Reliability, Availability, Maintainability, Dependability Plan
Task No. 5.3.1 (Deliverable No. 5.3.1 a15)

Prepared for:

Metro

Prepared by:
The Connector Partnership
777 S. Figueroa Street
Tenth Floor
Los Angeles, California 90017

<table>
<thead>
<tr>
<th>Review Copy</th>
<th>Date</th>
<th>Initials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Originator</td>
<td>10/21/11</td>
<td>Y.A.</td>
</tr>
<tr>
<td>Checker</td>
<td>10/27/11</td>
<td>O.M.A</td>
</tr>
<tr>
<td>Back checker (for Final)</td>
<td>11/01/11</td>
<td>O.M.A</td>
</tr>
<tr>
<td>Approved by</td>
<td>11/15/11</td>
<td>J.P.</td>
</tr>
</tbody>
</table>

January 12, 2012
Table of Contents

1.0 INTRODUCTION ................................................................. 1-1
  1.1 Background ................................................................. 1-1
  1.2 Purpose ................................................................. 1-1
  1.3 Goals and Objectives ...................................................... 1-1
  1.4 Scope ................................................................. 1-2
  1.5 Update Procedures ....................................................... 1-3
  1.6 Definitions ............................................................. 1-3
  1.7 Reference Documents ..................................................... 1-3
  1.8 Acronyms and Abbreviations ........................................... 1-4

2.0 SYSTEM DESCRIPTION ...................................................... 2-1
  2.1 General Description of the Project .................................... 2-1
  2.2 Operating Plan .......................................................... 2-4
  2.3 Systems Design .......................................................... 2-4
    2.3.1 General Requirements ............................................. 2-4
    2.3.2 Fare Collection ................................................... 2-5
    2.3.3 Train Control ........................................................ 2-6
    2.3.4 Rail Vehicle ........................................................ 2-7
    2.3.5 Communications .................................................... 2-7
    2.3.6 Central Control Facility ........................................... 2-7
    2.3.7 Traction Power and Distribution .................................. 2-8
    2.3.8 Fire-Life Safety .................................................... 2-9
    2.3.9 Emergency Conditions ............................................. 2-9
    2.3.10 Coordination and Dependencies .................................. 2-10
    2.3.11 Security ........................................................... 2-11
  2.4 Mechanical Design ....................................................... 2-11
    2.4.1 Ventilation Design ................................................ 2-11
    2.4.2 Elevators .......................................................... 2-15
    2.4.3 Escalators ........................................................ 2-15
    2.4.4 Wet Stand Pipe .................................................... 2-16
    2.4.5 Fire Sprinkler System ............................................. 2-16
    2.4.6 Plumbing Systems .................................................. 2-16
  2.5 Electrical Design ......................................................... 2-16
    2.5.1 Power Sources ..................................................... 2-16
    2.5.2 Power Supply Reliability ......................................... 2-17
    2.5.3 Power Distribution System ....................................... 2-17
    2.5.4 Supply Voltage and Voltage Drop ................................ 2-19
    2.5.5 Lighting and Lighting Controls .................................. 2-19

3.0 PROJECT ORGANIZATION .................................................. 3-1

4.0 RAMD PLAN TASKS .............................................................. 4-1
4.1 General ................................................................. 4-1
   4.1.1 DB Contractor’s RAMD Tasks During Final Design, Construction and Beyond ................. 4-2

4.2 Plans and Procedures ............................................ 4-2
   4.2.1 Prepare and Update System RAMD Plan ................................................................. 4-2

4.3 Analyses and Studies .............................................. 4-3
   4.3.1 Study Project System Design to Identify Potential RAMD Problem Areas ......................... 4-3
   4.3.2 Establish RAMD Definitions and Measures .............................................................. 4-3
   4.3.3 Develop RAMD Quantitative Requirements .............................................................. 4-3

4.4 Design Support ...................................................... 4-4
   4.4.1 Participate in Design Reviews and Change Order Requests ................................. 4-4
   4.4.2 Identify RAMD Requirements for Contract Documents ........................................ 4-4
   4.4.3 Review Design Packages for Adherence to System Assurance (RAMD) Design Criteria .... 4-4

List of Figures
Figure 2-1: California Regional Connector Map at Preliminary Engineering (PE) ............... 2-2

List of Tables
Table 4-1: RAMD Activities and Tasks During ACE/PE .................................................. 4-5

List of Appendices
Appendix A - RAMD Definitions .................................................................................. A-2
Appendix B - Regional Connector Project Org Chart ..................................................... B-2
Appendix C - Regional Connector Sample RAMD Specifications For DB Contractor ................ C-2
1.0 INTRODUCTION

1.1 Background

The System Reliability, Availability, Maintainability, Dependability (RAMD) Plan describes the system RAMD planning and program activities, which will take place during the Preliminary Engineering (PE) phase of the California Regional Connector Transit Corridor Project (hereinafter “Regional Connector”). In Section 4 of the plan, a table is included which lists the RAMD tasks, applicability of tasks to project phase (Advance Conceptual Engineering (ACE) and/or PE) in which each task is accomplished. The System RAMD Plan is consistent with METRO’s existing Systems Assurance Design Criteria. This plan is a dynamic document that is updated periodically to reflect additional tasks and activities related to: other phases of the project, changes in systems assurance organization, and completed tasks described herein.

1.2 Purpose

The purpose of this plan is to set forth the requirements for identifying, evaluating and implementing RAMD measures throughout the ACE and PE phases of the Project. The plan describes RAMD related tasks and activities commensurate with the ACE and PE phases including the following:

- Implementation of Metro Systems Assurance Criteria.
- Development of RAMD numerical indices.
- Review of design packages for adherence to systems assurance criteria.

Among the outcomes from the RAMD program during the ACE and PE phases will be the development of RAMD specification requirements by the PE Design Team, to be carried out and implemented by the Design-Build (DB) Contractor under the DB Contractor’s RAMD Program Plan during Final Design, Construction/Installation/Testing, Integrated Testing/Start-up, and during the first year of Revenue Service when a Reliability Demonstration Test (RDT) will be conducted.

1.3 Goals and Objectives

In accordance with the Metro Systems Assurance Design Criteria, the primary objective of RAMD plan is to establish guidelines to provide the highest levels of equipment and service reliability and minimize downtime due to maintenance and malfunctions. The system RAMD, in coordination with system safety and security, will be a primary consideration throughout the evolution of design, conceptual through preliminary engineering. To achieve this goal, state-of-the-art system engineering technology, applicable industry standards, and RAMD principles in compliance with Metro Systems Assurance Design Criteria will be applied to ensure that the system achieves a level of RAMD that equals or exceeds that of other similar rail transit systems.

During the ACE and PE phases of the project design, the emphasis of the RAMD Plan is to help maximize RAMD performance parameters through design analysis, review, and
equipment selection, as appropriate to PE phase. The goals and objectives of this Plan are to define activities and tasks to ensure that:

a) A method is provided to maximize the inclusion and incorporation of RAMD design considerations, compatible with other system requirements, into the equipment and systems design.

b) The design satisfies the Metro System Assurance (RAMD) Design Criteria.

c) A mechanism is provided for identifying, incorporating and enhancing RAMD performance parameters into the Regional Connector Light Rail Transit (LRT) system design throughout the ACE and PE phases of the project.

d) Establish RAMD Program requirements and specifications for the DB Contractor to ensure that RAMD performance parameters are further maximized and consistently applied through design analysis, review, and equipment selection during Final Design and Construction phases of the project, and verified during formal RDT.

1.4 Scope

This RAMD Plan identifies RAMD related activities that are commensurate with the ACE and PE phases including the implementation of METRO System Assurance Design Criteria as defined below.

a) The emphasis of this plan is to identify early in the design (ACE/PE) RAMD tasks for the project. The plan also imposes requirements on the DB Contractor, to be further developed and implemented by the DB Contractor in a RAMD Plan to be submitted early in Final Design, addressing the management and technical RAMD activities performed by the DB Contractor during Final Design, Construction/Installation/Testing, Pre-Revenue Operations and Revenue Service RDT.

b) This Plan contains the following sections:

- Section 1 describes the purpose, objectives, scope, definitions and the procedure for revision. A list of reference documents is also included.

- Section 2 provides general description of the project, including details from the “Basis of Design Report” (June 2011) addressing proposed changes to existing Metro Design Criteria.

- Section 3 defines the project organization including the interfaces of the Systems Assurance Manager with the Project Team.

