicating Trains. As a Train approaches an area associated with a neighbouring ZC, the VOBC begins to communicate with this 'takeover' ZC. During the transition between zones, the VOBC communicates with both ZCs, which also communicate between themselves. The VOBC stops communicating with the handover ZC once the Train is completely inside the takeover zone.

Train Doors

If door status is lost when the Train is stopped, the VOBC will prevent the Train from moving. If door status is lost while the Train is moving, the VOBC will stop the Train and alarm the Driver and CO. Upon restoration of Train-door closed-and-locked status, the ATS Operator will reset the emergency brake and the Train will start moving.

The VOBC will provide a door-enable signal on the platform side (as determined from its guideway database and Train orientation) only when the Train is aligned with a Station and is stationary with propulsion disabled. Upon completion of the platform dwell, and once the doors have closed, the VOBC will remove the door-enable signal.

Automatic Train Operation (ATO)

SelTrac ATO governs mainline functions such as speed regulation, programmed Station stopping and automatic door operation. ATO commands are always subordinate to ATP supervision functions. The ATO component of the CBTC system is primarily designed to provide automatic Train operation, Train movement, door open/close, alarms and communications, and information transmission to the ATS. The ATO process will monitor the active cab's master controller to allow the Driver to assert control as per the PA.

Data Communication System

All communications between subsystems are via the non-vital Data Communication System (DCS). Vitality of the data transferred via DCS is ensured by incorporating sequence numbers and CRCs in each message, and using an authentication algorithm applied to each message. Algorithms for generating sequence numbers and CRCs are known only by the vital devices, to prevent corruption by non-vital components of the DCS.

[redacted]

Backup Methodology in Case of Communication Failure

The SelTrac CBTC System has a high level of availability due to a robust architecture. The equipment is configured fully redundantly to provide high availability (in addition to redundancy to provide vitality). This is implemented from the processor through to field Input/Output modules. In this way the system tolerates the failure of one component with no impact to system operation.

[redacted]

System redundancy is explained further in **Section 5.4.4.9**. The following sections explain the reaction to specific failures.

Non-Communicating Trains (NCT)

[redacted]

Zone Controller Failure

[redacted]

Communication Failure

[redacted]

ZC to VOBC Communication Loss

[redacted]

[redacted]

Methodology for Broken Rail Detection

[redacted]

Yard Operations

The yard is divided into functional operations areas (see **Drawing 5.4.1.D-SK-106**):

- The area where the OC Transpo Drivers operate to pick up and drop off Trains will be equipped exactly as per the mainline to ensure common operating procedures. OC Transpo Drivers will pick up and drop off Trains as described below.

- The remainder of the yard will not be equipped with track circuits and signals. The YCO will control Train operation throughout the yard as required to support mainline operations and manage maintenance activities. Movement of unequipped Trains will be controlled by the YCO using Manual Route Reservations (MRR) in accordance with proven Canada Line procedures.
- The Transition Zone (TZ) is used to move Trains to and from the Maintenance Hall and to test Trains returning to service from maintenance. The TZ is within CBTC Territory while the Maintenance Hall and its approach apron are manual operation areas.
- The YCO will control moves between the Maintenance Hall and the TZ using an MRR to control the two-aspect signals which will be set to stop unless the YCO has set a route in response to an equipment move request (via radio) from an M&R hostler. Transponders in the TZ track will notify the VOBC that it is moving into or out of CBTC Territory and it will react as specified in the PA
- Similarly the YCO will control moves to and from the maintenance-of-way (MOW) storage track using an MRR. The MOW track is provides quick access to the mainline to maximize the usable nightly maintenance period.

Yard operations will not affect the mainline. The yard/mainline control boundary will be on the connector track between them. The precise location will be determined in conjunction with the development of operating procedures in cooperation with the City. The transfer of Trains across the boundary will be transparent to the CO, as is the transfer of Trains across any ZC boundary. To control the yard the YCO will use an ATS workstation which has full ATS functionally. The Region of Authority function will ensure that the YCO cannot execute commands that affect the mainline. Failure of the yard ZC will not affect the mainline. An FMECA will demonstrate that there are no credible CBTC yard equipment failure modes that can affect the mainline (including network failures).

Train Launch for Revenue Service

Prior to service start the mainline CO will select a timetable which defines the service level. The ATS will then:

- Select which parked Trains will be used to meet the service level (the YCO can edit this "launch list")
- Send each one a wake-up command at a configurable time before the Train is scheduled for service (to ensure that the interior temperature is comfortable)
- Route each Train as scheduled to one of the handover platforms for the OC Transpo Driver to board
- Route the Train onto the mainline upon Train mode changing to ATO (or ATP Only) and assign it to a run

Exceptions are as follows:

- The VOBC performs a start-up test upon receiving the wake-up command. The ATS informs the YCO if the test fails. The YCO will then route the Train to an inspection point or, if necessary, dispatch M&R personnel to manually drive the Train to the Maintenance Hall for service. The YCO will assign another Train to the launch list.
- If the OC Transpo Driver does not arrive in time the ATS will alarm the YCO to address the delay before service is affected.

Train Exit from Revenue Service

The ATS will select Trains to be taken out of service in accordance with the timetable as follows:

- Before arriving at the exit Station the ATS informs the Driver and the Passenger information system that the Train is being taken out of service.
- Upon completion of the dwell at the terminus Station the ATS routes the Train to one of the handover platforms in the yard.
- The Driver drives the Train to the handover platform, turns the cab off and exits the Train.
- Upon confirming that the Driver has left the Train, the YCO will normally command the VOBC to change to UTO mode and route the Train to a storage track where the Train will enter a low-energy-usage mode until commanded to wake-up. The YCO may also perform other actions as required:
- Route the Train to an inspection platform for inspection by a technician and/or cleaning staff.

- Route the Train to the wash and/or sanding facility.
- Route the Train to the Maintenance Hall. In this case the Train will come to a stop at the CBTC Territory boundary (see TZ in **Drawing 5.4.1.D-SK-106**) and wait to be boarded by an M&R hostler who will change the Train to Non-CBTC Territory mode and reque st a route into the Maintenance Hall as described above
- Uncouple a two-car Train to prepare for a timetable that requires shorter Trains, or to send one Vehicle to the Maintenance Hall.
- Couple to another Vehicle to prepare for a timetable that requires longer Trains.

5.4.4.8 System Safety Verification Standards

For the OLRT Project, Thales will adapt the System Safety Programme Plan (SSPP) plan that defines safety objectives, targets, and the required safety tasks for each of its projects. The OLRT SSPP will describe the methodologies and techniques to perform each safety task and address 'product' technical and management aspects. Other types of safety issues, such as site safety, will not be covered in this document.

This SSPP will describe the tasks and activities supporting application of the Thales generic SelTrac product safety case to the Project, building on the tasks and activities that have been performed in support of the product baseline. The tasks and activities within this scope, in many cases, take as inputs the artefacts produced in developing the product baseline, evaluating and updating based on the impact of the implementation details of the Project. The proposed solution is based on field-proven design which has been subjected to Independent Safety Assessment, the core of which remains intact for this Project. The existing safety artefacts will be confirmed and reused for this Project, where appropriate. In all cases, the existing artefacts are thoroughly reviewed to determine appropriateness and extent of reuse potential. The reuse of existing safety artefacts aids in building strong safety arguments for the OLRT Project.

The SSPP embodies the principles, methods, and best practices used in the transit signalling industry, and complies fully with PA safety requirements. It is based on the processes defined in EN 50126, EN 50128, EN 50129 and EN 50159 specifications. The SSPP also defines tasks and documentation per Thales' own ISO-9001 Manuals and Work Instructions (WI) as referenced.

This SSPP consists of eight sections which will describe each component of the Safety Programme for this CBTC Project:

- Section 1 defines the scope of this document and provides a brief description of each section.
- Section 2 (References & Terminology) identifies the standards and references that will be used to guide system design and implementation to achieve required safety targets. Abbreviations and acronyms used in this document are listed and definitions of safety terms are provided in this section.
- Section 3 (System Description) describes the proposed CBTC System with focus on system architecture and its interface with other systems.
- Section 4 (Safety Targets) describes the safety objectives required to be met by system design and implementation and the s afety process used to demonstrate the achieved performance.
- Section 5 (Safety Management Organization and Responsibilities) describes the CBTC project team organization and their responsibilities with respect to the safety programme.
- Section 6 (Safety Engineering) describes the CBTC project lifecycle and the safety tasks corresponding to each stage. The process to control safety-related hazards and service affecting failures throughout the Project lifecycle is described in this section. This process ensures that the implemented CBTC system attains the required safety targets.
- Section 7 addresses the strategy and necessary activities of the safety assurance and certification process.
- Section 8 lists the Project safety deliverables and briefly describes their content and delivery milestones.

5.4.4.9 System Redundancy

[redacted]

Figure 5.4-26 | DCS and Redundant Local ATS Workstations

[redacted]

With all its servers being redundant, hot-standby configured, Thales ATS offers high availability through an architecture that accommodates two modes:

- Multiple users, with either central or local (Station) access
- Multiple types of operator responsibility configuration in terms of authority and area of control

DCS is a redundant network implemented using high-quality COTS components, distributed between control locations (TSCC, BCC, Stations, YCC), equipment rooms, trackside and on-board the Trains. The wired (802.3) and the wireless (802.11) components of the DCS use open-standard network protocols.

Redundancy of the Train-to-wayside radio network is discussed in the next section.

5.4.4.10 Train/Wayside Communications Reliability

In a Train Control environment, performance, reliability and mobility are key considerations. The Thales DCS ensures performance by providing a low mean message (IP packet) latency and a low packet error rate (PER) by providing a redundant on-board radio link and redundant wayside radio coverage. Each Train has a radio at both ends, and all VOBCs on the Train are connected to both radios. All messages between the VOBC and ATS or ZC are sent twice, and the IP addressing scheme transmits messages over two separate radio links. Only one message needs to be received for a successful transmission to occur.

[redacted]

[redacted]

5.4.5 OPERATIONAL PERFORMANCE REQUIREMENTS

This section summarizes the results of simulations performed to demonstrate that the proposed system meets all the City's Operational Performance requirements. Simulation details are presented in the Operation Performance Simulation. A narrative can be found in **Section 10.0.4**.

5.4.5.1 Validation of Operational Capabilities & Capacity through System Performance Simulations

System Performance Simulation is performed using a software program known as Muesli Standard which simulates Train movement through the entire guideway. Numerous functions are incorporated into the simulation to model the characteristics of a modern transit system:

- Train data: acceleration, service deceleration, emergency brake rate, brake application delay
- Guideway data: grade, civil speed limits, Stations and switch locations
- System data: speed measurement errors, Train positioning errors
- Overspeed tolerance, safety distance calculation algorithm, process delays
- Routing data

To take into account the variations in travel times at different Station segments, stochastic simulations were carried out to estimate terminal-to-terminal trip time variances. These simulations confirm that RTG's proposed system for the OLRT meets or exceeds all of the City's operational requirements:

- Peak line capacity of 11,429 PPHPD in Operating Scenario 1 and 18,151 in Scenario 2, which can be increased to an ultimate capacity of 24,000 PPHPD in Scenario 3
- Average standee density of 3.33 Passengers/m^2 during peak service, with 40 percent of the capacity provided by seats, and average standee density of 0.80 Passengers/m^2 during off-peak service
- Minimum turnback headway of 79 seconds (Tunney's Pasture) and 88 seconds (Blair) in ATO mode and 86 seconds (Tunney's Pasture) and 90 seconds (Blair) in manual operation (ATP Only mode)
- Single-track outage headway of 14:52 minutes in the longest single-tracking segment
- Maximum trip time of 22:21 minutes including Dwell Time in ATO, and 22:46 minutes in Manual mode

5.4.5.2 Proposed Consist Arrangements

The proposed Train consist for peak service is a two-car configuration. Each Vehicle has a length of 48.5 m, with the distance between the farthest doors in the two units being 83.7 m (see **Drawing 5.4.1-SW-102**). The carrying capacity of the Vehicle is illustrated in **Table 5.4-19.**

Table 5.4-19 | Vehicle Capacity

Passenger Capacity	Scenarios 1 and 2 3.33 standees/m²		Scenario 3 4.0 standees/m²		Off-Peak 0.8 standees/m2	
Seated Passengers	120	40.13%	120	35.82%	120	73.62%
Standing Passengers	180	59.87%	216	64.18%	43	26.38%
Total Passengers per Vehicle	300	100%	336	100%	163	100%

Each Vehicle is capable of carrying 300 Passengers at 3.33 standees/m^2 in Scenarios 1 and 2, and 336 Passengers at 4.0 m^2 in Scenario 3 during peak service. In off-peak service the average standee density of 0.8 standees/m^2 provides an even higher degree of Passenger comfort. Seated Passengers account for 40 percent of the total capacity in Scenarios 1 and 2, and over 35 percent in Scenario 3, thus meeting the comfort level requirement outlined in PA Schedule 15-2, Part 1, Article 2.6 (c).

5.4.5.3 Terminal Operations

To optimize for lower Driver hours and tighter headways, the double-platform turnback is preferred during peak periods for the following advantages:

- Shorter minimum turnback headways, especially for Scenarios 2 and beyond
- Fewer Drivers required
- Longer dwell time at the terminus for Drivers to travel to the opposite cab to reverse direction

Under the double-platform turnback, the terminal dwell is set to be identical to the operating headway. Terminal dwell during Peak Period is illustrated in **Table 5.4-20**. Under all scenarios the terminal dwell offers more than enough time for Passenger loading and unloading, as per PA Schedule 15-2, Part 1, Article 2.6 (f).

Table 5.4-20 | Terminus Stations - Peak Period Dwell

Peak Terminal Dwell	Scenario 1	Scenario 2	Scenario 3
Tunney's Pasture and Blair	189 seconds	119 seconds	105 seconds

To comply with the Article 2.6 (f) (iv) requirement to demonstrate the ability to reliably meet terminal time requirements, we undertook performance simulations to verify the minimum turnback headway at both Tunney's Pasture and Blair. The result (see **Table 5.4-21**), confirmed that the minimum turnback headway at both termini is well below the shortest operating headway in Scenario 3.

Tunney's Pasture is not expected to be a terminus Station in Scenarios 2 and 3, as per the AM Peak boardings and alightings data for Service Levels 4 to 9 in PA Schedule 10. Nevertheless the proposed solution shows that the Tunney's Pasture Station can meet the strictest turnback headway requirements, should the City choose to use Tunney's Pasture as a terminus in Scenarios 2 and 3. **Section 10.0.4.3** describes terminus operations.

Table 5.4-21 | Terminus Stations - Minimum Headway

Terminus	Turnback Headway (ATO)	Turnback Headway (Manual Operation)
Tunney's Pasture	79 seconds	86 seconds
Blair	88 seconds	90 seconds

5.4.5.4 Station Dwell Time Analysis

As per PA Schedule 15-2, Part 1, Article 2.6 (e), nominal dwell times at all Stations were determined based on directional peak hour boardings and alightings provided in the Schedule. Factors taken into account for the determination include boardings and alightings, number of doors per Train, operating headway, Passenger throughput per door, system communication factors etc. As per Article 2.6 (e) (iv), an absolute minimum Dwell Time of 20 seconds is applied at all Stations. Dwell Times are then included in calculating the maximum terminal-to-terminal travel time, as per Article 2.6 (e) (i). **Section 10.0.4.4** fully describes the analysis.

5.4.5.5 Capability to Reliably Support Headway Requirements

To demonstrate the capability to reliably support headway requirements, RTG carried out two simulations. First, the minimum turnback headway was determined and compared against the peak headways of the System in Scenarios 1, 2 and 3. Second, the design headway of each inter-Station section of the guideway was also determined and compared against the peak headways.

The first step involves determining the minimum turnback headway. This is illustrated in **Section 5.4.5.3**, where minimum turnback headways at Tunney's Pasture and Blair are calculated to be 79 seconds and 88 seconds in ATO, and 86 seconds and 90 seconds in manual operation. All minimum turnback headways are comfortably below the tightest requirement of the105 seconds headway in Scenario 3. The second step involved determining the design headway of the guideway by performance simulation. Results of the simulation are presented in **Table 5.4-22**, where design headways in all guideway sections meet the 105 seconds headway. Combining the two steps demonstrates compliance with PA Schedule 15-2, Part 1, Article 2.3 (a): the System can reliably support a sustained operational headway of 2 minutes or less.

Table 5.4-22 | Design Headway at each Inter-Station Section

Inter-Station Section	Design Headway (Eastbound)		Design Headway (Westbound)	
	ATO	Manual	ATO	Manual
Tunney's Pasture – Bayview	59	61	36	36
Bayview - LeBreton	57	59	58	60
LeBreton – Downtown West	71	74	57	60
Downtown West – Downtown East	82	85	77	79
Downtown East – Rideau Centre	74	77	81	83
Rideau Centre – Campus	62	63	70	73
Campus – Lees	72	75	68	70
Lees – Hurdman	63	66	67	67
Hurdman – Train Station	62	65	69	72
Train Station – St. Laurent	57	60	55	57
St. Laurent – Cyrville	61	63	71	73
Cyrville – Blair	31	32	58	60

5.4.5.6 Single-Track Operation Headway

As per Schedule 15-2, Part 1, Article 2.3 (b), the System is designed to support a sustained operational headway of 15 minutes during a single track outage. To comply with this requirement, RTG simulated performance to determine the sustainable headway in all single track outage scenarios in the System. **Figure 5.4-25** illustrates the single-tracking scenarios. This calculation of the single-track operation headway takes into account the track length, number of Station dwells, and allowable speed between the switches used to bypass the failed track. The result of the simulation is presented in **Table 5.4-23.**

The worst-case single track outage headway is 14:52 minutes. System design thus complies with the Article 2.3 (b) requirement. The SelTrac CBTC System also supports “fleeting” of Trains through a single tracking section whereby multiple Trains can be sent through the section in alternating directions. This function has proven to significantly increase single tracking Passenger throughput on the Canada Line. RTG will recommend single0tracking fleeting when preparing OLRT operational procedures in cooperation with the City.

Figure 5.4-25 | Single-Tracking Scenarios

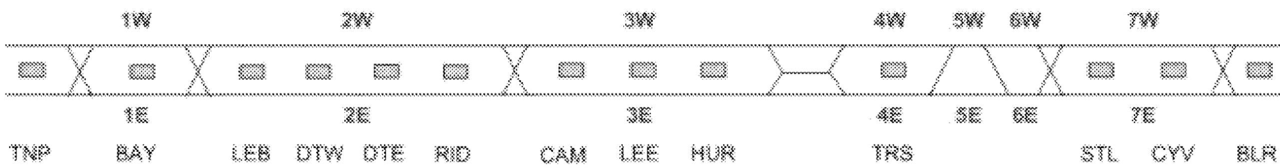


Table 5.4 -23 | Single-Track Operation Headways

Segment with Outage	Bypass Route	Minimum Headway (minutes)
1E	1W	5:10
1W	1E	5:03
2E	2W	14:43
2W	2E	14:52
3E	3W-Pocket	10:43
3W	Pocket-3E	10:02
4E	Pocket-4W-5W	4:37
4W	4E-Pocket	3:12
5E	5W	0:51
5W	6E-5E-4E-Pocket	4:59
6E	5W-6W	2:09
6W	6E	1:41
7E	7W	9:09
7W	7E	9:01
Pocket Section	4E-3E	13:53

5.4.5.7 Project End-to-end Trip Times

With all Inter-Station Travel Times and Station Dwells determined for Year 2021 and 2031 in both ATO and Manual operation, the End-to-End trip times are presented in **Table 5.4-24**. All scenarios meet the maximum terminal-to-terminal trip time requirement of 24 minutes in Manual mode and 23 minutes in ATO mode, as defined in PA Schedule 15-2, Part 1, Article 2.7.

Table 5.4-24 | End-to-End Trip Times

Direction	Year	Operations Mode	Trip Time
Eastbound	2021	ATO	22:17 minutes
Eastbound	2021	Manual	22:44 minutes
Westbound	2021	ATO	22:21 minutes
Westbound	2021	Manual	22:55 minutes
Eastbound	2031	ATO	22:15 minutes
Eastbound	2031	Manual	22:46 minutes
Westbound	2031	ATO	22:10 minutes
Westbound	2031	Manual	22:44 minutes

5.4.5.8 Validation of Operating Scenarios 1 and 2

With the relevant data presented in the above sections, **Table 5.4-25** presents the System capacity for Scenarios 1 and 2.

Table 5.4-25 | System Capacity

	Scenario 1 (Year 2021)	Scenario 2 (Year 2031)
Peak Headway	189 seconds	119 seconds
Terminal Dwell	189 seconds	119 seconds
Cycle Time	3052 seconds	2903 seconds
Capacity per Train	600	600
AM Peak Capacity	**11,429**	**18,151**
Capacity Requirement (Schedule 15-2 Part 1 Article 2.5)	**11,360**	**18,040**

5.4.5.9 Approach to System Expansion for Operating Scenario 3

At-grade Station platforms will be built to accommodate Scenario 2 (90 m) and designed to be expandable to 100 m to accommodate Scenario 3. The Underground Stations will be built to accommodate Scenario 3. The MSF site will be built to accommodate the LRVs required to meet Scenarios 1 and 2, as well as any non-revenue and specialty maintenance vehicles. The MSF Building will be designed to be expandable to accommodate Scenario 3. **Table 5.4-26** shows the headway for Operating Scenario 3 with the proposed Vehicle operating as a two-Vehicle Train, as well as options to achieve the compliant headway of 105 seconds.

Table 5.4-26 | Scenario 3 Operating Headway

Line Capacity	Vehicle Capacity	Passenger Density (p/m^2)	Percent Seated (%)	Proposed Headway (s)	Specified Headway (s)	Total Vehicles[1]
24,000	336	4	35	101[2]	105	58
For Compliant Headway:						
23,040[3]	336	4	35	105	105	56
24,000	351	4.27[4]	34.3	105	105	56

Line Capacity	Vehicle Capacity	Passenger Density (p/m²)	Percent Seated (%)	Proposed Headway (s)	Specified Headway (s)	Total Vehicles[1]
24,000	351	4	29.7[5]	105	105	56
24,000	Average 351[6]	4	35	114	105	10+46

Notes:

1 Not including spares

2 The system design will accommodate the 101s headway. A shorter headway is achieved regularly on by the Thales CBTC System on Vancouver SkyTrain between Broadway and Waterfront Stations

3 Non-compliant capacity by 4%

4 Non-compliant Passenger density by 7%

5 Non-compliant seated% by 5.3%

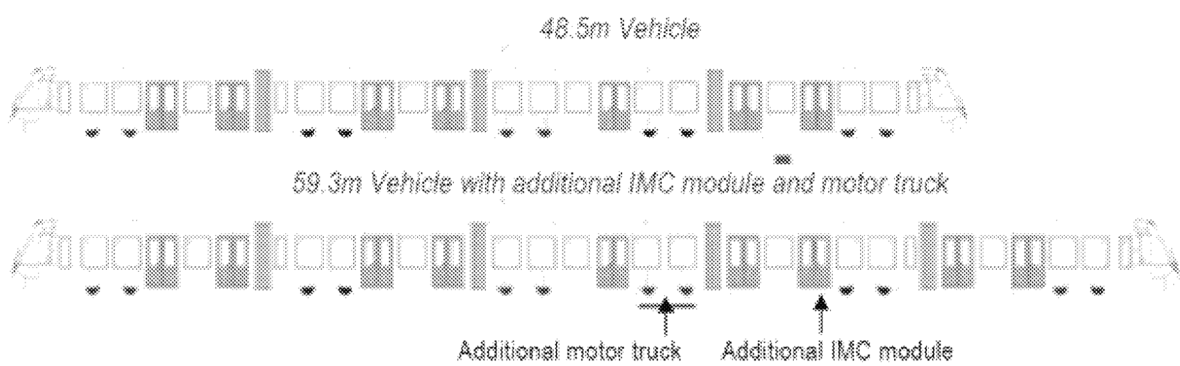
6 Average capacity of a mixed fleet of 48.5 and 59.3m long Vehicles (see below)

RTG will procure the Vehicles to accommodate the opening year. This will be accomplished with a two-Vehicle Train, each Vehicle being 48.5 m long (including the coupler the overall Vehicle length is 98 m). The distance between the outside faces of the end doors is 83.7 m. The Vehicles will allow for future fleet expansion to accommodate Scenarios 1, 2 and 3.

A headway of 114 seconds for Scenario 3 can be achieved with a mixed fleet of 48.5 m and 59.3 m long Vehicles as follows:

- The 59.3 m Vehicle is obtained by adding a new IMCx module to a 48.5 m Vehicle to increase Passenger capacity to 419 (see **Figure 5.4-26**).
- Coupling a 59.3 m Vehicle with a 48.5 m Vehicle will result in a 108.8 m long Train. The distance between the outside faces of the end doors is 94.5 m. The Underground Station platforms are sized to accommodate this and the At-grade Station platforms will be extended to 100 m to accommodate the longer Train. The MSF Building will be designed so that it can be expanded as required. Additional storage tracks will need to be built as shown on the drawings. The City can elect whether a storage shed is needed for these Vehicles.
- To comply with the specified peak hour headway, the average consist capacity should be 752 Passengers. This can be achieved with ten 108.8 m Train plus eighteen 98 m Trains. Therefore, 10 of the longer Vehicles are required.

Figure 5.4-26 | Addition of New Modules



The proposed timing of the changeover to the longer Vehicle is as follows. For Scenario 2 in 2031, 50 Vehicles (25 Trains) are required. This fleet will be increased to 58 Vehicles to handle Service Level 9 in 2046.

Once the City elects to initiate Scenario 3, the 10 additional IMCx modules will be manufactured and added to 10 of the existing 48.5 m long Vehicles. It will take six weeks to extend each Vehicle. To limit service impact, we propose to modify one Vehicle every three weeks, so only two Vehicles will be out of service at any one time. However, since two extra Vehicles are required for Service Level 9 the fleet will be fully operational even when two Vehicles are being extended. The total retrofit duration will be less than 1 year.

However, there are other options to achieve a 105 second headway which are more economical for the City:

- Slightly increasing Passenger density from 4 Passenger/m^2 to 4.3 Passengers/m^2 OR
- Nominally reducing the percentage of seated Passengers from 35 to 30 percent (a difference of approximately 10 seats)

5.4.6 NON-REVENUE VEHICLES

This section examines non-revenue vehicles, their specific tasks and lessons from other projects about purchasing vehicles.

5.4.6.1 Vehicles for Specific Maintenance Activities & Tasks

The non-revenue equipment that RTG proposes to use for maintenance of the system will consist of both Hi-Rail and Rail-Bound equipment (see **Table 5.4-27**). The strategy is to use Hi-Rail (road/rail equipment) wherever possible to maximize work time and accessibility to the system. Because much of the OLRT will be at grade, access points can be provided at various points on the system where Hi-Rail equipment can be driven to by public roadway. This will maximize available work time as this equipment can be ready to access or clear the system immediately at the start and end of the work window, and typically much closer to the work location. Because Rail-Bound vehicles are confined to rail movement, they have to be driven on the rails between the MSF and the work location, and typically after all Trains have cleared the system or before Trains have launched onto the system. This significantly reduces the amount of productive work time that is available for Rail-Bound equipment. Despite this disadvantage, there are numerous operations where Rail-Bound equipment is more capable; thus, RTG intends to use both. For specialized equipment that will not be used on a frequent or consistent basis, RTG intends to contract this work out rather than purchase and maintain equipment that would be vastly underused. Examples of such equipment would be production tampers, stabilizers, track geometry measurement equipment, and ultrasonic rail flaw detection equipment. All these services are readily available in the Ottawa area.

Table 5.4-27 | RTG Non-Revenue Equipment List (RB = Rail Bound, HR = High Rail)

Description	Type	Qty	Primary User	Anticipated Specifications
Train Shunter	RB	1	Shunt and position Trains in the MSF where no overhead power is available	Rechargeable battery-powered electric
Utility Maintenance Vehicle	RB	1	Crew transport, materials handling, track and OCS maintenance, Train rescue.	Requires towing capacity, deck, crane, crew compartment, bucket, hydraulic circuits, and Train couplers on both ends.
Trailers	RB	3	To be towed behind utility maintenance vehicle. One for general materials handling, one for cable handling, and one for tunnel wash equipment.	10 tonne useful load, air brakes, 7.0 m x 2.5 m decks.
Large Hi-Rail Trucks	HR	2	One for welding and heavier track maintenance One for OCS inspection and work	Ford F-750 or equivalent. One with complete welding set-up, one with double buckets for OCS work.
Smaller Hi-Rail Trucks	HR	2	One for guideway inspection and light repair One for signal system inspection and light repair	Ford F-350 4x4 crew cabs or equivalent
Ballast Regulator	RB	1	Regulating ballast in summer, snow clearing in winter	Industry standard ballast regulator with snow fighting attachments
Rail Grinder	RB	1	Rail grinding to address corrugation and rail	Minimum 8 stone, programmable

Description	Type	Qty	Primary User	Anticipated Specifications
			profile	rail profiling, sealed pressurized cab, dust collection.
Multifunction road/ rail Loader/ Excavator	HR	1	Multi-function materials handling, excavating, loading, rail handling, snow fighting, vegetation control.	360° road rail excavator with attachments
Spot Tamper	RB	1	Spot surfacing of slab to ballast sections, switches, low spots	Spot utility 16 tool tamping machine

NOTE: All motorized equipment will be diesel powered and equipped with scrubbers to reduce emissions and be tunnel safety compliant.