- Section 4 identifies the required tasks for the ACE and PE phases of the project, including tasks to be required of the DB Contractor, during Final Design and beyond.
Appendix A Provides RAMD Definitions

Appendix B Provides Regional Connector Project Organizational Chart

Appendix C Provide Sample RAMD Specifications requirements by the PE Design Team, to be carried out and implemented by the Design-Build (DB) Contractor under the DB Contractor’s RAMD Program Plan during Final Design, Construction/Installation/Testing, Integrated Testing/Start-up, and during the first year of Revenue Service when a Reliability Demonstration Test (RDT) will be conducted.

1.5 Update Procedures

A. The RAMD Plan will be updated, as necessary, to:
   - Refine and improve the current task descriptions and activities
   - Identify new tasks, which may be required as the design progresses.

B. The review and revision process of this plan is the responsibility of the Project Safety and Systems Assurance Manager. Inputs for the updates will be solicited from the Project Program Management, the Facilities Engineers and Architects, the Systems Engineering, and the METRO System Assurance Manager. Comments received from reviewers will be incorporated, as appropriate, subject to the approval of the METRO System Assurance Manager.

1.6 Definitions

Definitions of RAMD terms used in this document and in the implementation of RAMD tasks are included in Appendix A.

1.7 Reference Documents

The following are used as reference documents in this RAMD Plan:

- Regional Connector, Project Basis of Design Report, Task No. 5.1 (Deliverable No. 5.1.a11), June 2011.
- Regional Connector, Draft Project Implementation Plan, Task No. 2.8 (Deliverable No. 2.8.a11), December 2010.
• Item Software (UK): Item Toolkit; Reliability Block Diagram (RBD) Module; User’s Manual (2010).
• MIL STD-785, Reliability Program for Systems and Equipment Development and Production.
• MIL HDBK-217, Reliability Prediction of Electronic Equipment.
• MIL STD 756, Reliability Modeling and Prediction.
• MIL STD-781D, Reliability Testing for Engineering Development, Qualification and Production - Exponential Distribution.
• MIL STD-470A, Maintainability Program Requirements (for Systems and Equipment).

1.8 Acronyms and Abbreviations

The following acronyms and abbreviations used in this Plan have the following meaning:

A
ACE
AREMA
BLS
BOC
CCTV
CFD
CFM
CPJV
CPTED
CPUC
CTS
DB
DC
DEIS
DWP
EBPS
EDM
EIS
EMS
EPABX
EPROM
ETS
ETS
EVS
FA
FLS
FPM
FRP
HID
HP
Ampere, Availability
Advanced Conceptual Engineering
American Railroad Engineering and Maintenance of Way Association
Blue Light Stations
Bus Operations Control
Closed-Circuit Television
Computational Fluid Dynamics
Cubic Feet per Minute
CONNECTOR PARTNERSHIP Joint Venture
Crime Prevention Through Environmental Design
California Public Utilities Commission
Cable Transmission System
Design-Build
Direct Current
Draft Environmental Impact Statement
Department of Water and Power
Emergency Back-up Power System
Electronic Display Monitors
Environmental Impact Statement
Emergency Management System
Electronic Private Automatic Branch Exchange (Telephone)
Erasable Programmable Read-Only Memory
Emergency Trip System
Emergency Ventilation Systems
Fire Alarm (and detection)
Fire-Life safety
Feet Per Minute
Forced Reduced Performance
High Intensity Discharge
Horsepower
### Reliability, Availability Maintainability, Dependability Plan

**1.0 - Introduction**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>KV</td>
<td>Kilovolts</td>
</tr>
<tr>
<td>KVA</td>
<td>Kilovolt-amperes</td>
</tr>
<tr>
<td>LADWP</td>
<td>Los Angeles Department of Water and Power</td>
</tr>
<tr>
<td>LAFD</td>
<td>Los Angeles Fire Department</td>
</tr>
<tr>
<td>LB-LA</td>
<td>Long Beach- Los Angeles</td>
</tr>
<tr>
<td>LPA</td>
<td>Locally Preferred Alternative</td>
</tr>
<tr>
<td>LPSCFT</td>
<td>Low-Profile Simple Catenary Fixed Termination</td>
</tr>
<tr>
<td>LRT</td>
<td>Light Rail Transit</td>
</tr>
<tr>
<td>MCC</td>
<td>Motor Control Center</td>
</tr>
<tr>
<td>MIL-HDBK</td>
<td>Military Handbook</td>
</tr>
<tr>
<td>MDBF</td>
<td>Mean Distance Between Failures</td>
</tr>
<tr>
<td>MDT</td>
<td>Mean Down Time</td>
</tr>
<tr>
<td>MTBF</td>
<td>Mean Time Between Failures</td>
</tr>
<tr>
<td>MTBSF</td>
<td>Mean Time Between Service Failures</td>
</tr>
<tr>
<td>MTTF</td>
<td>Mean Time To Failure</td>
</tr>
<tr>
<td>MTTR</td>
<td>Mean Time to Repair</td>
</tr>
<tr>
<td>OCS</td>
<td>Overhead Contact System</td>
</tr>
<tr>
<td>OPE</td>
<td>Over Platform Exhaust</td>
</tr>
<tr>
<td>P</td>
<td>Pole</td>
</tr>
<tr>
<td>PA</td>
<td>Public Address</td>
</tr>
<tr>
<td>PE</td>
<td>Preliminary Engineering</td>
</tr>
<tr>
<td>PIP</td>
<td>Project Implementation Plan</td>
</tr>
<tr>
<td>RAMD</td>
<td>Reliability, Availability, Maintainability, Dependability</td>
</tr>
<tr>
<td>RBD</td>
<td>Reliability Block Diagram</td>
</tr>
<tr>
<td>RCTCP</td>
<td>Regional Connector Transit Corridor Project</td>
</tr>
<tr>
<td>ROC</td>
<td>Rail Operations Center</td>
</tr>
<tr>
<td>SC</td>
<td>Station Cooling</td>
</tr>
<tr>
<td>SCADA</td>
<td>Supervisory Control and Data Acquisition</td>
</tr>
<tr>
<td>SES</td>
<td>Subway Environment Simulation</td>
</tr>
<tr>
<td>SWFT</td>
<td>Single Wire Fixed Termination</td>
</tr>
<tr>
<td>TC&amp;C</td>
<td>Train Control &amp; Communications</td>
</tr>
<tr>
<td>TP</td>
<td>Traction Power</td>
</tr>
<tr>
<td>TPIS</td>
<td>Third Party Intrusion (alarm and detection) Systems</td>
</tr>
<tr>
<td>TPSS</td>
<td>Traction Power Substation</td>
</tr>
<tr>
<td>TVRA</td>
<td>Threat and Vulnerability Risk Assessment</td>
</tr>
<tr>
<td>UFS</td>
<td>Universal Fare System</td>
</tr>
<tr>
<td>UPS</td>
<td>Uninterruptible Power Supply</td>
</tr>
<tr>
<td>V</td>
<td>Volts</td>
</tr>
<tr>
<td>VMS</td>
<td>Variable Message Signs</td>
</tr>
</tbody>
</table>
2.0 SYSTEM DESCRIPTION

2.1 General Description of the Project

During the environmental process the Regional Connector was identified as the “The Fully Underground LRT Alternative,” which was selected by the Metro Board in October 2010 as the Locally Preferred Alternative (LPA). The Regional Connector will provide a direct connection from the 7th Street/Metro Center Station to the Metro Gold Line. The alignment will extend underground from the 7th Street/Metro Center Station following Flower Street, curving east under the 2nd Street tunnel and 2nd Street, continuing under the intersection of 1st and Alameda Streets, surfacing to connect to the Metro Gold Line within 1st Street and north of Temple Street. During the ACE phase, alignment modifications were developed to accommodate environmental mitigations and further develop the design to better accommodate rail operations and reduce and mitigate cost of project. Refer to Figure 2-1 for an overview of the current design at Preliminary Engineering (PE).

An underground junction (“wye”) splitting the rail line to a north and east directions would be constructed beneath the intersection of 1st Street and Alameda Street. Two portals are required to accommodate the split, one for the north alignment to Pasadena/Montclair and another for the east alignment.