5.4.6.2 Lessons Learned about Non-Revenue Vehicle Purchases from Other Projects

Purchase Equipment that is Industry Proven when Needed

Purchasing hi-tech equipment/vehicles (requiring specialized training to operate and maintain) at the start of an operation usually means that this equipment is not used as intended when required. The employees trained to operate and maintain the equipment are usually not the ones around when the equipment or vehicle is needed to perform maintenance or repairs. Technology changes and, in most cases, the equipment becomes obsolete.

Purchase Vehicles and Equipment that Fit your System

Purchase vehicles and equipment that can negotiate the track geometry in the yard and main line. On transit systems, smaller vehicles and equipment work better in the tighter clearance areas. Also, the hi-rail vehicles can manoeuvre better in urban environments and access the track easier.

Purchase Equipment that can do Multiple Tasks

A bucket truck can replace a platform truck for OCS maintenance and be more flexible in low-clearance areas. It can also be used by facility maintenance to support lighting maintenance and platform maintenance.

5.4.7 TRACTION POWER

5.4.7.1 Traction Power Supply Design Process

The design methodology of the traction power supply employs a computer simulation technique, computer-based "traction load flow modeling". The model used for this Project is Train Operation Model (TOM) comprising two parts: Train Performance Simulation (TPS) and Electric Network Simulation (ENS).

TPS requires accurate Train and guideway data as well as Train loading, Station dwell times and speed restrictions for inputs. TPS modeling results should provide the following information:

- Train power profile output
- Train trip distance shown in TPS output summary
- Train trip time shown in TPS ou tput summary
- Train energy consumption in each trip shown in TPS output summary
- Train energy consumption per km per car in TPS output summary

The computer ENS modeling requires accurate traction power electric network data, Train operation data as well as the Train power profile from the output of the TPS. ENS simulates a fleet of Trains based on Train operation data and calculates the current voltage and power flow on the proposed traction power network modelled. ENS modeling results should provide the following information:

- Current output measurement along the traction power electric network, which includes transformer-rectifier dc rms current at each substation, RMS currents on dc feeders from each substation to OCS
- Load curve output at each substation rectifier
- Transformer-rectifier dc current graphs in each substation
- Train voltages, in voltage scattering charts

ENS results will be used to verify adequacy of substation capacity, OCS and its associated dc feeder cable current rating in the proposed traction power supply system and the minimum Train operation voltage given by Alstom. If the simulation indicates components of the traction power system are overloaded or under-used, adjustments would be made to the traction system model and the simulation redone.

5.4.7.2 Traction Load Flow Modelling Results & Parameters

The traction power system will be designed for the capacity of Scenario 2 (18,040 pphpd) with the capability to be upgraded to Scenario 3 (24,000 pphpd). The system will be able to sustain full performance service in both normal (all TPSS in service) as well as in contingency (any one TPSS out of service).

A simulation was performed based on equipment sizes and TPSS locations indicated in **Section 5.4.7.5**. The traction power system characteristics included the following:

- 8 TPSS – each with one 3 MW extra heavy-duty rectifier
- 1500 V dc traction voltage
- Feeder Cables from TPSS to OCS – 3x500 kcmil
- OCS – one 500 kcmil messenger wire and one 350 kcmil contact wire (20 percent wear)
- Running rail – 115 lb AREMA with 10 percent wear

Scenario 2 was simulated with all TPSS in service and each TPSS out of service, for the contingency situations. The following acceptance criteria validated the proposed traction power system:

- Rectifier RMS current does not exceed 2000 A (rated load of rectifier) if no TPSS is out of service
- Rectifier RMS current does not exceed 3000 A (150 percent rated load of rectifier) if the neighbouring TPSS is out of service
- No more than one percent of the total Train voltage samples falls below the minimum Train operation voltage of 1000 V

Simulation results indicate the traction power system proposed meets or exceeds OLRT requirements. **Table 5.4-28** summarizes the TPSS loading and Train voltage from the simulation. See **Cut Sheet 5.4.3-RP-100** for the simulation graphs.

Table 5.4-28 | Scenario 2 – TPSS Transformer Rectifier Unit Loading

Traction Power Substation	Normal Case Rectifier Output Current (A rms)	TPSS Out of Service Maximum Rectifier Output Current (A rms)
TPSS-01	896	1385
TPSS-02	1126	1808
TPSS-03	1052	1541
TPSS-04	819	1356
TPSS-05	843	1332

Traction Power Substation	Normal Case Rectifier Output Current (A rms)	TPSS Out of Service Maximum Rectifier Output Current (A rms)
TPSS-06	1086	1401
TPSS-07	1305	1697
TPSS-08	978	2161

Scenario 3 was simulated with all TPSS in service and each TPSS out of service, for the contingency situations. The result of the simulation indicates an extra messenger wire will be required to minimize voltage drop along the OCS and therefore increase the Train voltage to an acceptable level for the contingency cases. An additional feeder cable (to 4x500kcmil) from the TPSS to the OCS will also be required. **Table 5.4-29** shows is the TPSS loading and Train voltage with these additions. See **Cut Sheet 5.4.3-RP-100** for the simulation graphs.

Table 5.4-29 | Scenario 3 – TPSS Transformer Rectifier Unit Loading

Traction Power Substation	Normal Case Rectifier Output Current (A rms)	TPSS Out of Service Maximum Rectifier Output Current (A rms)
TPSS-01	1439	2277
TPSS-02	1719	2558
TPSS-03	1629	2375
TPSS-04	1391	2063
TPSS-05	1079	1626
TPSS-06	1104	1657
TPSS-07	1160	1697
TPSS-08	707	1299

5.4.7.3 Traction Power Supply Design, Failure Modes & Mitigation

Traction Power Supply Design

The traction power system will be designed based on the loadflow study. The medium-voltage ac switchgear, transformer rectifier units, 1500 Vdc switchgear, isolating disconnect switches, feeder cables and overhead contact system will be designed to accommodate the rms current loads as well as peak overloads typical for a transit system without detriment to the equipment.

A negative rail grounding switch will be provided in each TPSS to ensure the negative bus-to-ground voltage does not exceed PA requirements by shorting the negative bus to ground if the voltage exceeds a preset level. The rail grounding switch also provides an analog output to SCADA of the negative bus voltage to ground voltage

Failure Modes & Mitigation

To mitigate service deterioration in system failure mode all OCS sections are tied at substation locations through dc switchgear buses. Each OCS section is fed from two neighbouring substations at both ends. Two bypass power switches will be provided for both eastbound OCS and westbound OCS at each substation location except two terminal substations. In addition one power switch will be provided at each terminal substation for emergency tie between eastbound OCS and westbound OCS.

If the traction power supply system is in failure mode (either the substation out of service or breaker in dc switchgear tripped), the bypass power switches will close to ensure that the OCS section passing through the failed substation is still fed from two neighbouring substations at both ends. If the terminal substation is out of service or the breaker in terminal substation dc switchgear is tripped, the emergency tie switch will close to ensure that the OCS section passing through the failed substation is still fed from two dc feeder breakers at both ends, although two breakers are located in the same dc switchgear in the neighbouring substation.

Since all OCS sections are tied and fed from two ends in both normal mode and failure modes, this traction power supply design is very reliable. Since the traction power equipment rating in this design is based on 150 percent overload for two hours, the OLRT system can operate with one substation out of service for two rush hours without any service degradation.

Even if the traction power supply system is in failure mode with more than one substation out of service, all OCS sections are still fed from two ends and the system is still very reliable and can operate with reduced service.

The two lead tracks to the MSF will be provided with feeds from the MSF Yard TPSS and the mainline TPSS-06. In normal operation the lead tracks will be fed from the MSF Yard TPSS with the feeds from mainline TPSS-06 normally open. If a Hydro Ottawa outage occurs to the MSF Yard TPSS, the feeders from mainline TPSS-06 can be closed to provide limited 1500 Vdc traction power to the MSF Yard.

The MSF Yard will be sectionalized with separate feeders to the storage lanes and other tracks in the Yard. Each feeder for the storage lanes will not feed more than four lanes. Tracks to the vehicle wash, vehicle inspection platforms and vehicle lathe will also be separately sectionalized. All sections, with the exception of the vehicle wheel lathe, will be provided with manually operated disconnects to provide alternate feeding to the section.

Interfaces to Hydro Ottawa (HOL)

Medium voltage service of either 13.2 kV or 27.6 kV will be provided by HOL for the Traction Power Substations, underground stations and the MSF. The feeds provided will be looped, radial or distribution loop. The medium voltage will follow HOL's Planning Report.

For each medium voltage service, RTG is responsible to provide HOL switchgear pad (or room for Downtown West Station, Rideau Station and MSF Building), grounding and the necessary ducting as per HOL requirements. HOL will supply and install the HOL switchgear and metering transformers.

A branch feed will be provided at the TPSS to feed the Station transformer for Stations close to the Traction Power Substation:

- Tunney's Pasture
- LeBreton
- Hurdman
- Train
- Cyrville
- Blair

Stations that are not close to traction power substations will be fed separately via low voltage from HOL, in which HOL will provide and install the HOL switchgear, metering and power transformer. These Stations are as follows:

- Bayview
- Campus
- Lees

Underground Stations (Downtown West, Downtown East and Rideau) will be fed from a dual loop from HOL at Downtown West and Rideau and the two feeds will be looped between the three Stations. The HOL feeds will be as per Option F of the HOL Planning Report.

Power Management and Monitoring

The medium-voltage ac switchgear feeder cells will be provided with digital metering devices to monitor power flow. This will be connected to SCADA for monitoring and logging at the Control Center. For Stations that are not fed from a nearby traction power substation, digital metering will be provided on the main low-voltage switchboard and will be connected to SCADA.

5.4.7.4 Preliminary Single Line Diagram

Preliminary single line diagrams are provided for the mainline and MSF:

- For the mainline, refer to **Drawings 5.4.3-SW-101 to 5.4.3-SW-106**
- For the MSF, refer to **Drawings 5.4.3-SW-108 and 5.4.3-SW-109**

5.4.7.5 Proposed Substation Locations

The eight TPSS will be located along the mainline and two TPSS will be located in the MSF as per **Table 5.4-30**. The actual location and space requirements of the mainline are shown in **Drawings 5.4.5-SW-101 to 5.4.5-SW-108**.

Table 5.4-30 | TPSS Locations

TPSS	Chainage	Location
TPSS-01	98+150	West side of Tunney's Pasture Station
TPSS-02	100+270	LeBreton Station
TPSS-03	102+470	Within Rideau Station
TPSS-04	104+110	
TPSS-05	105+540	
TPSS-06	106+850	
TPSS-07	108+710	West of Cyrville Station
TPSS-08	110+610	East of Blair Station
TPSS-YARD		
TPSS-SHOP		Within Admin/Shop Building

5.4.8 OVERHEAD CATENARY SYSTEM

5.4.8.1 OCS Description

The mainline OCS will a simple catenary consisting of a 350 kcmil hard drawn copper contact wire and a 500 kcmil, 37 strand hard-drawn copper messenger wire. Typical stagger will be 300 mm maximum. The OCS will be designed for the temperature variation and ice loading of the Ottawa environment.

5.4.8.2 Typical OCS Arrangements

For the at-grade and elevated sections of the mainline, Simple Catenary auto-tensioned will be used. The contact wire height from top of rail will vary to provide clearance from the structures, and system depth will be 1200 mm. The poles will be round tapered and generally be between the tracks with spacing no more than 60 m. The poles may be coloured to blend into the surroundings. Tension lengths will be no more than 600 m to accommodate the large variation of ambient temperature in the Ottawa environment. Tensioning will be by balanced weight assemblies. Short tensioning sections, for example in the special trackwork, will be done by spring tensioners.

Insulated overlaps will be provided at TPSS for sectioning the OCS. Insulated overlaps will also be provided at crossovers to further sectionalize the OCS. These overlaps will be located to allow for Train movement and turnback without loss of traction power. Pole-mounted disconnect switches (normally closed) will be provided at these overlaps to allow normal power flow in the OCS section.

For the MSF Trolley, fixed termination system will be used. The contact wire will be supported by either single or back-to-back pole-mounted cantilever arms or head-span arrangements. For the storage lanes, the single contact wire will be supported by head spans.

Tunnel OCS Arrangements

For tunnels and underground areas, rigid conductor rail will be used for this Project. This includes the downtown section underground section, St. Laurent and the tunnel on the MSF connector. The benefits of rigid conductor rail include the following:

- Ease of installation
- Minimal maintenance required
- Higher conductivity than simple catenary to reduce voltage drop to the Trains
- Reduced tunnel height
- No tension, therefore wire breakage is not an issue

Height-Constrained OCS Arrangements

Elastic supports will be used at existing overpasses with minimal clearance:

- The Transit structure just west of Tunney's Pasture Station (4.44 m clearance)
- Highway 417 at Lees Station (4.6 m clearance)
- Highway 417 off-ramp (4.6 m clearance)

For these low-clearance areas, the messenger wire may be terminated onto the overpass (fixed termination) or guided under the overpass using insulated pulley wheels.

5.4.8.3 Minimization of the Visual Impact of the OCS

To minimize the visual impact of the OCS on the mainline, the OCS will be designed to have a pole spacing of 60 m and typically be located in the centre to minimize the number of poles. The poles will typically be round and tapered and can be coloured to match the surrounding environment. Further aesthetic design to ensure the OCS poles blend into the surroundings will be developed.

5.4.8.4 Power Controls & Sectionalization

Sectionalization will be provided as shown on the preliminary traction power system single line drawings. For the mainline, sectionalization will be provided around crossovers. For the isolation of faulted sections, the mainline will be provided with motorized disconnect switches and the MSF will be provided with manually operated disconnect switches. Control of the mainline switches and monitoring of all the switches will be provided through SCADA from the Control Centre.