The project includes three underground stations. These are:

- 2nd/Hope Street Station: Southwest of intersection of 2nd and Hope Streets
- 2nd/Broadway Station: 2nd Street between Broadway and Spring Streets
- 1st/Central station: Southeast of intersection of 1st Street and Central Avenue

At this time, the project includes special trackwork at the following locations:

- 6th Street
- At 2nd and Broadway Station
- 1st Street and Rose
- Alameda Street
- Wye at 1st and Central

The following subsections describe operational concepts and basis for design considerations (Ref. submittal Project Basis of Design Report dated June 2011) for system elements and subsystems of the Regional Connector Transit Corridor Project (RCTCP), including aspects of Fire-Life Safety and Security. These descriptions enhance the understanding and determination of “failure to perform as intended” which is the basis for modeling of inherent availability and unavailability, service failures and service availability of system elements and subsystems. Qualitative and Quantitative Reliability,
Availability and Maintainability requirements for the RCTCP are described in Section 4. These will guide the design team during PE and be included in the DB Contract Specifications, to be implemented by the DB Contractor under its RAMD Program Plan during the project phases of Final Design, Construction/Installation/Testing, Integrated Testing/Start-up, and during the first year of Revenue Service when a Reliability Demonstration Test (RDT) will be conducted. Definitions of RAMD terms are included in Appendix A.
Figure 2-1: California Regional Connector Map at Preliminary Engineering (PE)
2.2 Operating Plan

The Regional Connector project will link the current terminus of the Blue Line at 7th/Metro Center to the Gold Line near the Little Tokyo Station in a new underground alignment along Flower Street and Second Street in Downtown Los Angeles. The project is anticipated to be operational in 2019.

Prior to 2019, the Expo Line will be implemented and will also terminate at 7th/Metro Center. The Expo Line will originate in Santa Monica and will join the Blue Line at a junction at the Washington/Flower intersection, which is 1 mile south of the Regional Connector project.

At the north end of the Regional Connector, a junction in Little Tokyo will allow trains from the project to connect to the existing Gold Line alignment to East Los Angeles (with a future extension to South El Monte or Whittier) or Pasadena (with a future extension to Montclair). Therefore, the Regional Connector project will form the trunk segment for two lines. The entire trunk segment extends from the Washington/Flower junction to the Little Tokyo junction.

Although the Regional Connector project is exclusive right-of-way (ROW) in an underground alignment, each branch of the Blue and Expo lines will operate along ample amounts of semi-exclusive ROW and Street-Run. Performance (adherence to schedule) of the transit lines running through the Regional Connector portion of the system is largely predicated by these environments.

The working Operating Plan enabled by the Regional Connector project is to discontinue the existing Gold Line service pattern, continue all Blue Line trains from Long Beach, through the Regional Connector towards Pasadena/Montclair, and all Expo Line trains from Santa Monica to South El Monte or Whittier (only one of the two termini: South El Monte or Whittier will be selected by others from a separate study). Each line will ultimately operate as 3-car trains at 5- minute schedule headways through the trunk. Combined schedule headways would be 2.5- minute headways in the trunk.

2.3 Systems Design

The System Designs for the Regional Connector Project are described in the Project Basis of Design Reports. The descriptions that follow are summaries of these system designs with updates to the previously issued system design documents and are included here as a reference to assist in the evaluating the RAMD Plan details. Refer to the following project deliverables for additional system details:

- Project Basis of Design Report, Deliverable 5.1.a11, dated 6-29-2011
- Final Project Basis of Design Report, Deliverable 5.1.a11, future issue date TBD

2.3.1 General Requirements

This subsection describes design and interface requirements pertaining to key system elements and subsystems of the Regional Connector with existing Metro systems. This encompasses Fare Collection, Train Control, Rail Vehicles,
Communications, Traction Power and Distribution, Fire-Life Safety, and Security Systems required for the project. The systems design parameters were developed during the EIS using Metro design criteria and Metro Operating Plan for the project. Additionally, other requirements from Metro projects in operation, e.g., Metro Red Line, Blue and Metro Gold lines, are subjected, where appropriate, to trade-off studies and other analysis. Regarding Metro Operation & Maintenance, the engineering and planning groups participate in the development of basis of design for each system element. The Project Design Team participates in design coordination meetings among and within the various design disciplines, Metro staff and outside agencies as required, in order to produce an integrated system design.

For most systems work, technical specifications will be performance-based, but some equipment may require detailed specifications to meet the interface requirements of the Metro light rail vehicles, wayside equipment design and the existing Control Center [Rail Operations Center (ROC)]. Design documents are in accordance with the California Public Contracts Code Section 3400 and all other local applicable codes. Sole source specifications will be avoided, unless a detailed justification of requirements which limits the sources of supply is provided and accepted by Metro. Specifications will also require addressing interface issues and meeting safety and security requirements of subsystems in order to meet overall system safety and security goals.

The output from the ACE and PE project phases will result in the production of the necessary DB Contract documents.

### 2.3.2 Fare Collection

The design shall ensure that the layouts of the fare vending/validator machines are compatible with the Metro Universal Fare System (UFS) system-wide vending machine procurement contract. Further, the placement of machines must comply with Metro security requirements for monitoring (CCTV/intrusion alarms). Infrastructure at the stations must satisfy UFS requirements for power and communications services, and protection of equipment from the elements.

The design must incorporate Metro UFS machine requirements, including physical space layouts, power, conduit, and communications requirements. CCTV surveillance of the UFS machine arrays and SCADA intrusion alarm points will be accommodated in the station fare vending machine area designs. Conduits and wiring for power will be provided. 56K-bit communications channels will be incorporated in the cable transmission system design, as well as additional fibers for future connection on a dedicated UFS Fiber Network.

Fare Collection assumptions include the following:

- Universal Fare System Project Contractor will provide and install the fare collection equipment
- Metro will provide the fare collection equipment requirements study based on ridership numbers and station configurations
2.3.3 Train Control

The design of the Train Control system (including related on-board equipment) shall provide a design that is fully integrated into the civil, facilities and other subsystem designs in accordance with Metro Design Criteria and the overall operation plan for the project.

The capacity of a transit system can be limited by its track configuration and Train Control system. To the extent practical, the Train Control System shall function to maximize operating efficiency, while enforcing the safe separation between trains and preventing conflicting moves at converging routes and preventing more than one train from occupying the same ventilation zone. A key element in the achievement of these goals is the design of the block layout. Based on the existing Metro Design Criteria, the Project Design Team develops detailed assumptions and criteria to be used in the block design, coordinating it with the Metro staff. The system will be engineered to meet system headway requirements, compatibility with existing on-board equipment, and meet the safety requirements as outlined by the California Public Utilities Commission (CPUC), and to the recommended practices of the American Railroad Engineering and Maintenance of Way Association (AREMA).

The existing Metro Blue Line south of the 7th/Metro Center station platforms and north of the tunnel portal has signaling in one direction only. As part of the Exposition Line project, signaling will extend north from the junction to Pico Station, leaving a gap from Pico to the portal. Although not incorporated in the Draft PE, additional signal design work will be undertaken to eliminate this gap and to create a fully bi-directional signaling system. This will necessitate that additional equipment be installed in the Train Control and Communications (TC&C) Room in the vicinity of 6th Street, as there is insufficient room in the 7th/Flower TC&C Room. In order to control traffic between 7th/Metro and Venice Interlocking, it will be necessary to modify the circuits and programming at Venice. The extent of the changes cannot be evaluated until Venice Interlocking is in service and as-built drawings are available. A vital communication link must be installed between the two locations. Due to the extent of the changes and the age of the equipment at 7th/Metro, it will be necessary to replace the existing equipment with more modern equipment such as is installed on the Expo Line and which is to be used on other portions of the Regional Connector.

A System Operation Simulation will be performed by the Project Design Team using the final alignment, including station stops, speed restrictions and the train performance characteristics. The simulation will identify the interlocking locations and the minimum headway requirements. The signal system design will incorporate these to verify that the alignment can meet the minimum headway requirements. The Train Control Systems baseline design will be developed from the final alignment and will represent those blocks required to accommodate the interlocking, negative current returns and sectionization of the power distribution system.

The design of the Train Control system will be coordinated with the civil designer to ensure continuity between the civil and the signal design. Also, coordination with the civil group will be undertaken to achieve, where possible, modifications to improve
throughput. Special attention will be given to ensure compatibility with the existing Metro light rail signal system and vehicles.

2.3.4 Rail Vehicle

A comprehensive review of the existing Rail Transit Vehicle characteristics and critical system interfaces will be necessary to ensure that the non-vehicle systems and infrastructure provided in this extension are suitable for the full and unimpeded operation of the vehicle. Technical provisions will be reviewed to confirm all vehicle/systems interfaces. For the purposes of the Regional Connector project design, the P2550 LRT vehicle will be used.

2.3.5 Communications

The Communications work will be subdivided into several major areas: radio, cable transmission system (fiber optics), telephone, public address (PA), variable message signs (VMS), closed-circuit television (CCTV), security, on-board system’s equipment interface, fire alarms, gas, seismic detection, Emergency Management System (EMS), and Supervisory Control and data Acquisition (SCADA). Metro’s Design criteria and the existing subsystem will be analyzed and upgrading to new equipment, which will meet the project need. The development of this design will consider radio systems’ inter-operability, design constraints and other requirements provided by Metro Security, fire life safety, operations departments and local jurisdictions (Police/Fire/Ambulance). The design must also incorporate lessons learned in communications design and installation of existing MTA operating lines.

The design of the cable transmission system must be compatible with the current Metro system ring configuration. The Regional Connector sub-ring system shall interface with the main hub located at the Metro Gold Line Train Control and Communications (TC&C) room located at Union Station. It shall be designed to minimize impact in the revenue operations of the Metro Gold Line.

The Regional Connector Communications subsystems shall be designed to achieve high Availability goals as shown in Section 4.

2.3.6 Central Control Facility

Based on the Metro Rail future expansion plan and to co-locate the Bus Operations with Rail Operations, the existing Central Control Facility located at Rosa Parks in Compton will require major reconstruction and systems rearrangement should it be selected. The Project Design team was directed to prepare a list of equipment and spaces required to integrate the Regional Connector project with existing Metro Blue, Expo and Gold Lines.

The design team will review the existing system configuration and will identify equipment and corresponding layout required at the Rail Control room, the CCTV Monitoring room, the Computer room and the Communication room. This information
will be used to determine the project cost contribution to the reconstruction of the Central Control Facility.

2.3.7 **Traction Power and Distribution**

The design of the Traction Power Supply and Distribution System shall ensure that it meets the performance requirements and is fully integrated with all related vehicle subsystems, civil and facilities design. The design shall adhere to Metro Design Criteria requirements. The development of the design of the traction power and distribution system will take into account the existing substations and vehicle characteristics. The design will contain all engineering data required to produce the plans, specifications, and estimates required. The design will integrate all Traction Power and Distribution System design elements with related systems elements from other disciplines. The integration of related systems into the traction power design is a critical element. The Traction Power and Distribution System design will require coordination with design elements of other disciplines (signaling, communications, structures, civil, etc.), as well as with third parties, such as utilities and local cities.

A traction power simulation program using the latest project data will be employed to establish the locations and ratings of the traction power substations via dynamic load flow analysis. The load flow simulation study will also be used to determine the traction power substation (TPSS) equipment ratings, DC feeder sizes and the adequacy of the standard overhead contact system (OCS) to support the planned train operations through the Regional Connector line in normal and contingency operations. The OCS will be reinforced with a parallel positive along-track feeder to cater for the load demand, and the load flow simulations will be used to determine the size of the parallel supplemental feeder.

The design of traction power substations and DC distribution system shall deliver DC power to the vehicles in compliance with the requirements of the Metro Design Criteria and the Operating Plans. For the purposes of the traction power load flow analysis, the P2550 LRT vehicle will be used. To be noted, the P2550 car features forced reduced performance (FRP) capability at low voltage conditions.

The TP load flow study will also be used to determine the impact of the Regional Connector on the existing LRT system, especially in contingency operations with an adjacent existing TPSS being out of service. If reinforcements are required for the existing adjacent TP system in order to meet the MTA Design Criteria, the scope and extent of such reinforcements will be determined by the load flow study, and Metro will be duly advised.

Traction power substations (TPSSs) will receive power from the Los Angeles Department of Water and Power (LADWP). The 34.5 KV AC primary voltage will be transformed and rectified to 750 V DC nominal to feed the LRT trains. The TPSS is located in a room within the transit station below ground. The design of TPSS and DWP rooms shall be coordinated with the station design to include equipment access directly from the street above. DC positive and negative feeder conduit routings shall be coordinated with the station design as well.
A Transfer Trip System will be provided to facilitate immediate tripping of associated feeder breakers once a fault is detected in the electrical circuit. Emergency Trip System (ETS) or Blue Light Stations (BLS) will be provided for de-energization of specific section of tracks under emergency situations.

The Overhead Contact System (OCS) shall be designed to minimize impact in the revenue operations at 7th/Metro Station for the LB-LA Blue Line and Little Tokyo Station for Metro Gold Line during installation. In addition, cut-over requirements will be specified.

The OCS types within the tunnel will incorporate the Low-Profile Simple Catenary Fixed Termination (LPSCFT) for the mainline track and Single Wire Fixed Termination (SWFT) will be used at crossovers. The LPSCFT in the tunnel shall be terminated beyond the portal, and the new OCS at grade shall tie into the existing auto-tensioned OCS. The catenary system will include one (1) 500 Kcmil copper stranded messenger wire and two (2) 350 Kcmil groove copper contact wires. The OCS will be sectionalized as per Metro Design Criteria to employ DC circuit breakers and motorized disconnect switches.

2.3.8 Fire-Life Safety
The fire-life safety elements of the Regional Connector Transit Corridor Project (RCTCP) include tunnel, stations and all their systems’ elements and sub-elements.

The station design will include conceptual level designs for each station with architectural features, fare gate provisions, mechanical (including ventilation), electrical/electronic, and fire life safety requirements provided for, in appropriately located and sized spaces with consideration for conduits, duct banks, and air-ducts. Further development of mechanical and electrical requirements will be completed in subsequent phases of work. The station fire-life safety design will comply with NFPA 130 (2010) “Standard for Fixed Guideway Transit and Passenger Rail Systems” requirements, including means of access for the first responders, and passenger egress. Each station will respond to the unique circumstances of site, surrounding transit relationships, particular uses, and neighborhood character. The design will incorporate the details required for the safety and security of Metro passengers and staff in a station area under normal operating conditions as well as under emergency conditions. The requirements are based on Metro criteria and rules, regulations and codes as they apply to passengers and employees positioning and movements, access, egress, and refuge under multiple scenarios, locations and paths. The results of evaluating each station's conditions and scenarios dictate signage, communication systems, alarms, security, lighting, ventilation, emergency egress, and a multitude of other features. The design will be compatible with existing Metro criteria and practices.

2.3.9 Emergency Conditions
As stated above, all stations will meet the requirements for emergency evacuation as established by the fire-life safety and security criteria. Emergency exit calculations, number and capacity of exits, entraining and detraining load requirements,
definitions, and occupant load determinants are contained in the criteria. They will be used when determining the platform, concourse and station exit stairs and other vertical and horizontal circulation elements. Exit capacity requirements will be prepared for each station. Special evaluation and reviews will be made for any unique areas, such as train evacuation in the tunnels.

2.3.10 **Coordination and Dependencies**

The primary interfaces are with station architecture, civil, power, communications and train control systems related to issues including:

- Location and size of ventilation fan rooms, shafts, and track dampers including trackway exhaust systems;
- The length of the running tunnels, which will dictate the need for mid-tunnel ventilation fans and structure;
- Power requirements for ventilation systems and tunnel drainage systems;
- Underground station geometry, concourse configuration/design;
- Train operations, headway, and maximum number of trains allowed in a tunnel section;
- Train control;
- Coordination with Metro Fire-Life Safety Committee; and
- Coordination with Los Angeles Fire Department and other first responders.

The Communication Systems design is subdivided into several major areas as follows: Radios, fiber optics and cable transmission networks for telephones, Public Address (PA), Variable Message Signs (VMS), Closed-Circuit Television (CCTV), Fire Alarm and detection (FA), Third Party Intrusion alarm and detection Systems (TPIS), Emergency Management System (EMS), Universal Fare System (UFS), seismic detection, and Supervisory Control and Data Acquisition (SCADA) system, facilities, and equipment design and installation.

Metro's Design Criteria and the existing subsystems will be analyzed to meet the project requirements. The development of this design will consider radio systems interoperability, design constraints and other requirements provided by Metro's Security, Fire-Life Safety, Operations departments and local jurisdictions (Police/Fire/Emergency Services).

The fare collection design will ensure that layouts of the fare vending machines are compatible with Metro's Universal Fare System (UFS) system-wide vending machine procurement contract.
The placement of each machine will comply with Metro security requirements for monitoring with closed-circuit televisions and intrusion alarms.

The design will be updated to include any additional requirements as more detail becomes available, and inputs as required will be incorporated in the architectural, civil, and systems designs.