5.4.8.5 Passenger & Public Protection from OCS Failures

Clearance to the live parts of the OCS will adhere to EN 50122-1. Where clearances cannot be met, protective screen or guards will be installed. Metallic guards or other metallic items which may become energized due to an OCS failure will be properly bonded to the grounding system.

Catenary shrouds will be provided on bridges and other locations where pedestrian traffic is close to the messenger/contact wire. Signage warning will be provided along the guideway warning the public of the proximity of high voltage.

5.4.8.6 Methods to Reduce EMI Impacts to Sensitive Receptors along the Alignment

EN 50121 will be used as the design basis for the component and overall System emissions and immunity. All equipment procured will be expected to carry certification of testing and compliance with the section of the standard relevant to the equipment and its application.

Knowing the design basis, and in accordance with the requirement of PA Schedule 15-2, Part 4, Article 9.1 (h), we will then develop an "Electromagnetic Compatibility Identification" document which will lay out all expected sources and levels of electromagnetic noise coming from the OLRT, seek to identify all sensitive receptors along the alignment, and then provide information to those receptors on the EMI emanating from the new OLRT.

It is expected that these receptors, along with other Stakeholders, will use this information to review their equipment and operation and advise if they believe that there is a risk from rail operation to their systems or equipment. Upon receipt of any concerns from the receptors and external Stakeholders, we will review the nature of their concerns and, if necessary, discuss and agree on the most appropriate way of mitigating such interference to an acceptable level.

Additionally, the document will also identify any known, existing, external systems that lie within the limits of the OLRT's operating area that may themselves pose a risk to the safe operation of the railway and need to be mitigated accordingly.

Having identified the potential risks, both from and to the railway, we will develop an "EMC Control Plan'", based around EN 50121-1, that will lay out a systematic, layered approach to all identified risks, ensuring we meet the required level of management of the risk of EMI to the OLRT and to the parties adjacent to the line.

This is the approach adopted and used successfully to engage with parties such as the Vancouver Airport Authority and NAV CANADA for the Canada Line in Vancouver.

5.4.9 COMMUNICATION SYSTEM

RTG's OLRT Communications System will meet PA Schedule 15-2, Part 4 requirements. The systems and their component elements will use modern, Project-appropriate technology for safe, efficient operation to be centred in the MSF and TSCC.

Fixed-facilities communication systems will be designed around a backbone of a new Communications Transmission Systems (CTS) linking Belfast Road's TSCC and MSF with the new transit Passenger Stations and sub-stations. The CTS will be the transmission medium for all internal operations-related communication systems (e.g. SCADA, public address (PA), telephony, CCTV) and external systems (e.g. Fare Collection

Communication systems transmission between Train and wayside will be designed around high-speed radio systems transmitting CCTV and other bandwidth-intensive data both to and from the Train, when the Vehicle is either in a Station or in storage at the MSF. Lower-speed data and voice communications to and from the Train will use the future Ottawa PSR system linked to dispatchers in the TSCC and servers in the MSF.

The individual communication systems provided will be built to comply with the latest editions of the codes, regulations, and standards listed within PA Schedule 15-2 Part 1 and will meet the reliability, availability, maintainability, and safety

(RAMS) requirements. See **Drawings 5.4.6-SW-102** for Communications Systems context and interaction and **5.4.6-SW-103** for overall system topology.

5.4.9.1 Facilities

OLRT Control Centres

There are three Control Centres to be delivered as part of the OLRT Project: the Transportation Services Control Centre (TSCC) at 875 Belfast Road, the Back-up Control Centre at the MSF and the Yard Control Centre, also at the MSF. Additionally, the main communications servers for the OLRT System will be located in the Main Communications Room (MCR) in the MSF.

TSCC

The TSCC is currently the Bus Control Centre that will be extended to become the main control centre for the OLRT System. As part of the Project, we will provision three new workstation locations in the existing Bus Control Centre at 875 Belfast Road; each workstation will be fully equipped to interface with the systems detailed above. In addition to workstations, we will install CTS communications equipment, video servers and long-term storage and a new Overview Video Wall displaying SCADA, CCTV and CBTC information.

We will also interface to existing systems such as the PA/PIDS workstation, the existing IAC system and the TSCC PABX as well as to future systems including the new Ottawa PSR system.

The TSCC will interface to the communications servers in the MCR at the MSF over the CTS; it will also communicate out to the Constellation Data Centre for off-system OLRT data storage.

BCC

The Back-up Control Centre (BCC) will be located adjacent to the Yard Control Centre in the MSF. It will provide an alternative control centre location for OLRT Operations should the TSCC become unavailable for any reason. As with the TSCC, it will interface to the Communications servers in the MCR.

YCC

The Yard Control Centre (YCC), located adjacent to the BCC in the MSF, will provide for operation of the MSF Building and yard including security and facilities monitoring and control. The YCC will use the communications servers in the MCR to monitor and control the Yard in the same way as the TSCC and BCC use the servers to monitor and control the main line.

OLRT Stations and Fixed Facilities

The OLRT has 13 Stations along the alignment each allowing Passengers to enter/exit the OLRT System and, in several cases, providing intermodal transfer with buses. Additionally, 10 Traction Power Substations (TPS) will be built to provide electrical motive power to the Trains along with Station power in instances where facilities are co-located. These facilities will be monitored by the Communication Systems with data provide to both TSCC and YCC staff.

At Stations, the communication systems will include CCTV for both operational and security needs, PA system to inform the public audibly on travel and other important information, and Passenger Information Display Systems (PIDS) that will provide visual information. Help Phones will be located throughout the public spaces to provide Passenger assistance facilities, with other telephony devices distributed throughout the facilities to provide service for both OC Transpo and RTG staff. Other facilities such as BAS/BMS and SCADA will enable TSCC staff to manage Station facilities with IAC systems providing building and facility security protection.

Similarly, other fixed facilities (e.g. TPS) will be managed through SCADA and provided with telephony communications and IAC system for protection

Main Communications Room

Central communication systems equipment will be located in the Main Communications Room (MCR) in the MSF with local facilities being located in Station communication rooms and satellite locations such as TPSs. Links will be established between the MCR and TSCC operator workstations to enable interaction between TSCC staff and the distributed communication systems; in a similar fashion, local links within the MSF B uilding will connect the BCC and YCC workstations to the MCR.

5.4.9.2 OLRT Key Subsystems

This section describes the following key OLRT subsystems:

- CTS – Communications Transmission System
- PA – Public Address
- PIS (PA and PIDS)
- CCTV – Closed Captioned Television
- IAC – Intrusion Access Control
- Telephone and Intercom
- SCADA – Supervisory Control And Data Acquisition
- CBTC – Communication-Based Train Control
- BAS
- BMS
- Radio – Radio communications
- Train-to-Wayside Wireless system

The overall systems topology diagram, communications subsystems conceptual diagram, and all other subsystem specific diagrams referenced in the following text are listed in **Table 5.4-31** with their drawing numbers.

Table 5.4-31 | System and Subsystem Drawings

Drawing Title	Drawing Number
Communication System Context Diagram	5.4.6-SW-102
Overall Systems Topology/ Connection Diagram	5.4.6-SW-103
Communications Fibre Cable Distribution Conceptual Diagram	5.4.6-SW-104
Comms Passenger Information System Conceptual Diagram	5.4.6-SW-106
Communications Telephony System Conceptual Diagram	5.4.6-SW-107
Comms CCTV System Conceptual Diagram	5.4.6-SW-108
Comms SCADA System Conceptual Diagram	5.4.6-SW-109
Comms Train-To-Wayside Wireless System Conceptual Diagram	5.4.6-SW-110
Comms Station BMS Connection Diagram	5.4.6-SW-113
Communications General Connection Diagram	5.4.6-SW-114
Comms Station LAN Connection Diagram	5.4.6-SW-115
Comms TSCC & Data Centre LAN Connection Diagram	5.4.6-SW-116
Comms MSF LAN Connection Diagram	5.4.6-SW-117
Communications -Train Control Context Diagram	5.4.6-SW-119

Communications Transmission Systems

The Communications Transmission System (CTS) will comply with PA Schedule 15-2, Part 4, Article 6 requirements; it will comprise both WAN and LAN components in each operational building and it will be equipped with a Network Management System (NMS).

CTS – System Description

The CTS will comply with the PA Schedule 15-2, Part 4, Article 6 operational and performance requirements; it will comprise both WAN and LAN components in each operational building and will be equipped with a Network Management System (NMS).

In general, the system will provide operational interfaces, connectivity and transportation for the following:

- Supervisory Control and Data Acquisition system (SCADA)
- Telephony and PABX
- Closed Circuit Television System (CCTV)
- Public Address system (PA)
- Passenger Information Display System (PIDS)
- High-Speed Wayside Radio Communications subsystem
- Automatic Fare Collection system (AFC)
- Signalling system
- OC Transpo and M&R corporate LANs (Station LANs back to TSCC or MSF)

Provision will be made on the direct fibre network to support fire- and life-safety system connectivity. RTG recognizes that we cannot carry certain fire- and life-safety services over core hardware due to regulatory restrictions.

The overall fibre-based network will provide high-speed, resilient transmission and connectivity of the systems listed above between all Stations and substations on the new line, and to the new MSF and TSCC. Local fibre and copper cabling will be used to connect individual devices and local networked equipment to the dual-pathed and redundant high-speed network nodes.

The CTS deployed will be of the latest proven technology, will comply with all applicable standards and will be compatible with the existing OC Transpo CTS system as required in PA Schedule 15-2, Part 4, Article 6. The final selection of equipment, functionality and topology will be carried out during the design phase to gain maximum benefit from the latest available and transit proven technologies.

Nodes

All CTS node equipment, including local device interfaces, will comply with IEEE standards and International Telecommunication Union ITU-T recommendations for Ethernet based networks. All nodes will have common features across the deployed system:

- High reliability and availability as shown through RAMS analysis
- Flexible equipment configuration and control
- Integrated interface for maintenance operations through the Central NMS
- Integrated alarm monitoring on all local nodes and through the Central NMS
- Non-traffic affecting test points on all nodes.

CTS nodes will provide network connections for all interfaces required for this Project; we do not anticipate any need for separate converters. All nodes are to be supplied with a minimum 50 percent spare capacity that can be used by any selected function or facility as required.

The CTS network will provide 100 percent protection to all traffic in the event of a network fibre break and will be capable of executing a network re-route in less than 50 ms from detection of network failure on the primary path; the final protection strategy will be agreed during the design stage. **Drawing 5.4.6-SW-114** shows the general network connection design for RTG's proposed CTS with drawings showing Station LAN, TSCC LAN and MSF LAN listed in **Table 5.4-31**.

Integration with OC Transpo systems and details on security of the overall network are discussed in **Sections 5.4.9.3, 5.4.9.4** and **5.8.4.5** of this Response.

CTS Fibre Architecture

Two single-mode, 48-strand fibre-optic cables will be run from the TSCC passing through the new MSF and out to the Stations and other operational buildings. The cables will be installed in a Station-hopping configuration as described below to provide communications path redundancy and diversity. The fibre cable used for the CTS will be standalone from the CBTC fibre backbone and Access Point fibre distribution cables.

All fibre optic cables will be installed in accordance with the manufacturer's recommendations in terms of minimum active bend radius, cable support requirements, tensile loads and temperature. All fibres, including connections, will be tested in accordance with Telecommunications Industry Association standard TIA/EIA 526-7 OFSTP-7, Method A2 and Method B.

The fibre cables will be protected for their service, will be sheathed to be water- and UV-resistant and will meet Low Smoke Zero Halogen (LSZH) requirements as required by the application into which they are being installed. The fibre backbone proposal is shown in **Drawing 5.4.6-SW-104**, for full reference this drawing also shows the CBTC backbone that is run in an independent fibre cable.

Central Network Management System

The Network Management System (NMS) will manage the network equipment and devices for faults, administration, configuration, performance, and security. Located in the MSF MCR, it will provide system information in a hierarchical, graphical format with the top level of the hierarchy showing the fibre loops and Station network nodes, lower level screens will show individual nodes and individual cards/ports at the lowest level.

Public Address System

The system will be designed to provide clear, audible announcements throughout the Stations and MSF from both local microphones and the Control Centres (TSCC/YCC/BCC) with both ad-hoc and pre-recorded message broadcasts being supported. See **Drawing 5.4.6-SW-106** for details of the PIDS conceptual design including the Public Address System.

The OLRT Public Address (PA) system has two main subsystems; the Station/MSF PA systems and the Vehicle PA systems. The Train-based system will comply with the Operational and Performance requirements in Schedule 15-2, Part 4, Article 3 and is discussed elsewhere within this Response.

PA System – System Description

Station-based PA systems will comply with Schedule 15-2, Part 4, Article 6 operational and performance requirements with the MSF PA system complying with Part 6, Article 7 requirements. These systems will comprise speakers, microphones, amplifiers and signal processors in each operational building, with microphone facilities available at the TSCC and MSF as necessary.

It will be possible to make ad-hoc announcements from the local Station and the TSCC, to trigger pre-recorded general and emergency announcements, and to trigger automatic Train movement and travel announcements. Automatic Train arrival announcements will be generated through data connectivity with the Train control system and will be delivered to the arriving platform and to concourse areas where applicable. All pre-recorded messages will be available in English and in French.

All messages not manually generated at the Station will be delivered or triggered over the CTS network for the Control Centres. Transportation Control messages will be delivered using VoIP or similar technology over the CTS network to the Station signal processor, and recorded messages will be stored digitally at the Stations and triggered from the Control Centres. All local, manual, Station announcements will be generated as analogue audio from local microphones.

Delivery of synchronous audio and visual messages to Passengers will be accomplished through links between the PA and PIDS subsystems so that standard travel messages and normal operational recorded messages are delivered to the Station subsystems together. Ad-hoc messages built at the TSCC will also have this functionality, allowing important travel and emergency information to be coordinated.

To achieve this level of functionality, the PA system will be integrated with the following systems.

- SCADA System
- CTS network
- Central Master Clock
- Train Control system
- PIDS subsystem
- Fire Detection & Alarm System

RTG has successfully integrated Public Address systems with these capabilities on projects such as Vancouver's Canada Line.