Locations (frames/wiring blocks/interconnection points) of added system interfaces with existing Metro systems equipment will be addressed in the design. The design will incorporate lessons learned from the existing Metro Rail Lines for all facilities.

### 2.3.11 Security

The primary objective of a security program is to ensure that the design includes features that enhance both the actual and perceived security of the public users. Of nearly equal importance is the need to protect employees from crime and harassment, and property from loss, damage, or vandalism. Several of the Communications subsystems of the Regional Connector Project enhance security as well as safety of passengers and employees and protect physical infrastructure as well as cyber/ electronic assets against damage and malevolent attack. Therefore, the following communications subsystems which enhance system security will be designed with high Availability as a goal: Radios, fiber optics and cable transmission networks for telephones, Public Address (PA), Variable Message Signs (VMS), Closed-Circuit Television (CCTV), Third Party Intrusion alarm and detection Systems (TPIS), and Supervisory Control and Data Acquisition (SCADA). Initial quantitative Availability goals are listed in Section 4.

### 2.4 Mechanical Design

#### 2.4.1 Ventilation Design

**2.4.1.1 Change to Criteria - Station Cooling (SC) and Over Platform Exhaust (OPE) Systems**

This section covers key changes in the ventilation design from existing criteria and describes mechanical systems.

Station cooling systems specified in the design remove heat generated by the train from above the vehicle. Emergency Ventilation Shafts (EVS), in addition to exhausting smoke, could also be used for station cooling and for gas mitigation. Over platform exhausts (OPE) were not previously considered in the existing light rail system. Parallel work on Metro’s Westside Extension is relevant to the Regional Connector. An Over Platform Exhaust (OPE) System is being evaluated as part of the emergency ventilation study underway for the Westside Project. In parallel to the Westside Extension work but with a lag of several months time, the basis of design for Regional Connector is proceeding to demonstrate by engineering analysis the efficacy of an OPE.

For the track-to-track venting for the Regional Connector project, it is recommended that the damper sizes be increased. The bypass system/Emergency Ventilation configuration
for the Regional Connector project should be re-evaluated. It is possible to eliminate the by-pass dampers and allow the air from the piston effect of the train to move through the fans. One larger turnaround located 50-75 ft from the end of the platform is recommended. The effect of potential lengthening of the station box needs to be considered with this recommendation. Alternatively, rearrangement of the ancillary rooms could be considered to provide space for the larger turnarounds. In addition, the distance of the tunnel damper to the platform should be evaluated. Fan rooms do not have to be within 50 to 75 feet of the platform.

2.4.1.2 Peak Air Velocities for Normal Operations

Recommended air flow velocities for ventilated station assumes in the middle segment of station (50 ft. to 220 ft.) peak air flow velocity of 1,000 fpm. The 170-foot middle station segment is based on typical station length of 270 feet and is where the expected passenger distribution is on the platforms.

2.4.1.3 Train Boundary Layer Exclusion

Air velocities less than two feet away from the outer surface of the train, are excluded from the station air velocity criteria. The high air velocities immediately adjacent to the trains’ exterior cannot be controlled by station design.

Peak Air Velocities generated on the Sloping Surfaces (escalators and stairways), where the majority of the passengers are expected to access station levels (via passenger escalators and stairways), before and after receiving train service are as follows:

- Peak downward air velocity at stairway from Platform Level to Concourse, and from Concourse to Street Level is 1,000 fpm.
- Peak upward air velocity at stairway from Platform Level to Concourse, and from Concourse to Street Level is 500 fpm. Air velocity should not be exceeded more than 10% of the time during peak operation (rush hour). Average station velocity should not exceed 600 fpm.

It is noted that criteria for Peak Air Velocities generated on the Sloping Surfaces applies to center of escalators and stairways, to negate wall effects. Train Boundary Layer Exclusion means that air velocities less than two feet away from the perimeter of the train are to be excluded from the station air velocity criteria.

2.4.1.4 Station Outdoor Air Requirements

Following the ANSI/ASHRAE Standard 62.1, the outdoor air rate for the station should be 7.5 cfm per person plus 0.06 cfm/ft² for transportation waiting areas. If occupancy data cannot be obtained from the link load analysis or other means, the outdoor air requirement shall use the standard recommended design occupancy of 100 people per 1,000 ft². If necessary, the station outdoor air requirement can be adjusted based on the procedures in Standard 62.1, Section 6.2.6 “Design for Varying Operating Conditions.” This is possible because peak occupancy may only occur for a short duration.
2.4.1.5 Fire Heat and Smoke Release Rates
In accordance with Metro’s policy, the maximum allowable temperature in evacuation routes shall be 120°F, which meets or exceeds the criteria outlined in Annex B (Ventilation) of the National Fire Protection Association Publication, NFPA 130. Temperature and smoke concentration in stations will be determined using a three-dimensional computational fluid dynamic (CFD) model to assure the ventilation system meets criteria. The fire heat release rates for tunnels will require further discussion with Metro FLS and LAFD.

2.4.1.6 Air Velocity in the Path of Evacuation
Air velocity in the path of evacuation shall not exceed 2,200 fpm opposing egress. Above 2,200 fpm, people may experience difficulty in walking. The minimum airflow required during an emergency applied at the site of the fire shall be at least 150 fpm or critical velocity, whichever is higher, in the full tunnel area in the path of egress.

2.4.1.7 Ventilating for Methane gas and Hydrogen Sulfide
At present, the recommended air velocity to control methane and hydrogen-sulfide is 150 fpm. This air velocity may be required continuously in gassy areas and may lead to recommendations to operate at low speeds continuously during operations in the higher gassy areas. This requirement is not expected to control ventilation capacity. Consideration will be given in the ventilation model analysis to both daytime and nighttime operations, with recommendations developed for review by Metro. The analysis will be based on the 2nd/Broadway Station, which is the deepest and most challenging from a ventilation standpoint.

2.4.1.8 Emergency Ventilation Equipment
Emergency ventilation equipment capacities and operating modes must account for the adjacent tunnel acting as a path of egress.

2.4.1.9 12.1.2.8 Annular Critical Velocity
The Regional Connector project will adhere to critical air velocity calculations, which are based on the annular cross sectional area. The annular cross sectional area is calculated by subtracting the cross section area of the train from the full cross sectional area of the tunnel.

2.4.1.10 Assessment Tunnel Shafts
During a fire emergency, a circumstance to be avoided is two stopped trains between adjacent ventilation shafts with one train on fire. Depending on the direction of evacuation selected, the operation of the ventilation system could move smoke over the non-fire train and thus harm its passengers. Therefore, the safest system is one that has only one train stopped between adjacent ventilation shafts during a train
Having two trains between ventilation shafts should be avoided under all circumstances, in accordance with Metro’s current operating policy.

2.4.1.11 Air Velocity Test

A station air velocity test was performed during normal operations in the existing Red Line in order to determine the effectiveness of the fan bypass. The peak air velocities recorded on the station platform were 2046 fpm.

Currently, there are two tunnel-to-tunnel air turnarounds, the fan intake plenum and the bypass damper intake plenum. It is recommended that they be combined into one larger, more effective turnaround located 50-75 feet from the end of the platform.

The current design at Hollywood/Highland station features the following characteristics:

- The tunnel dampers appear to be undersized to be effective in allowing air to circulate from one tunnel to the other tunnel.

- The bypass dampers appear to be undersized to be effective in allowing air to circulate from one tunnel to the other tunnel and to discharge to the surface through the blast relief shaft.

- The current system has two small tunnel-to-tunnel air turnarounds in parallel (the bypass dampers and the track dampers). One larger turnaround located about 50-75 ft from the platform end is recommended.

2.4.1.12 Goals of Ventilation Analysis

At the conclusion of the ventilation analysis, the fan capacities for Station Cooling (SC) and Emergency Fans will be determined for the light rail system.

The LA Metro tunnel ventilation system will be modeled and simulated using the Subway Environment Simulation (SES) computer program version 4.1 (or later) for design of the tunnel ventilation system. The procedures used to model the system will follow the SES Version 4.1 (or later) user’s manual. The SES simulates train movement, airflow, humidity, air and wall temperatures, and emergency fire situations. Simulations will be performed to assure the system meets the design requirements.

For emergency station ventilation, the station will be modeled using a three-dimensional computation fluid dynamics (CFD) created in a commercially available program such as Fluent, FDS or another package with approval. Transient simulation of the large fire will show that the ventilation system can maintain a tenable environment for the specified time of tenability.

The SES simulations will be performed for the operational scenarios shown below:

- Normal Operations
- Train Movement
- Full Normal Operations:
  - Congested Operations
  - Emergency Simulations
  - One train in the incident tunnel
- One open cross passage
- Maintenance Simulations

The DB Contractor shall be required to verify through analysis and testing that emergency ventilation fans are sized adequately for the design-fire scenarios under nominal and degraded configuration/performance conditions. For example: When one emergency ventilation fan (of the four provided at each station) is unavailable due to scheduled preventive maintenance, or due to (unscheduled) corrective maintenance in the event of a fan failure, the emergency ventilation fan array capacity of all remaining fans in the proper supply/exhaust regimen, including at adjacent stations, will meet critical velocity requirements for a design fire scenario in the tunnel and at the station.

### 2.4.2 Elevators

Elevators will be installed in all stations. Design of the street to the concourse level elevator enclosure is at the discretion of the Section Designer during the final design phase, but the enclosure must be transparent and comply with Metro Design Criteria and Architectural Standard Drawings. The concourse to platform elevator enclosures is a standard design for all stations.

Elevators will be located to keep the travel distance to the platform at a minimum. In stations with parking facilities, parking for the handicapped will be located near the elevator. Elevator cabs will be sized for accommodating a gurney for Fire Department use. The elevator will be glazed or have transparent panels to allow an unobstructed view both into and out of the car.

Elevator finish materials are brushed finished stainless steel on all glazed wall surfaces, doors, frames, sills, and trim, as indicated on the Architectural Standard and Directive Drawings. The hoistway doors will be safety glazed and are of standard design. Elevators shall be the hydraulic type, with separate or combined elevator equipment rooms. All associated embedded piping for the future elevators shall be provided in the design.

### 2.4.3 Escalators

Each entrance to the station will include at least two escalators and two stairs. Escalators will be paired with stairs to provide required exiting capacity. If it is not
possible to provide all four devices at the station portal, stair/escalators can be split into single pairs.

All escalators will be 48 inches nominal width, dual direction, with 90 feet per minute (fpm) in both directions in accordance with Metro Design Criteria. Escalators are specified as capable of operating 24 hours non-stop.

Escalators are system-wide, standard elements as indicated on Metro’s Architectural Standard and Directive Drawings. All escalators shall have stainless steel cladding.

### 2.4.4 Wet Stand Pipe

Wet standpipes shall be a class 1 automatic-wet standpipe system installed to provide protection throughout the underground guideway and shall conform to National Fire Protection Association (NFPA) 14, California Building Code (CBC) Chapter 9 and Metro Fire-Life Safety Criteria. A Class III automatic-wet standpipe system shall be provided throughout all underground/enclosed stations in accordance with NFPA 14, CBC Chapter 9, and Metro Fire-Life Safety Criteria and as modified by local codes.

Two independent water supply connections shall be provided in all standpipe systems.

### 2.4.5 Fire Sprinkler System

Automatic fire sprinkler systems shall be provided in accordance with Metro Fire-Life Safety Criteria and NFPA 13, and shall include enclosed stations, all public spaces as well as ancillary spaces and trainways between the ends of the enclosed station platform.

Undercar deluge systems shall be provided at underground and enclosed stations, supplied from the standpipe system and shall be manually and remotely activated. Each track will have a separate control system. For the train control room, a pre-action sprinkler system shall be provided.

### 2.4.6 Plumbing Systems

The Water Supply and Drainage systems shall be provided in accordance with Metro Rail’s Mechanical Design Criteria and the California Building Code.

### 2.5 Electrical Design

#### 2.5.1 Power Sources

The underground stations will be powered from two independent utility power sources. Each underground station will be powered by the local electrical Utility Company serving the station. The electrical utility serving all stations along the Regional Connector alignment is the Los Angeles Department of Water and Power. The requested electrical service primary supply voltage at each station shall be 34.5kV. A second remote 34.5kV electrical service supplied from an independent utility power grid shall be supplied to each station from either another station within
the regional connector alignment or by the existing trainway feeder, located at the 7th and Metro Station, supplied from the existing Redline yard 34.5kV electrical service. The emergency ventilation system shall have two independent power sources from the Utility Company. Other station normal and emergency loads shall also be supplied from these independent power sources.

2.5.2 Power Supply Reliability

Auxiliary power for each station shall be provided by two Unit Substations. Two Auxiliary Power Transformers in each substation shall step-down the voltage from 34.5kV utility voltage to 480V to provide both primary station power and trainway feeder independent utility power to all station facility equipment. Each unit substation switchboard shall include a normal power supply bus and an emergency power supply bus to provide continuous power to station equipment under normal conditions. If either power supply is interrupted, an automatic transfer tie breaker shall connect these two buses to enable either normal or emergency power supply to provide continuous power to all station equipments. US-1A and US-1B are typical assigned unit substations designations. Designations as US-1W or US-1E are depending on the specific orientation of the station final design. This configuration shall provide a continuous delivery of 480V power to all station facilities from two independent utility sources and shall automatically supply 480V power to all facility equipment upon failure of the station primary utility power.

The Emergency Back-up Power System (EBPS) generator shall provide standby power to operate ventilation equipment for gas mitigation, egress lighting and emergency communication and control equipment for a minimum of 24 hours of operation during an extended system-wide power outage. The existing yard EBPS generator serving Redline segment 1 stations will be upgraded to handle the Redline segment 1 and Regional Connector stations. The existing station trainway feeder located at the 7th/Metro station will be extended to the Regional Connector stations to support the supply of generator power during a system wide power outage. The typical EBPS standby generator power distribution design shall be the same as that implemented on all previous Metrorail projects using a 480V to 34.5kV transformer to step up the 480V, 3 phase generator output voltage to 34.5kV and utilizing the 34.5kV trainway feeder to supply standby power to all alignment stations. Studies are in progress to connect the exiting 34.5kV trainway feeder at 7th/Metro Center to the Regional Connector by a conduit routed either through the underground structures or through an underground conduit along 7th Street and Flower Street.

Integral to the EBPS operation is the operation of station-wide equipment load-shed controls that will shed power to all station equipment except those required for Fire-Life safety system operation, emergency communications, egress lighting, control power to ventilation equipment and emergency ventilation equipment for tunnel egress.

2.5.3 Power Distribution System

The power distribution system will provide power to all station facility equipment via Unit Substations (US-1A & US-1B) switchboards located on both sides of the station in auxiliary power rooms. Unit substation switchboards shall provide power to motor
control centers, station emergency ventilation fans and fire pumps at 480V, 3 phase, 4 wire branch circuits. Unit substation transformers shall include monitoring of 480V secondary ground fault conditions used to trip upstream 34.5kV supply breakers upon detection. Unit substations switchboards shall also include monitoring of transformer high temperature and high-high temperature alarms used to initiate load shed controls and unit substation breakers. Motor center pairs identified as essential buses 1 and 2 will be located on both sides of the station in dedicated auxiliary power rooms. Modular electrical equipment designations with suffixes "A" and "B" will be used to identify the equipment located on side A and side B of the station. Station sides are typically associated with the location of the traction power substation, electrical incoming service room and the train control and communication rooms at stations which can vary in specific station design configurations and orientations. The final station equipment designations will be assigned as East (E), West (W), North (N) or South (S) based on the specific station orientation and equipment location at each station. The station ventilation equipment and facility equipment controls and indications will be centralized at the station MCCs.

Tunnel power shall be fed from tunnel power panels located in platform electrical rooms to 480V, 3 phase, 4 wire crosspassage and sump pump structure load centers. The crosspassage and sump pump structure load centers shall be 120/208V, 3 phase, 4 wire, 40 amp panels and will be grounded with dedicated ground rods protected by a methane boot. The load centers shall be connected to a 480V, 3 phase 20 amp circuit via a 480V, 3P to 120/208V, 3 phase, 4 wire, 9kVA wall mounted transformer via a 480V, 3P, 20A enclosed circuit breaker. The load center shall include branch circuit breakers to supply power to local sump pumps, sump pump motor heaters, communication equipment, exhaust fans, dampers and general receptacles.

Incorporated into the electrical design documents will be new tunnel and public area power and lighting branch circuit rating requirements, required by NFPA 130, to provide 2 hour branch circuit fire rating and branch circuit wiring insulation material that is rated as low smoke zero halogen rated.

Booster fans are currently planned to be located at the East and Northeast portals. These fans shall operate similar to station emergency ventilation fans. The booster fan motor controls at the portals shall be located in a dedicated motor control center and electrical room nearby the portal.