PA System – Basic System Design Philosophy

PA system design will use the following basic principles:

- Application of the latest applicable Codes of Practice and International Standards, including NFPA-130, EN 54-16, IEC 60849 (buildings) and IEC 60268-1
- Service-proven design in a similar application environment
- Ease of maintenance and low lifecycle cost with interchangeable line-replacement modules
- High reliability and availability with redundant modules as necessary
- Adherence to operational performance requirement while being environmentally friendly

Train PA System Operation

The Train PA System will provide audio coverage for Passenger areas of the Vehicle with control of PA announcements available from the Driver's cab, from the TSCC and microphones, and through the use of recorded general travel and emergency announcements. The operation of the Train-based public address systems is detailed elsewhere in this Response.

PA System – Coverage and Environmental Intrusion

The building PA System will provide audio coverage of all public areas and all non-public areas, including the MSF, with control of audio volume through zone-selectable announcement areas and Ambient Noise Sensing (ANS) microphones as appropriate. To ensure the delivery of clear, audible and understandable PA messages, speaker design will be coordinated with building design to ensure a high final design STiPA value.

RTG recognizes that some Stations will be located in residential areas and that loud PA announcements can be a source of annoyance and environmental intrusion to local residential populations. During the design stage, Station PA modeling will be undertaken to aid in the selection of speaker location and type to meet the performance specification while minimizing environmental intrusion. Additionally, time-based volume reduction strategies will be used to minimize night-time intrusion into local communities.

PA System – Prioritization of Messages

Important Passenger announcements will be prioritized to take precedence over normal operational announcements. It will be possible to set different priorities for announcements from different sources. For example, ad-hoc voice announcements could be configured to take priority over recorded messages at all times. Life-safety and emergency announcements will take precedence over all other announcements with Station PA systems being interfaced to the Station FDAS for such purposes. The final determination of priorities will be made with the City during the design stage.

PA System – Availability

The individual Station and MSF systems will be supervised at all times for equipment and speaker line failure with alarms being reported both through the local system and through the SCADA system to TSCC operational staff.

The PA system will be designed to have an availability of greater than 99.3 percent for any one Station PA system with an overall OLRT PA system availability of 99.9 percent as required by Schedule 15-2, Part 4, Article 6.3 (c) (v). System design will ensure that failure of any local Station PA, or local Station PA facility, does not cause a failure of the overall PA system.

PA System – Speaker Types

The speakers shown in **Table 5.4-32** are expected to be deployed to buildings along the alignment, with the possibility of an additional type being deployed in storage sheds at the MSF.

Table 5.4-32 | Speaker Types

Speaker Type	Description
Projection Speakers	■ For Station platforms, projection speakers will be used, allowing sound to be delivered to a targeted area.
In-ceiling Speakers	■ For locations within Stations where false, or drop ceilings are used, in-ceiling speakers will be used to provide a flush finish.
Surface Speakers	■ In ancillary rooms and corridors, metal box wall and ceiling speakers will be used.
Horn	■ Within the Maintenance Hall at the MSF, horn speakers will used to provide coverage.
Yard	■ For the main rail storage areas

Passenger Information Display Systems

OLRT Passenger Information Display Systems (PIDS) have two main subsystems: Vehicle PIDS and Station PIDS. Vehicle PIDS will comply with PA Schedule 15-2, Part 4, Article 3 operational and performance requirements and are discussed elsewhere within this Response. Station PIDS will comply with PA Schedule 15-2, Part 4, Article 6 operational and performance requirements and will comprise variable text/graphic signage displaying pre-recorded and Control Centre generated ad-hoc messages as necessary. There will be no PIDS installed at the MSF other than units used for training, which will comply with the requirements of the Stations. See **Drawing 5.4.6-SW-106** for details of the PIDS conceptual design including Passenger Information Signage.

PIDS – System Description

Station PIDS will comprise ADA/OADA compliant dynamic electronic signage and Station controllers in Station arranged to provide Passenger travel information on both Station platforms and concourses.

Delivery of synchronous audio and visual messages to Passengers will be accomplished through links between the PA and PIDS subsystems so that standard travel messages and normal operational recorded messages are delivered to the Station subsystems together. Ad-hoc messages built at the TSCC will also have this functionality, allowing important travel and emergency information to be coordinated.

To achieve this level of functionality, the PIDS will be integrated with the following:

- The existing PIDS
- CTS network
- Public Address subsystem
- Central Master Clock
- Train Control system

PIDS – Basic System Design Philosophy

PIDS design will use the following basic principles:

- Application of the latest applicable Codes of Practice and International Standards
- Service-proven design in a similar application environment
- Ease of maintenance and low lifecycle cost
- Use of interchangeable and module line replacement units
- High reliability and availability
- Low energy consumption
- Adherence to operational performance requirements

Station PIDS Operation

Station PIDS will provide travel, operational and emergency information messages to the public using alphanumeric characters and graphics. Signage will be designed and located to provide maximum visibility to Passengers. Use of ADA-compliant colours and legible text fonts will enhance the usability and visibility of the signage.

The signs will provide date and time information, destination of the next two to three Trains along with their expected time of arrival. This information may be augmented with ad-hoc and recorded OLRT operational information, bus travel information and weather information, and may also be used for emergency or other informational messages such as 'No Smoking' or future maintenance activities. To comply with ADA, we will use monochrome, amber-on-black LED signage to provide maximum visibility with fonts chosen to provide maximum readability.

All TSCC messages will be developed on the PA/PIDS Customer Service Console and delivered over the CTS network using IP communications to the Station controller from where they will be sent to the PIDS. Recorded messages and graphical displays will be stored digitally at the Stations and triggered from the TSCC. Local Station triggering of recorded messages will be possible in case of network failure allowing service interruption messages; for example, to be displayed without connectivity to the TSCC. Train arrival and departure information will be triggered using data received from the CBTC system at the MSF and passed to local Station controllers in the same way as TSCC-generated messages.

Displays will be designed, arranged and mounted to ensure maximum visibility for Passengers, with two mounted on each platform and others located throughout Station public areas, especially around fare collection areas. Messages will be formatted and delivered for specific locations, functions and occasions. The system will be designed to enable each PIDS display to be individually addressed from the TSCC.

PIDS – System Availability

Individual Station units and overall system will be supervised at all times for equipment and major subsystem failure with alarms being reported through the SCADA system to the TSCC operational staff.

The system will be designed to have an availability of greater than 99.3 percent for any one Station system with an overall OLRT PIDS availability of 99.9 percent. The design will ensure that failure of any local Station PIDS display does not cause a failure of the overall Station display system.

PIDS Signs

All PIDS signs will be housed to prevent damage from moisture, dust, ultraviolet light and vandalism. Where signs are mounted outside, for example on platforms, they will be configured to ensure readability in direct sunlight by changing their light output in line with changing ambient light levels.

CCTV

The OLRT Closed Circuit Television (CCTV) system has two main subsystems: the Station/guideway/MSF (fixed facilities) CCTV systems and the Vehicle CCTV system. The Vehicle CCTV system is detailed elsewhere in this Response.

Fixed-facilities CCTV systems will comply with PA Schedule 15-2 Part 4, Article 6 and Part 6, Article 7 operational and performance requirements including interfacing with the IAC and emergency telephone systems to provide staff with the best view of an event. **Drawing 5.4.6-SW-108** provides details of RTG's conceptual CCTV system design.

CCTV – System Description

The CCTV system will be built up from several subsystems: cameras, power supplies, network devices, video recorders/storage and displays, all of which will be integrated into one coherent system providing security and operational monitoring for the OLRT.

Fixed and PTZ cameras will be deployed at Station entrances, along Station platforms, in Passenger circulation areas, covering DWAs, at tunnel entrances, for monitoring fare collection equipment, and at other areas that need to be covered following CTPED reviews. These cameras will be connected back to their respective Station equipment using a mix of fibre and copper technologies as determined by their location, distance and application. Data compression at the camera, (e.g. H264/MPEG4), will be used to provide high quality video at a manageable bandwidth.

A digital link, via the wayside high-speed radio system, will enable Station streams to be sent to the Vehicle for display on the Vehicle cab's video panel when it is stationary.

Fixed Facilities CCTV System Design Philosophy

CCTV system design will use the following basic principles:

- Application of the latest applicable Codes of Practice, International Standards and Laws, including Transport Canada guidelines, APTA IT -CCTV-RP-001-11, ULC-S317-96 and all applicable Privacy Legislation
- Service-proven design in a similar application environment
- Ease of use and maintenance together with low lifecycle cost
- Use of interchangeable and module line replacement units
- High reliability and availability
- Adherence to operational performance requirement

Cameras will be designed to operate in the environment at all times, day and night, and at all times of year without the need for additional or augmenting floodlights within the operational parameters of an LRT system. Cameras will use ¼" or 1/3 CCDs with fallback from colour to black and white images in times of low light. In some more specialist cases, specific thermal image CCTV devices may be deployed for perimeter or intrusion detection.

Within the MSF, cameras will be deployed for operational and security purposes such as perimeter and intrusion monitoring, monitoring of Train movements and covering of any track crossings. Data from these cameras will be routed over a fibre network to the local MCR in the MSF.

At the local Communications Room, cameras will be networked into facility-based storage providing a minimum of 31 days of high-quality (30 FPS at 4CIF) video archiving. Long-term storage, at reduced frame rat, will be provided on networked video storage devices located in the Belfast Road TSCC, with backup system servers installed in a Data Centre. Data will flow between these two locations using the existing data connection between the Data Centre and 875 Belfast Road.

Sentry or guard tours will be configurable for areas where intrusions are a concern and the use of analytical detection techniques will enhance the ability of the system to detect anomalies. The system will support analytical technologies to both detect intrusion into unpermitted/unauthorized areas and to support more advanced security features, the use of which will be limited to approved personnel and Transit Law staff. Selected Station images, such as platform edge cameras, will be sent to a new Overview Video Wall installed in the TSCC and BCC; in the MSF, selected cameras will be sent to a new video wall in the YCC.

All images will be made available through the head-end CCTV display system with access to specific views restricted by specific access controls with security related streams being available to Transit Law and other authorized personnel and operational streams being delivered to the TSCC/YCC. Authorized personnel will be allowed to configure the inclusion or exclusion of automatic display of video coverage of any device, type of device, specific event, or general event type as needed. It will be possible for streamed images to be copied or recovered from the system by authorized personnel for use outside the transit system. Such copying will be logged within the system.

The system will be designed for future expansion of the installed camera base and deployed with spare storage capacity protecting for the addition of up to 40 percent more camera feeds.

CCTV – Cameras

All cameras deployed under the Project will be commercially available, "off-the-shelf" units; there will not be any specific manufacture or customization of any units. All units will be of good quality from a reputable, established manufacturer with a proven record of equipment deployment into applications similar to the OLRT.

The cameras in the Stations will be chosen both for their ability to meet functional specifications and also for their appearance. They will be able to operate in all expected light levels down to a level of <1 lux with auto-switching from colour to black and white image capture should it be deemed to be necessary during the design stage.

All cameras, both indoor and outdoor, will be housed in enclosures that are sympathetic to their surroundings and environment with mounting options for pole, ceiling, wall and post. Enclosures will be to NEMA 4X (IP66), have tamper/impact resistant covers and be made of material that is suitable for the environment into which it is to be deployed.

CCTV – Operating Environment

Fixed-facilities cameras will be designed to meet environmental conditions for service and operation in the differing conditions to be found in the Stations, Yards and along the guideway. All will meet the operating temperature requirements; those exposed to harsher conditions will be provided with blower and/or heaters as well as wipers if deemed necessary during design development.

CCTV – Applications & Integration Software

CCTV application software will provide several basic and advanced functions to enable the system to operate as required and to provide the Controller or Station staff with the facilities to carry out their monitoring and security functions. For instance, the SCADA system will interface to the CCTV system to pass Emergency Telephone or IAC activation information so that cameras can be homed to a pre-determined position that will show the device generating the input. To achieve these interactions, the CCTV application software will use several interfaces to other systems:

- SCADA
- CTS
- Video Wall

With the alarm/event handling functionality enabled, it will be possible to trigger audio files over the network and, possibly, interact with other systems such as the Passenger Information System for Public Address announcements. All alarms captured into the CCTV system, such as IAC notification or E-Tel activation, will be watermarked and archived along with the images captured during the event.

CCTV – Surveillance Systems – Central Management System

As part of system deployment, RTG will configure the system to provide "Smart Detection" on general motion in an image area, if an item is no longer present (missing) within an image area, and if a definable foreign object appears within the image area. Such smart detection will cause an internal alarm to be stored to a central alarm database on the Central CCTV Server which will also store details of any externally generated alarms passed to the CCTV system, such as those from the SCADA system causing a PTZ camera to 'home' to a pre-set position.

CCTV – Overview Video Wall

Part of the new Video Wall system for the TSCC will be dedicated to providing fixed camera views from platform edge cameras while other elements will be allowed to display operator selectable images from elsewhere with the system; for example, Station entrance doors.

The Video Wall will be configured so that each camera image takes up 1 of 9 or 1 of 16 squares of any single wall panel, the final layout and size being agreed during the design phase in consultation with the City. The Video Wall will also be configured to enable at least one panel to be set aside to provide a full (panel) size video image from individual cameras selected by the Communications Operator or, possibly, triggered by an event captured by SCADA or the CBTC.

Video walls deployed to the BCC/YCC will be more dynamically configurable, allowing selection of images depending on operation needs.

Intrusion and Access Control (IAC)

The IAC system will control the access to all non-public areas of the OLRT System as well as detecting any unauthorized entries into these areas or into key elements of the alignment such as tunnel portals and the MSF Yard. See drawing 5.4.6-SW-118 for details of the initial IAC design from RTG.

IAC – System Description

Entrance to non-public areas will be controlled through Access Cards, which will be read by a door controller that will release the lock if the card is authorized for the door at which it is presented. If the card is not authorized the door will remain locked and an alarm will be raised on the workstation in the Control Centre.

As a minimum, the following areas will be secured by the IAC system:

- Public to non-public doorways
- TPSS
- Communication rooms
- Elevator machine rooms
- Escalator machine rooms
- Electrical equipment rooms BCC
- MCR
- External doors, entrances and exits of the MSF
- MSF Yard perimeter and access gates

Should an unauthorized entry be made into a room or area (e.g. the door is forced), the IAC will send an alarm to TSCC operators over the SCADA system as well as to the IAC system within Transit Law.

A subsystem will be deployed at the tunnel portal and Station tunnel entrances to monitor for intrusions by humans or other large objects into the tunnel segments. This subsystem will be monitored by the CBTC to pass a message to the Driver of the intrusion detection, and at portal locations to cause the Train to stop. At the MSF, data will be passed between the CBTC and SCADA system to cause the alarm occurrence to be flagged to TSCC operators for response by Station or Transit Law staff as appropriate and to cause CCTV image display.