Separation of the Uninterruptible Power Supply (UPS) for the facilities emergency lighting required to operate for 90 minutes according to the MTA Design Criteria (typically 40kVA located at each side of station) and communications UPS required to operate for 4 hours according to the MTA Design Criteria (typically 40kVA at one side of station only).

Per specification of Absorb Mat Glass Batteries for all UPSs, the possible elimination of the dedicated battery rooms and dedicated battery room exhaust fans. Location of battery rooms adjacent to Auxiliary Power Rooms, Train Control and Communication Rooms UPS invertors and Maintenance By-pass switches to be located in Auxiliary Power Rooms and TC&C rooms.
**Grounding**

Two grounding systems will be implemented for the project, a facilities electrical grounding system and a communication grounding system. The facilities grounding system shall be buried ground grid system to assure that all exposed electrical equipment is bonded to prevent any electrical hazards. A direct grounding system or single point ground shall be provided for the communications system. This reference ground system will be provided in the Train Control and Communication (TC&C) room. The facilities electrical ground system and the communication ground system shall be kept independent and separate from each other to prevent the backflow of facility electrical harmonics and other electrical noise into the communication ground system. The incoming electrical service utility ground system shall be installed per the utilities detailed final design drawings and shall be separate from the station facilities electrical ground system.

**2.5.4 Supply Voltage and Voltage Drop**

Station alternating current power for the station facilities equipment shall be supplied at 480 volts, 3-phase, and 4-wire, 60 Hz. Station and tunnel lighting shall be operated at 277 volts single phase. Motors 1 hp and greater will be supplied at 480 volts, 3 phase power. Motors less than 1 hp will be supplied at 120 volts, single phase power. Station and crosspassage receptacles shall be supplied at 120 volts single phase power. All 120 volt receptacles shall be ground fault type.

The station electrical power distribution design shall comply with the following voltage regulation requirements. Voltage drop from the auxiliary transformers to the farthest device or equipment shall be no greater than 5 percent. Power distribution feeders to branch circuit panels shall be no greater than 2 percent voltage drop. Lighting and power branch circuits shall be no greater than 3 percent voltage drop.

**2.5.5 Lighting and Lighting Controls**

Normal and emergency lighting systems will be kept independent of each other. Station lighting will consist of decorative high intensity discharge (HID) and/or fluorescent lighting for platform edge lighting and other type of lighting fixtures following MTA’s lighting standards. Tunnel light fixtures will be powered from tunnel lighting panels located in station platform electrical rooms at both ends of the tunnels. Tunnel emergency light fixtures shall be spaced to maintain the minimum foot-candle levels along the egress pathway as required by Metro Design Criteria. Station normal lighting will be classified as non-essential loads and automatically shed upon system-wide loss of power. Public area lighting circuits to be controlled by station centralized lighting control panels located in auxiliary power rooms with remote lighting control switches located in the station entrance staff/security rooms. Tunnel normal lighting circuits to be controlled by switches located in platform electrical rooms and shall be controllable from station platform electrical rooms at both ends of the tunnels. Tunnel light fixtures shall be specified as LED type fixtures and located at 25 foot centers within tunnels.
Station emergency lighting systems will be classified as critical loads and sourced by UPS powered vital power panels for a minimum of 90 minutes under battery power. All Lighting circuits serving day lit areas will be controlled by daylight photo sensor controls. All non-emergency ancillary room and corridor light fixtures will be controlled by local occupancy sensors. All egress pathway light fixtures to be non-switched and connected to dedicated egress lighting circuits.

All lighting fixtures in the stations to be utilized as up-lighting mounted on the walls in lieu of the HID high bay. This may eliminate the need for expensive scaffolding to replace HID lamps mounted on the high ceilings at some locations. Provide specification and design of network-based station lighting control panels for station lighting controls. Provide emergency lighting fixtures with 90 minutes battery back-up ballasts at select locations such as emergency exit stairs.
3.0 PROJECT ORGANIZATION

The project organization and reporting relationships for the ACE and PE phases of the Regional Connector Project is presented in Appendix B of this plan, displaying an excerpt organization chart from the Regional Connector Project Implementation Plan (PIP), dated December 2010, Figure 2-2 therein, titled “CONNECTOR PARTNERSHIP Team Organization”.

The role of the Systems Assurance Manager (supported by RAMD specialists as required) and his/her reporting relationships within the Project Team, is shown as reporting directly to the CONNECTOR PARTNERSHIP Project Manager, in a similar fashion to the System Integration Manager. The present organizational structure in Appendix B is established to direct the design through ACE and PE phases of the Project. In a dotted line the chart in Appendix B also projects future functions during construction and start-up. As shown, the Project Design Team is divided into four major design groups headed by the Design Manager; with a separate group for Planning and Environmental Support; and a separate group for Project Control/Support Services. The group managers report directly to Project Manager of the CONNECTOR PARTNERSHIP Joint Venture (CPJV). Since the Project Systems Assurance program will require support from and participation of multiple departments and staff, the Systems Assurance Manager, supported by specialty technical personnel (Reliability, Availability, Maintainability, Dependability analysts) reports to the Project Manager. Since the primary support to Systems Assurance function during ACE/PE will come from the Design Manager and the various design disciplines reporting to him/her, both the Design Manager and the Systems Assurance Manager report to the Project Manager. The Design Manager will ensure that Systems Assurance contents (e.g., RAMD requirements such as mean time between failures, mean time to repair, mean time between services failures, and/or mean distance between service failures, if vehicle requirements apply) are incorporated into the specifications and drawings of system elements and subsystems by the various design disciplines. This is done in close coordination with the Systems Assurance Manager, who also performs safety and security engineering coordination functions during ACE/PE. The Systems Assurance Manager reports to Project Manager, who has the authority to enforce compliance with Systems Assurance (as well as Safety and Security) requirements, on all project participants. The Systems Assurance Manager has the responsibility to coordinate systems assurance-related activities and development of RAMD specifications requirements development for RCTCP.

Since Systems Assurance/RAMD design details may involve one or several departments/design disciplines, the Systems Assurance Manager will coordinate the Systems Assurance input into the design effort with the Design Manager, and with the individual design discipline leads. The Design Manager will facilitate exchange of information among the design disciplines and the Systems Assurance Manager and his/her staff, and ensure compliance with the RAMD Plan and incorporation of RAMD requirements into the specifications and drawings by all discipline leads. The design coordination, input and involvement by the Systems Assurance Manager may include review of design documents, and participating in formal and informal design reviews, providing written input and participation in discussions, participating in design coordination meetings, and independent verification of compliance with Metro Systems Assurance criteria. This process/methodology assures inter-departmental coordination, flow of information, and verification of compliance.
and resolution of conflicts related to systems assurance/RAMD requirements when design documents are prepared and coordinated by one or several design disciplines/departments.

The System Assurance Manager has the authority, enhanced by his reporting relationship on the project Org Chart, to work with all departments/disciplines (through the department head/Design Manager) to receive information, identify systems assurance concerns, conduct internal reviews, and develop recommendations and corrective action plans to address systems assurance concerns, track and verify the implementation of recommendations and corrective action plans, and report findings to the Project Manager.
4.0 RAMD PLAN TASKS

4.1 General

A primary goal of the Regional Connector RAMD Program is to help develop and operate a safe and reliable light rail transit system that provides the desired level of service dependability. Service dependability can be achieved by incorporating reliability, availability and maintainability (RAM) principles into the system designs, and by effectively planning for the maintenance of the operational system.

Reliability: Reliability is an equipment attribute that reflects the ability of the equipment to perform its intended function under stated conditions for a stated period of time. It is usually expressed as a probability of successful operation for a specified time. For design purposes, a system or subsystem probability is sometimes converted to equivalent component failure rates or its reciprocal, Mean-Time-Between-Failures (MTBF). The failure rate or its reciprocal, MTBF, are also used to specify reliability requirements and measurement of achieved reliability in tests or in service. The most basic method of achieving a reliable product is through the use of a mature design that has a history of reliable service in similar applications on other rail transit systems.

Maintainability: Maintainability is the probability that a device will be restored to its prescribed functional operation within a given time period when the maintenance action is performed in accordance with prescribed procedures. As with reliability, this defined probability can be converted to equivalent component repair rates or Mean-Time-To-Repair (MTTR) values. The repair rates or MTTR values are also used to specify maintainability requirements and measurement of achieved maintainability in tests or in service.