At the MSF, the system will interface to Yard perimeter monitoring systems to capture unauthorized intrusions. The perimeter monitoring system will protect both fenced areas and access gates, and will be linked with the CCTV system to cause camera homing and image display to the MSF operator.

IAC – Service Life

IAC equipment and cabling deployed as part of the OLRT System will be designed to have a minimum service of 20 years and will be compatible with the City's chosen IAC system.

Telephony System

OLRT Telephony system has two main subsystems: the telephones/intercoms connected to the existing TSCC PABX and the telephones/intercoms connected to the new MSF PABX. The various telephony devices deployed throughout the OLRT will provide service to the travelling public, OC Transpo operations staff and M&R Team personnel.

Telephony - System Description

Telephone systems will comply with PA Schedule 15-2, Part 4, Article 6 and Part 6, Article 7 operational and performance requirements and will comprise emergency telephones, elevator telephones/intercoms, staff telephones and maintenance telephones in various quantities and arrangements in each operational building reporting to either the TSCC or MSF as per their function. **Drawing 5.4.6-SW-107** provides details of RTG's conceptual design of the OLRT Telephony Systems.

In addition to providing line-based voice-communication services, emergency telephones and elevator telephones/intercoms will be interfaced to the CCTV system for Passenger security purposes and non-public telephones will be interfaced into the Ottawa Public Service Radio (PSR) telephone system for operational purposes.

Telephony – Design Philosophy

The telephone systems design will use the following basic principles:

- All telephones will use VoIP communications and provide clear and intelligible communication suitable for the environment in which the telephones are installed
- All telephone traffic will be carried over the CTS infrastructure Station Emergency telephones, elevator telephones/intercoms and staff telephones will be routed through the existing TSCC PABX
- Emergency telephone and elevator telephones/intercoms will be automatically routed to the OLRT Control Desks in Belfast Road
- Station, substation and MSF -mounted maintenance telephones will be routed through a new PABX in the MSF

Telephony – MSF PABX

The new MSF PABX will be sized to provide the service and functionality required to maintain the OLRT and operate the MSF facility, including the Yard. The PABX will be tied into the TSCC PABX to support routing of calls directly between TSCC and MSF staff and to enable OC Transpo staff operating out of the MSF to contact OC Transpo staff throughout the organization. It will interface to maintenance and administrative telephones and intercoms located throughout the alignment, the Yard and the MSF Building.

Telephony – TSCC PABX

The TSCC PABX will be expanded under the Project to support the additional devices mounted throughout the OLRT and to provide tie-connections with the MSF PABX.

Telephony – Instrument Types

All telephone handsets will use VoIP technology.

All staff and administrative phones will be conventional, office-style devices with dial pads and handsets, and will be capable of being wall mounted or located on a desk. Maintenance phones will be more rugged, but will still be supplied with dial pads and handset.

Emergency telephones (E-Tels) will be provided with a handset that automatically connects the device to the TSCC when lifted; they will not be fitted with a dial pad as it is not required. At this time the E-Tels are not required to be supervised for availability, we would welcome the opportunity to discuss this with the City during the design phase.

Elevator telephones/intercoms will be hands-free devices requiring the user to simply push a 'call-button' to raise a call to the TSCC. Where necessary, this button will also activate an alarm to the SCADA system to indicate its activation. All intercom speakers will be amplified to comply with ADA/OADA volume requirements.

Telephony – Communication Interfaces

All local telephone extensions will be wired to Station MDFs in the local Communication Rooms from where they will be connected to Station CTS node telephone multiplexing equipment. From the local node, data will be transported back to the TSCC/MSF over the CTS and fibre network where it will be presented to the appropriate PABXs.

Telephony – Service Life

PABX equipment and cabling deployed will be designed to have a minimum service of 20 years in the application and the environment of the OLRT. While it is possible for some telephony handsets to last 20 years, it is not practical to expect such devices to last more than 7 – 10 years.

SCADA for Stations, Traction Power, Tunnel Ventilation, BAS and BMS

SCADA – System Description

The SCADA system will comprise a redundant server Master workstation with operator workstations at the TSCC and MSF (BCC and YCC) providing graphical and text-based monitoring and supervisory control of Station E&M Systems and Traction Power systems for the complete OLRT. The system will also provide remote monitoring and alarm handling for the distributed communication systems across the line.

Remote Terminal Units (RTUs) will be provided at all Stations, traction power substations and the MSF to act as the field interface between the SCADA Master station and the end field devices. Depending on the application, the RTUs may be passive input/output (I/O) devices or may be more complex and able to carry out some level of intelligent control.

General interfaces between field devices and RTUs will be via digital (discrete) I/O whereas interfaces that are more complex and measurements will be carried out using analogue I/O. However, to capture BAS and BMS data more completely, we will be providing BACNet interfaces for all RTUs and connecting building systems to them using this interface.

All interfaces between the RTUs and the central SCADA Master station will be IP-based and will occur over the OLRT's CTS network, with individual RTUs connected to the CTS over a mix of copper and fibre as appropriate for the distance travelled and service that are monitoring.

At the TSCC, the colour-mimic, alarm, event and historian screens will be used to provide interfaces for the staff to both monitor and control the systems that they are looking after. Graphical displays will provide Schematic, TP one-line, pictorial, and alphanumeric displays of the plant being monitored.

The CBTC system will not be displayed through the SCADA system but will instead use its own discrete user interface directly coupled to the main CBTC servers. The Tunnel Ventilation System, although PLC-based and not reporting through a SCADA RTU, will connect to the head-end SCADA over the CTS and the TSCC HMI will provide operator interaction for this facility.

Drawing 5.4.6-SW-109 provides a high-level introduction to the SCADA system network and system connectivity design.

SCADA – Systems Design Philosophy

SCADA system design will use the following basic principles:

- Application of the latest applicable Codes of Practice and International Standards, including IEC 60870 or DNP 3 protocols, EEMUA 191, IEE 730 and 829
- Service-proven design in a similar application environments
- Ease of use and maintenance together with low lifecycle cost
- Use of interchangeable and module line replacement units
- High reliability and availability
- Redundant servers
- Adherence to operational performance requirement

The Master station will communicate with 13 new Station RTUs, 8 new Traction Power RTUS and 3 PLCs over the new CTS equipment.

The system provided will be built to comply with the latest editions of the applicable codes, regulations and standards listed within and will be designed to meet RAMS requirements.

SCADA – Master Station Overview

The architecture will be a dual redundant Master Station at the centre of a distributed architecture with all system interconnections being made over Ethernet Local Area Networks (LANs) utilising TCP/IP for communications.

SCADA – Hardware Architecture

Two new SCADA Servers will be provided and installed in the MSF MCR together with seven new workstations: three at the TSCC, two at the Depot YCC and two for the BCC. All workstations will be connected to the SCADA LAN together with any printers and network switching/routing devices.

The SCADA Master Station LAN will be designed in a redundant configuration with two intelligent switches forming the core of the local area network in both the MSF and the TSCC.

The SCADA LAN will connect to the main OLRT CTS for data communications to the Remote Terminal Units (RTUs) to support data recovery from, and supervisory control to the Passenger Stations, Traction Power Sub-stations and TVS plant. The CTS NMS will connect to the SCADA LAN to enable data to be recovered from the NMS and presented to the TSCC staff for review.

The system will interface to the upgraded Overview Video Wall installed in the TSCC and to the new units to be installed in the BCC/YCC. .

SCADA – RTU

The new RTUs will be mounted in a 19" cabinet, will be microprocessor-based, will be 120 V AC (Station) or 125 V dc (Traction power) powered and equipped with dc power supplies suitable for delivering all required voltages for operating the RTU and delivering the I/O. Drawing 5.4.6-SW-113 provides an overview of the systems and equipment that are expected to connect to the local RTU network.

Each RTU will have a front panel display to aid in maintenance and fault diagnostics and will support a diagnostic terminal. Each RTU will also support duplex communications and be provided with dual communication ports to provide redundant path connectivity to the CTS and from there to the TSCC.

The RTUs will be sized to meet the expected requirements of the OLRT and will be provided with a minimum of 25 percent spare capacity above the configured and wired I/O compliment.

SCADA – Discrete Plant Interfaces

All monitor and control wiring from Station equipment and TPS equipment will be terminated at the respective marshalling panels before interface with the Remote Terminal Units.

For Station equipment, all Digital Inputs (DIs) will be interfaced to the RTU using dry contacts wetted at 24 V dc while all Digital Outputs (DOs) will be interfaced using relays outputs, rated for the appropriate service.

For traction power equipment, all DIs will be interfaced to the RTU using dry contacts wetted at 125 V dc, with DOs will be interfaced using change-over relays rated for the application.

The analogue inputs for both services will use 4-20 mA or 1-5 V dc inputs with any analogue outputs using 4-20 mA.

The communication between the SCADA servers in the MSF MCR and the field devices will be via industry standard open protocols.

SCADA – Intelligent Plant Interfaces

For facilities management systems, such as Building Automation Systems (BAS), Building Management Systems (BMS) and escalators/elevators we will implement intelligent interfaces to the RTU and through the SCADA system to the TSCC and maintenance systems in the MSF. These are described more fully in the *Facilities Management Systems* section below.

SCADA – Life-Safety Interfaces

The Tunnel Ventilation System (TVS) performs a fire- and life-safety (FLS) function and will be interfaced directly with the tunnel and Station Fire Command Post (FCP) at the below-grade Stations including that at St Laurent.

The TVS has a direct impact on Passenger safety and well-being. Controls for this system are complex and are best handled by a dedicated PLC-based control system linked to the SCADA system. TVS alarms will be immediately raised on the SCADA system and seen by an operator who can alter settings and direct Passengers accordingly. The TVS will not be operated automatically based on smoke detection or sprinkler system activation as neither smoke detectors nor sprinklers are provided in the public areas of the Stations. See elsewhere in this Response for further details on the control of the Tunnel Ventilation System.

Facilities Management Systems

The control and monitoring of HVAC systems and sumps for Stations will be available through the BAS at that Station's SCADA RTU, and will be monitored from both the TSCC and the MSF on the main SCADA system.

Room thermostats will be used to control the amount of heating and cooling supplied to maintain the specified temperature range of each room. A sensor will be located in the outdoor intake shaft to determine when economizer cooling will be used instead of mechanical cooling. Direct digital controls and a series of motorized dampers will be used to control this system. Where unit heaters are provided, electrical interlocks will be provided to ensure heating and cooling by ventilation does not occur simultaneously.

A separate computer room and remote-controlled air-conditioning system will be provided.

FM System – System Overview

To fully monitor each Station, maintain an acceptable Passenger environment, and provide controlled environments for deployed technical equipment, two systems will be used alongside each other that together make up a complete Facilities

Management System: a Building Automation System (BAS) and a Building Management System (BMS). Each system is a composite collection of facility data brought together to provide component- and system-level control.

The BAS will be deployed to each Station to monitor and control Station mechanical and electrical facilities that have some level of automation associated with them:

- Environment management, including HVAC plant
- Station sump pumps (where needed)
- Station lighting

Each system will be built around an open protocol (BACNet) LAN to interconnect all devices in the Station and to interface to the SCADA connection for onward connectivity to the TSCC and MSF. At each Station, a workstation will be provided to enable local monitoring of the system and the associated plant.

The BMS will be deployed to monitor all non-automated Station facilities for normal/abnormal operation and to allow general overview of Station mechanical and electrical items and devices:

- Doors
- Fire Detection and Alarm System (FDAS)
- Station sump levels (where appropriate)
- Operational room temperatures
- Vandal/tamper alarms, some of which will come from the IAC

It is expected that the BMS will monitor some elements that are controlled by the BAS, thus providing a level of redundancy over critical plant monitoring. These two Facility Management Systems (FMS) will report to the Station SCADA RTU from where their information will be sent to the TSCC (operational monitoring) and the MSF (alarm/failure management) for display to Control Room Staff.

FM System – BMS

Door Monitoring

Door monitoring is carried out in conjunction with the IAC system. Monitoring door status (open/closed) through the BMS provides an independent and redundant status check. This is especially important for Station public area security (vandalism) and technical room security (break-ins) where unauthorized entry must be detected.

Fire Detection and Alarm System (FDAS)

The FDAS will be self-contained units and are described elsewhere in this Response. However, it is important that key alarms are picked up and transmitted to the Control Centres (TSCC and MSF) for remote monitoring and response. Alarms received will include the Station Fire Alarm being active, and tunnel dry-stand pipe valves being operated.

Station Sump Levels

As a redundant measure against loss of the BMS or pump controllers, we will monitor each sump with a separate high-level alarm that will trigger an alarm to the TSCC and MSF control centres before water levels affect operations.

Operational Room Temperatures

Technical room temperatures must be controlled within tight tolerances; if room temperatures are too far out of specification, damage may occur to the equipment that could lead to downtime and loss of service. For example, Communications and Signals Rooms with sensitive electrical equipment will be monitored and alarmed back to the MSF if their temperatures go too low or too high.

FM System – HVAC

Room thermostats will be used to control the amount of heating and cooling supplied to maintain the specified temperature range of each room. A sensor will be located in the outdoor intake shaft to determine when economizer cooling will be used instead of mechanical cooling. Direct digital controls and a series of motorized dampers will be used to control this system. Where unit heaters are provided, electrical interlocks will be provided to ensure heating and cooling by ventilation does not occur simultaneously. A separate remotely controlled air conditioning system will be used for the computer room.

Vandal/Tamper alarms

Fare equipment, such as Ticket Vending machines, is a target for vandalism (breakage/disabling and robbery). Such machines will be monitored (e.g. for tipping over), with alarms routed to TSCC for response by Transit Law.

FM System – BAS

Station Sumps

Where Station sumps are required, they will be configured with a two-pump arrangement (duty/standby or duty/duty assist) using centrifugal pumps with level monitoring achieved via level probes or ultrasonic heads depending on operational conditions. Operation controls will be based upon level monitoring and will ensure complete discharge of the sump into City facilities. It is expected that this control will use a packaged discrete controller interfacing into the overall BAS network.

Station Lighting

For Station lighting, the BAS will provide a facility level control of interior and exterior lights in functional (e.g. platform, concourse, ancillary) or operational (e.g. all Passenger areas, all non-Passenger areas) configurations. Such lighting control will allow illumination to be determined remotely (TSCC staff via SCADA), locally (OC Transpo staff on site) or automatically (local photocells), with each being determined by lighting type, function and location.

FM System – Elevators/Escalators

Elevators and escalators will be linked on an intelligent network with a gateway to the Station SCADA RTU allowing monitoring, and permitted remote control, functions to be carried out by TSCC and YCC staff via the OLRT SCADA system.

FM System – Tunnel Ventilation

RTG notes the requirement for Tunnel Ventilation to be part of the BAS and for the control network to be UUKL- 864 listed. We would welcome the opportunity to discuss this further as we do not believe this is the best approach to achieving the control and operation of this life-safety critical function. The controls for transit tunnel ventilation systems typically prove to be too complex for a standard BAS.

We believe it more appropriate to build a discrete TVS system based around redundant, high-availability controllers with redundant I/O and meeting SIL-2 as a minimum. This system would be independently linked to the main OLRT SCADA system and would interface directly into local FDAS and local control panels for emergency personnel use.

Lastly, we recommend not operating the tunnel ventilation system automatically based on smoke detection and/or sprinkler system activation. It is not possible for the system to automatically know all the parameters necessary to determine how to initialize the TVS. We believe activation is best achieved by TSCC staff in consultation with the Driver.

Radio Communications System

Radio systems will form a key part of the operational deployment of the OLRT providing Train control communications, availability of wayside data and voice/data coverage for all staff and Vehicles. Three systems will be deployed: two dedicated to the OLRT and a third, part of the overall City of Ottawa radio system.

RTG believes the delivery of cellular communications into the tunnels and below-grade Stations, in a similar manner to that achieved on Canada Line and Calgary West, should be considered as part of the radio system roll-out.

RC System – System Description

The first system (DCS) will be for the CBTC and is not discussed in this section as it is an integral part of the Train control system (see **Section 5.4.4**).

The second system is the new high-speed wireless data network for interfacing the wayside with the Vehicle at both the Stations and the MSF. This system will comply with PA Schedule 15-2, Part 4, Article 6 and Part 6, Article 7 operational and performance requirements and will comprise antennae, wireless access point radio nodes and interface equipment for connection into the local CTS network node. This Wi-Fi will be used to pass streaming and recorded CCTV data to/from the Vehicle, to pass Passenger count information to the wayside and to automatically collect non-CBTC diagnostic information from the Vehicle.

The third system will be the new Ottawa P25 system that we understand will replace the existing Ottawa Public Service Radio (PSR) in 2015. The radio will be used for wayside/Vehicle voice communications, including ad-hoc PA messages, and for low-speed data transfers, for example to trigger recorded PA announcements or update Train PIDS. The design of this system does not lie within the scope of this Project and only its potential use within the system is described herein.

RC System – Wayside High Speed Radio System

For new data radio systems deployed on Station platforms; the antenna will be located so that Train communication can commence a specified distance away from the platform, enabling Station arrival/departure information, maintenance information and streaming video to be delivered when required and providing maximum time for information transfer.

Design Philosophy

The wayside radio system design will use the following basic principles:

- Application of the latest applicable Codes of Practice and International Standards, including 802.11, EN 50155/50121-3-2 and EN 50121-1/50121-4
- Service-proven design in a similar application environments
- Ease of maintenance and low life cycle cost
- Use of interchangeable and module line replacement units
- High reliability and availability
- Redundant modules as necessary
- Adherence to operational performance requirement

The overall conceptual design of the Train-to-Wayside Wireless System is shown on **Drawing 5.4.6-SW-110**.

Wayside Implementation Considerations

As the system will operate in the 802.11a frequency bands, consideration must be given to the public use and the unlicensed nature of these bands. The system will need to be secure from outside-the-network interference and be designed to provide maximum bandwidth even when operating close to a large Wi-Fi user base, such as Campus Station. The design must also consider the operating presence of the CBTC radio system in the 802.11b/g/n bands.

Radio equipment will be housed in enclosures that provide equipment security and environmental protection. Antennae will be constructed of robust corrosion-resistant materials and antenna cabling will be connected with high-quality, coaxial cables and connectors supplied by a reputable manufacturer. As with other key systems, power will be sourced from a four-hour protection UPS.

Radio Coverage

Radio coverage will be provided for the Station and +/- 15 seconds of travel time in each direction from each platform. This will provide ample time to exploit this system to its fullest.

Digital Radio Capacity Requirements

The system will use 802.11a technology to get maximum data capacity over the network whilst maintaining segregation from the CBTC radio. It will interface to Station CTS and CCTV systems to transfer information and video data with the smallest possible latency.

Vehicle Mounted Ottawa PSR Equipment Considerations

As the Ottawa P25 system will be installed by others during the life of the Project, we do not anticipate carrying out any work on radio infrastructure; however we will collaborate with the P25 Radio System Supplier to manage the supply, installation and testing of the radio system within the OLRT alignment and to ensure that the OLRT design is not compromised.

RTG is expecting to be able to use the new Vehicle mounted P25 radio system to transmit low-speed data messages between TSCC and the Trains for activities such as PA message triggering. See **Drawing 5.4.6-SW-106** to see how this interface will be executed along with **Drawing 5.4.6-SW-110** to see how the future Ottawa PSR fits in with RTG's expected Wayside Radio System.

Operation Control Centre Voice Recorders (OCCVR)

OCCVR – System Overview

The existing Voice Recorder system at the Belfast Road TSCC will be upgraded and expanded, as necessary, to support the additional PA and telephony traffic resulting from the OLRT Project. Project work includes upgrading and enhancing equipment, adding new interfaces as necessary and commissioning the upgraded system with the new equipment to ensure that all OLRT telephone and TSCC ad-hoc PA messages are recorded. Other recording and replay facilities will be provided as per the existing system.

OCCVR – Functionality

The upgraded and expanded Voice Recording system will capture all speech communications into and out of the OLRT Control Centre and all speech communications over the new radio system whether originating at the Control Centre or not. All recordings made by the system will be able to be reviewed by authorized personnel should the need arise.

Central Time System

To keep all operational systems synchronised, a Central Clock will be installed at the MSF MCR with GPS antenna diversely mounted on the building roof.

System Overview

The system will comprise two GPS-based network time-management servers configured to provide a redundant Stratum-1 level service to the Communications systems and the Thales CBTC system using NTP. See **Drawing 5.4.6-SW-117** for network location and connectivity.

5.4.9.3 System Safety and Security

OLRT Operational Systems

The CBTC and Communication systems are directly involved in the real-time operation and control of the OLRT System and must be protected from interference, either deliberate or accidental, to maintain the inviolate state of the System. To achieve this, real-time systems will be closed from all external connections except those required to achieve data transfer for performance reporting and operational travel planning data which will occur through secured firewalls at the MSF.

Data transfer between the systems, such as Train position information from the CBTC system to the Communication system, will occur over secure links within MSF equipment rooms with security between systems achieved through mechanisms that meet the requirements of the system suppliers without affecting throughput at the time of implementation.

With a closed system, there should be no route for external software to be introduced in an uncontrolled manner other than through unprotected disk drives or USB ports. To provide maximum security against unauthorized software installation, or file removal, access to all external drives/ports will be protected via system configuration and password controlled user privilege. Operational computer systems will also be provided with current revisions of commercial grade security and anti-virus software that will be maintained by the M&R Team as part of their system administration and maintenance tasks.

All servers will be maintained in secured rooms with strict access control protocols restricting entry to authorized personnel. All equipment directly involved in Train operation will be protected behind secure doors with access limited to personnel who are directly involved in CBTC operation and maintenance.

External Systems

For data transfer to agreed external systems, such as the Operations and Maintenance Interface (OMI) and Operation Performance & Travel Data (OP&TD) servers, firewalls will control data flow between these systems and the operational equipment delivering the data to them.

For receiving and developing the Daily Reports (among other data), the OMI server will reside within the M&R Team's network, secured from the operational systems by a firewall (see **Drawing 5.4.6-SW-117**). Data for reports will be pushed from the CBTC and Communications Systems to the reporting server in an unsolicited manner; there will not be any requests for data to these systems allowed through the firewall to protect them from activity within the M&R Entity's corporate network. Data from within the M&R Team's network (e.g., Help Desk statistics, Asset Management information), will be secured in a manner consistent with M&R Entity IT security policies.

The Operational Travel Data server will be placed in a DMZ between the operational systems providing data and the OC Transpo corporate system(s) requesting it (see **Drawing 5.4.6-SW-117**). The OP&TD server will receive real-time operational and travel service related data from the CBTC and Communication Systems through a back-end firewall as well as receiving ad-hoc and scheduled data from the OMI server across the M&R Team's network. Connection from the OP&TD server to the OC Transpo network will be via a second front-end firewall that will further protect and secure the OLRT operational systems as well as isolating and protecting OC Transpo and the M&R Team networks from each other.

Access to these servers will be secured and protected in the same manner as the Operational systems described above.

Network and System Management

To manage the CTS, a Network Management System (NMS) will be installed in the MSF's Electronic Equipment Room. This NMS will be configured to monitor system performance, detect and annunciate faults, allow configuration/re-configuration of devices and services, and manage overall CTS security.

5.4.9.4 Open-Data Link

From PA Schedule 15-2, Part 4, Article 6.2 (b) (iii), RTG understands that the City wishes to have OLRT operational travel data provided for use by external, City-approved, third-party software applications through a firewalled server supplied as part of RTG's delivery. It is not expected that operational performance data will be provided outside OC Transpo. Further, the requirement calls for data to be provided in XML format for use by SIRI or other such applications.

CBTC system design includes an SQL database containing data relating to the signalling system and Train operational performance (e.g. destination, next Station, time to next Station). This database will be replicated to the OP&TD server forming the basis for information to be provided to external applications. Other information, such as the daily timetable, will be uploaded from other sources to the OP&TD system to provide a comprehensive data repository of OLRT travel information. In addition to this scheduled and real-time information, provision will also be made for ad-hoc service interruption or special-event information to be input to the system either manually or selected through menu options.

Information received from these various sources will be combined within the OP&TD server to provide a robust data service for real-time travel information on OLRT services that will be made available to external third-party applications in accordance with the provisions of CEN standard TS 15531 (Service Interface for Real-Time Information relating to Public Transit Operations).

The system will support both Request/Response (ad-hoc request from an external interface) and the Publish/Subscribe (scheduled and repeated data pushes to a subscribed external interface) Client/Server interaction patterns. The final functional delivery specification of which SIRI features and data exchange the interface will support, will be defined during design development and review.

5.4.9.5 Integration of Proposed Communication Systems with Existing City Communication Systems

Five existing City communication systems will be integrated into the new OLRT systems:

- Ottawa Public Service Radio (PSR)
- TSCC Private Automatic Branch Exchange (PABX)
- OC Transpo PA/PIDS
- OC Transpo Intrusion and Access Control (IAC)
- OC Transpo Corporate Systems

RTG recognizes that there are several existing City communication systems that the new OLRT systems must integrate with and there are different levels at which that integration may occur.

OC Transpo and Passenger telephony equipment will link through the CTS to the existing, expanded PABX currently housed in 875 Belfast Road. This equipment will use Voice over IP (VoIP) technology to communicate with the PABX routed through the CTS. The M&R Team's PABX, to be installed at the MSF, will be used for OLRT maintenance and M&R Team telephony communications, and will be linked through to the OC Transpo PABX to allow operational and M&R parties to contact each other easily.

Ad-hoc Public Address (PA) announcements made from the TSCC will be recorded on existing City voice recorders at 875 Belfast Road in accordance with the requirements of Schedule 15-2, Part 4, Article 6.3 (c) (xii).

The Intrusion and Access Control (IAC) system deployed will monitor the Stations, TPSS, guideway, MSF and other ancillary facilities for unauthorized access, as well as provide controlled access for authorized parties to authorized areas. It is expected that OC Transpo and M&R Team staff will use the same system with some areas of common access and some areas of restricted (to each party) access. RTG will work with the City to ensure the deployed IAC system is compatible with the City's future IAC system to allow ease of card access for OC Transpo and City staff to authorized OLRT facilities.

The IAC will be interfaced to the CCTV system allowing images to be called directly to an operator's screen or to the video wall in the event of an intrusion or alarm. During system commissioning, the City will be involved in selecting the images to be called in the event of such an occurrence; after commissioning/set-to-work the City will be capable of including or excluding automatic display of video images of any device, type of device, specific event, or general event type in accordance with PA Schedule 15-2, Part 4, Article 6.3 (e) (vi).

All images recorded on the CCTV system will be stored, sufficient for evidentiary purposes, for 31 days on servers installed in the Data Room at 875 Belfast. RTG understands that the City wishes to use an off-site Data Centre to house back-up storage and system servers and that the existing data connection between the Data Centre and 875 Belfast is to be used for data transfer. The bandwidth available on this link is unknown to RTG. Should any upgrade be required it is assumed that this will be undertaken by the City outside the OLRT Project.

The SCADA system will provide the head-end interface to the BAS, among others, at the TSCC as in PA Schedule 15-2, Part 4, Article 6.2(i) (iv) and providing a common Control Room interface to all E&M facilities across the OLRT System. At each operational area (e.g. Stations) dedicated building automation control equipment will look after each service and/or function (e.g. temperature control, HVAC management); where end devices (e.g. air flow dampers) provide tight shut-off to prevent smoke they will be independently interlocked with the FDAS for activation should the need arise.

The BAS equipment network will communicate over a local redundant link to the Station gateway, provided by the Station SCADA RTU, from where it will use the CTS to pass data upstream to the SCADA Master Station and TSCC Operators. This design of the local BAS equipment and network will be such that local control will continue should connectivity to the SCADA Master station fail.

The CTS will be fault-tolerant, diverse-path, redundant-ring architecture designed to provide the OLRT with the required level of performance to meet OLRT operational needs and speed. Final system layout and equipment selection will be defined during the design phase in consultation with the City's Representative, ensuring that the design is compatible, where possible, with existing City systems while noting that the OLRT CTS must, for reasons of operational integrity, be kept separate.

Ottawa PSR

The Ottawa PSR provides the primary voice communications path between the TSCC/BCC and OC Transpo staff operating the OLRT. We understand that the City is implementing a new P25 system during the Project Term and that RTG will be integrating terminals of this new system into Train fleet where it can be used for bi-directional voice and low-speed data transfer.

TSCC PABX

All new Passenger and OLRT operations telephony devices will use the existing TSCC PABX for telephony routing and management. The PABX will be expanded as necessary to provide the requisite number of internal lines with expanded PSTN interfaces should they be required following anticipated use requirements.

OC Transpo PA/PIDS

PA Schedule 15-2, Part 4, Article 6 requires the OLRT and OC Transpo PA/PIDS to interface at the TSCC. We assume this is to keep a common interface between bus and Train operations. Part of the design process will be to review the ability to include the CBTC System in these communications and extract the maximum benefit from interfacing with the CBTC and High Speed Data Radio systems.

OC Transpo IAC

To maintain common accessibility control across the OC Transpo network, the OLRT Access Control system will be an extension of the existing OC Transpo IAC. This will allow existing access cards to be used to gain entry to the new facilities by a simple reprogramming of the existing system rather than having to issue new and additional cards to OLRT staff; it will also enable M&R staff to have access to OLRT facilities through common access control infrastructure.

OC Transpo Corporate Systems

To allow external approved parties and third-party applications hosted on the OC Transpo Corporate LAN to retrieve operational performance and travel data from the OLRT systems, a data server will be established as part of the extended CTS. This server will produce data in an XML format and will be designed to be interoperable with Service Interface for Real Time Information (SIRI) or other applicable standards. The final configuration of data transfer and content will be defined during the Design Phase.

5.4.10 MEDIUM VOLTAGE DISTRIBUTION

5.4.10.1 Typical Medium Voltage Service

For the mainline, each traction power substation will provided with either 13.2 kV or 27.6 kV feeders from Hydro Ottawa (HOL) to HOL switchgear and metering cubicle assembly. The pad and grounding for this switchgear and the associated ductwork will be provided by RTG. **Table 5.4-33** provides the expected feeder types for each TPSS as per the Planning Report provided by HOL.

For the MSF, three HOL 13.2 kV feeds will be provided as per the Planning Report. A separate feed will be provided for the TPSS Yard, TPSS Maintenance Shop and MSF Building distribution.

Table 5.4-33 | Expected Feeder Types

Traction Power Substation or Underground Station	Feeder from Hydro Ottawa Substation	Feeder Type	Voltage
TPSS-01	Hinchey TS	Looped	13.2 kV
TPSS-02	Lisgar TL	Looped	13.2 kV
TPSS-03	King Edward TK	Looped	13.2 kV
TPSS-04	Riverdale TR & King Edward TK	Looped	13.2 kV
TPSS-05	Riverdale TR	Looped	13.2 kV
TPSS-06	Overbrook TO	Looped	13.2 kV
TPSS-07	Cyrville MTS	Radial	27.6 kV
TPSS-08	Cyrville MT	Distribution Loop	27.6 kV
Downtown West Station	Lisgar TL	Dual Looped	13.2 kV
Rideau	Slater TS	Dual Looped	13.2 kV
TPSS-MSF Yard	Overbrook TO	Looped	13.2 KV
TPSS-MSF Shop	Russell TB	Looped	13.2 KV
MSF Building	Russell TB	Looped	13.2 KV

Stations

A high-voltage feed and distribution transformer will provide low-voltage power to At-Grade Stations close to the traction power substation:

- Tunney's Pasture Station from TPSS -01
- Le Breton Station from TPSS-02
- Hurdman Station from TPSS-05

- Train Station from TPSS-06
- Cyrville Station from TPSS-07
- Blair Station from TPSS-08

Medium-voltage distribution for the facilities will be provided for the Underground Stations (Downtown West, Downtown East and Rideau). The feeders from HOL will be based on Option F as outlined in the Hydro Ottawa Planning Report for this Project. This will provide a dual looped 13.2 kV feed to Downtown West Station and a dual looped 13.2 kV feed to Rideau Station. Each HOL feed will be cabled to the three Underground Stations providing redundant power feeds to each Station.

Medium-voltage distribution will provide redundant 13.2 kV power feeds required to provide power to the tunnel ventilation system. For single line diagram, refer to **Drawing 5.4.3-SW-121**.

Although TPSS-03 will be located in Rideau Station, it will be provided with a separate feed from HO, and HOL Metering Switchgear will be housed in a separate room in Rideau Station.

St. Laurent Station is an existing Station which will also require redundant utility feeds to supply the emergency ventilation system. It is assumed that the existing HOL feed will be used as the primary feed. For the redundant back-up feed a 13.2 kV feed will be provided from TPSS-07.

TSCC

A separate HOL MV feed will be provided for the MSF Building. This will provide power for the TSCC, YCC and BCC.

YCC & BCC

Discussed in **Section 5.6**.

5.4.10.2 Drawings

Drawings 5.4.5-SW-101 to 5.4.5-SW-108 include the location of substation transformers and ancillary equipment (breakers, bus bars and isolation switches).

5.4.10.3 Redundant Supply Methodology

Discussed in **Section 5.5**.

5.4.11 CORROSION CONTROL

5.4.11.1 Corrosion Control Strategy

The OLRT traction power system will be 1500 V dc overhead contact system with the running rails as negative return to feed power to the Trains. With the running rails as a return there will be various levels of dc stray current leaking into the surrounding structures or ground which can cause corrosion of nearby metals.

Stray current cannot be eliminated but can be mitigated to reasonable levels. As a general strategy to mitigate the corrosion due to stray current, the following will be considered:

- Minimize the level of stray current through track design
- Review underground metallic utilities under or near the guideway and provide necessary protection
- Ground and bond guideway structures
- Provide surveys of stray current levels during stages of construction and operation

A NACE-certified corrosion specialist will be provided for this Project with these duties:

- Soil resistivity measurements and analysis along the guideway and yard

- Review of structure design
- Review of grounding system design
- Review of underground utilities and existing cathodic protection
- Provide recommendation on cathodic protection requirements and test points
- Stray current and corrosion measurements during construction and start of revenue service.

Corrosion Control – Underground Elements

Underground metallic utilities near or crossing under the guideway will be documented. Each Utility Company will be contacted to determine the type of underground material and existing corrosion protection (e.g. coatings, cathodic protection), as well as their ability to monitor any adverse effects to that protection when the OLRT goes into service.

Corrosion Control – Structural Supports & Services

The effect of any corrosive environment on guideway bridges, structural culverts, retaining walls and general structural supports for LRT systems will be controlled through the means of design and construction, utilizing methods that are compliant with the requirements of Schedule 15-2 of the Project Agreement. These methods will ensure the indicated service life is attained, without replacement of any major components. For concrete structures, these methods may include providing sufficient concrete cover to the outer layers of reinforcing steel, using epoxy coated, stainless steel, or Glass Fiber Reinforced Polymer (GFRP) reinforcing bars, if required, and will consider the requirements for bridge substructures in splash zones of adjacent roadways. For steel structures, appropriate coatings will be applied, if required this may include hot dip galvanization for general structural supports for LRT systems. For steel piles, site specific soil corrosion levels will be considered during detailed design.

To minimize the corrosive effect of stray current in guideway structures, metal in the structures will be provided with bonding so that it is electrically continuous along the guideway. This will be done by installing continuous bonding conductors along each track, providing bonds to the rebars at a maximum of 30 m intervals, as well as at any discontinuities of the structures. Using metal wire ties and welding selected rebars will also ensure electrical continuity of structure rebars. These measures will ensure the metallic reinforcements in the structure are electrically continuous which will allow stray current to flow along the structure and minimize stray current flowing in the ground. For bored tunnel where metal reinforcements in the segments will be difficult to bond together, metallic mesh will be provided in the invert and will be bonded to the continuous bonding conductor to provide a low-resistance path for the stray current to flow, thus minimizing stray current flow outside the structure.

5.4.11.2 Reducing Stray Current

Design Concepts

The primary method to control the level of stray current is to provide good electrical insulation between running rails and the guideway structure or ground, and provide a low-resistance path for the negative return current to travel back through the running rails to the TPSS. Good electrical insulation between the running rails and the guideway structure or ground can be achieved as follows:

- Insulated rail fasteners
- Good drainage of the trackbed
- Clean ballast of proper depth, kept from contacting the running rails
- Insulated track switch operating, locking and point detection rods
- Prevent any grounded equipment or materials from touching the running rails

A low-resistance path along the running rails for the negative return current will minimize the voltage rise from running rail to earth and therefore reduce the level of stray current. This can be accomplished as follows:

- Large weight running rail
- Continuously welded rail
- Cross-bonding between rails and tracks (coordinated with signal ling)
- Electrically bonded rails around movable points and other mechanical connections in special trackwork areas

Stakeholders & Sensitive Receptors Requirements Management

Metallic utilities which may be affected by stray current from the LRT system will be documented. Each Utility Company will be contacted to determine the type of underground material and existing corrosion protection (e.g. coatings, cathodic protection) as well as their ability to monitor adverse effects to that protection when the OLRT goes into service. The Utility Company and RTG would also discuss and agree if additional measures are required to ensure the OLRT system does not affect their utility.

The Project Agreement has identified three Stakeholders which might be affected by EMI from the OLRT system: CBC, NRCan and University of Ottawa. Other Stakeholders may be identified through the Public Engagement Process in which they will have the opportunity to bring their concerns to RTG. RTG will contact Stakeholders that could be affected by EMI to advise them of the standard levels the OLRT system equipment will emit.

5.4.11.3 Stray Current Monitoring & Metering During Construction & Operation

Stray current measurements will be performed and documented in three phases:

- Stray current levels once construction of the guideway and relocation of underground utilities is completed
- Stray current levels after the completion of all construction
- Stray current levels after the commencement of normal revenue service

Measurements will be documented and checked to ensure that stray current emanating from the OLRT during normal revenue operation does not exceed the polarized potential of the structures as outlined in NACE RP0169.

Rail-to-ground insulation resistance will also be measured and verified during construction. For each section of completed track, the resistance will be measured as per ASTM G165 and to ensure it is at least 250 Ohm per 300 m. Completed track will have insulated rail joints which are required for the signalling system. This can be used to isolate sections of track for rail-to-ground insulation resistance measurements after construction.

5.4.11.4 Stray Current Best Practices

Other best practices which will be applied on the OLRT Project to minimize stray current include the following:

- Use of 1500 Vdc instead of 750 Vdc to reduce traction current and therefore reduce the rail-to-ground voltage
- A floating negative traction system for mainline, no diode grounding
- Electrically isolate the Mainline, Yard and Maintenance Hall running rails
- Track design with running rail to earth electrical isolation of at least 250 Ohm per 300 m and provide a rigorous testing program during installation to ensure this criterion is met

5.4.12 EMI/EMC

The presence of electromagnetic interference (EMI) and the resulting need for determination of electromagnetic compatibility (EMC) is a problem faced by all electrified railway systems around the world. It is important the OLRT system is designed to operate safely with the presence of an acceptable limit of EMI and to generate only an acceptable level of EMI to parties adjoining the alignment.

5.4.12.1 EMI/EMC Strategy

In line with PA Schedule 15-2, Part 4, Article 9 requirements, we will use EN 50121 as the design basis for the railway and the subsystems within it.

First and foremost, the railway has to operate safely at all times, so immunity to EMI of all major subsystems is of prime importance; this includes the Vehicle, CBTC and overlaid signalling (e.g. track circuits). All rolling stock or wayside equipment determined to be safety critical, or feeding into safety-critical systems will be reviewed for their proven compliance with EMI emission and immunity requirements in EN 50121. Where possible, all equipment used on the system will have a proven track record in a similar operating environment where it can be shown to not cause and to not suffer from EMI at the levels acceptable under EN 50121.

We will generate an "Electromagnetic Compatibility Identification" document and an "EMC Control Plan" to describe and identify the risks both to the railways from adjacent parties and to the adjacent parties from the railway (including the Sensitive Receptors identified in **Section 5.4.11.2**). Toward the completion of construction we will generate an "EMC Demonstration Plan" that will set out the method of demonstrating that the system has met required performance criteria and can operate safely. After executing this demonstration, we will prepare and issue an "EMC Demonstration Report" outlining and summarizing the results of the tests.

5.4.12.2 Applicable Design Techniques

Good design practice and the use of established design guidelines is the starting point of all design. In North America, APTA, AREMA and IEEE standards and guidelines are used extensively; European (EN) standards and International (IEC) standards are also used should the project require them or where they are seen as best practice.

The starting point for all system design is to confirm that equipment procured for the Project has an EMI impact (to the Vehicle, wayside or adjoining parties) complying with EN 51021. This will limit exposure of the overall system to unwanted levels of EMI and EMC.

Once equipment has been selected, it is important to look at the installation of that equipment together with its protection from external forces. Lightning protection and grounding are two important design issues to be addressed. We expect to produce a Lightning Protection and Grounding strategy document at the outset of the Project to provide common understanding of the problems and design direction across all Project elements.

One key component of the system that produces EMI is the Overhead Catenary System (OCS), especially in Ottawa where ice formation on the lines and the subsequent removal of it by the pantograph has the potential to generate EMI across a large frequency range. Any arcing at the pantograph/contact wire junction will cause EMI. During the design phase we will work with Alstom to determine the best method of mitigating these problems.

Other traction power considerations that have an effect on EMF, and therefore EMI, are the location and size of substations relative to the expected draw from the system.

5.4.12.3 Mitigation Measures

Most EMI problems exist for only a few tens of metres around the source due to the limited power available within the equipment to generate high-voltage fields. The traction power system is an exception to this by virtue of its function and operation. For low-voltage equipment, positioning within the Vehicle and/or alignment should be sufficient to nullify EMI effects as it will allow the EMF to fall away to non-impacting levels before reaching sensitive equipment outside the Project.

If we determine that a piece of equipment is susceptible to EMI or will generate EMI problems for other equipment, we will review the product and then either replace it or take steps to reduce its footprint in accordance with standards and recognized practices. Obvious exceptions to this are wayside signalling equipment mounted close to the tracks that will be expected to operate close to the Vehicle trucks, some of which will have traction motors mounted to them. Working with key vendors of this equipment to test and certify their systems together will allow us to, if necessary, take steps to protect components and subsystems.

The final selection of mitigation techniques will be made if a problem is identified and needs to be mitigated because it cannot be reduced to non-impacting level.

5.4.12.4 EMI/EMC Best Practices & their Applicability to the OLRT Project

Standards-based design to reducing EMI/EMC and recognizing potential sources and receptors is the best approach to reducing and mitigating unwanted EMI and EMC.

Best Practices

The US Department of Transportation's Federal Transit Administration has produced a document, "Guidance on the Prevention and Mitigation of Environmental, Health and Safety Impacts of Electromagnetic Fields and Radiation for Electrical Transit Systems". This document discusses and summarizes best practice for reducing and mitigating EMI/EMC to both equipment and to persons.

Applicability to the OLRT Project

We recognize the importance of reducing the risk of EMI and EMC on the OLRT and of mitigating it where there is a risk of occurrence that cannot be removed. To do this we will employ best practices from both North America and Europe in our designs, using the skill sets of our international Design Team and recognized external experts to review and advise on individual issues.