Availability: Availability is an attribute that reflects the readiness of the system to perform its intended function when called upon at a stated instant of time or over a stated period of time. It is usually expressed as the probability that the item will be available when required, or as the proportion of total time that the item is available for use. The availability of an item, system element, or system is, therefore, a function of its reliability and maintainability attributes.

Availability is an important consideration in all transportation systems. High reliability alone is not sufficient to ensure that the system will demonstrate high operational availability. To achieve high in-service availability, the reliability and maintainability principles should be emphasized in the design together with proper maintenance management of systems and equipment. For a system the inherent availability will be computed as follows.

\[
A = \frac{MTBF}{MTBF + MTTR}
\]

\[A = \text{Availability (Inherent)}\]
\[MTBF = \text{Uptime of the system (in hours) divided by the number of system failures}\]
MTTR = Corrective Maintenance Downtime (in hours) divided by the number of system failures

This inherent availability definition excludes preventive maintenance downtime, logistic delays, supply delays and administrative delays. Since these other causes of delay can be minimized or eliminated, the availability value that considers only the corrective maintenance downtime is the inherent or intrinsic property of the system, and is commonly used in RAM specifications.

One of the key elements of this RAMD plan is to ensure that appropriate requirements are specified in the contract specifications and that the contractors establish and maintain an efficient RAMD program to support a cost-effective achievement of overall program objectives.

Table 4-1 lists the RAMD activities and tasks that are identified for the ACE and PE phases of the Regional Connector Project. The numbers in the left column of the table identify applicable paragraphs in this section. The applicability of each task is shown for each phase in the respective column.

The RAMD activities and tasks have been segregated into three areas, representing the major efforts of the Project Systems Assurance.

- Plans and Procedures
- Analyses and Studies
- Design Support

4.1.1 DB Contractor’s RAMD Tasks During Final Design, Construction and Beyond

Among the outcomes from the RAMD program during the ACE and PE phases will be the development of RAMD specification requirements by the PE Design Team, to be carried out and implemented by the Design-Build (DB) Contractor under a DB Contractor’s RAMD Program Plan during Final Design, Construction/Installation/Testing, Integrated Testing/Start-up, and during the first year of Revenue Service and warranty, when a Reliability Demonstration Test (RDT) will be conducted.

A sample of RAMD specifications requirements to be carried out and implemented by the DB Contractor during the project phases of Final Design, Construction and beyond, are shown in Appendix C.

4.2 Plans and Procedures

4.2.1 Prepare and Update System RAMD Plan

The METRO System Assurance Criteria are used as a guiding document for the development of this plan. The RAMD Plan defines the management and technical tasks to be performed during the ACE/PE phases. Based on the Project program objectives for a safe system which meets or exceeds the desirable RAMD level, the plan will be updated as required, and as described in Section 1.5 of the plan.
4.3 Analyses and Studies

4.3.1 Study Project System Design to Identify Potential RAMD Problem Areas

As part of the design process it is necessary to identify RAMD problem areas and recommend corrective actions to mitigate them. In the preliminary engineering phase of the design, the RAMD analyses can only be general in scope and depth because the details of the subsystem are not known. Even at this early design stage, however, studies and reviews are useful because they identify potential problem areas. As the design develops, more detailed reviews can be performed. This will be a continuing process through the PE phase of the project. The design packages will be reviewed to ensure that the design includes features that enhance system RAMD.

4.3.2 Establish RAMD Definitions and Measures

The RAMD definitions in Metro System Assurance Design Criteria and in this plan will be used in the development of RAMD requirements. The definitions will establish a common baseline for RAMD measures prior to development of quantitative requirements.

4.3.3 Develop RAMD Quantitative Requirements

During the PE phase quantitative RAMD requirements will be identified for inclusion in the contract specifications. The quantitative requirements will be initially defined in terms of Availability Goals (in percentage) and subsequently refined by project team (during PE) and by the DB Contractor (during Final Design) in terms of Reliability (MTBF or its reciprocal, failure frequency), and for Maintainability requirements will be expressed in MTTR in hours. The level of development of quantitative requirements is commensurate with the method of procurement/ project delivery, and how the contracts are packaged. In general for Design/Build (D/B) contracts an overall Availability requirement will be established for a system element. The contractor will be required to provide allocations to lower level for subsystems, assemblies, and/or lowest replaceable units (LRUs). For Design/Bid/Build (D-B-B) contracts the allocation of RAMD requirements will be provided for system elements, major subsystems, and/or equipment level as necessary.

At present the following system elements / subsystems/ equipment have been identified for which RAMD requirements will be developed.

- Communications
- Elevators and Escalators
- UPS
- Traction Power
- Train Control
- Emergency Ventilation System
- Electrical System

Initial quantitative Availability goals (in Percentage) have been set as follows for the Regional Connector Project system elements and subsystems, limited to the geographical boundaries and physical scope of the Regional Connector Project, up to the point of interface with other existing Metro system elements:
1. Radio: 99.99%
2. Cable Transmission System (CTS), (fiber optics): 99.9998%
3. Emergency Telephone: 99.9995%
4. Public Address (PA): 99.99%
5. Variable Message Signs (VMS): 99.99%
7. Fire Alarm and detection (FA): 99.999%
8. Third Party Intrusion alarm and detection Systems (TPIS): 99.99%
10. Universal Fare System (UFS): 99.9%
11. Seismic detection: 99.999%
12. Supervisory Control and Data Acquisition (SCADA): 99.9999%
13. Elevators: 99.9%
14. Escalators: 99.9%
15. UPS: 99.999%
16. Traction Power: 99.99%
17. Train Control: 99.99%
18. Emergency Ventilation System: 99.999%
19. Electrical System: 99.99%

4.4 Design Support

4.4.1 Participate in Design Reviews and Change Order Requests

The Project Systems Assurance Manager will be responsible for ensuring that RAMD issues are adequately reflected in system design. The engineer will participate in all reviews where system RAMD could be affected by design decisions. These reviews include Preliminary Design Reviews and other in-progress Design Reviews.

4.4.2 Identify RAMD Requirements for Contract Documents

During the PE phase, the Project System Assurance Manager will identify RAMD requirements for inclusion in procurement or furnish/install contract documents. This will include RAM related analyses, tasks, and submittals that form part of the contract specifications. The quantitative requirements will be based on the performance expected from current technology. Contractors will be required to show, through analysis and/or testing, that their equipment meets the specified quantitative requirements. Program participants will assist in identifying and establishing the RAMD requirements.

4.4.3 Review Design Packages for Adherence to System Assurance (RAMD) Design Criteria

The Project Systems Assurance Manager will participate in technical reviews of the completed preliminary design packages to ensure that the METRO System Assurance criteria and established goals and requirements are properly reflected in contract drawings and specifications. Any discrepancies will be documented and resolved.
Table 4-1: RAMD Activities and Tasks During ACE/PE

<table>
<thead>
<tr>
<th>Paragraph No.</th>
<th>RAMD Activities and Tasks Title</th>
<th>ACE</th>
<th>PE</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.2</td>
<td>Plans and Procedures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.2.1</td>
<td>Prepare and Update System RAMD Plan</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>4.3</td>
<td>Analyses and Studies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.3.1</td>
<td>Study Project System Design to Identify Potential RAMD Problem Areas</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>4.3.2</td>
<td>Define RAMD Definitions and Measures</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>4.3.3</td>
<td>Develop RAMD Quantitative Requirements</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>4.4</td>
<td>Design Support</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.4.1</td>
<td>Participate in Design Reviews and Change Order Requests</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>4.4.2</td>
<td>Identify RAMD Requirements for Contract Documents</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>4.4.3</td>
<td>Review Design Packages for Adherence to System Assurance (RAMD) Design Criteria</td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

ACE = Advance Conceptual Engineering  
PE = Preliminary Engineering
APPENDIX A
RAMD DEFINITIONS
# Appendix A - RAMD Definitions

<table>
<thead>
<tr>
<th><strong>ASSEMBLY</strong></th>
<th>A number of parts or subassemblies or any combination thereof together to perform a specific function.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AVAILABILITY</strong></td>
<td>The probability that a system or system element will be operational when required. Mathematically, the ratio of the mean time between failures and the sum of the mean time between failures and the mean down time. When the mean down time is limited to active repair time only (also known as mean time to repair or mean corrective maintenance time) then the Availability expressed as the ratio of the mean time between failures and the sum of the mean time between failures and the mean time to repair, is known as “Inherent Availability”, and is most commonly specified in RAM specifications.</td>
</tr>
<tr>
<td><strong>COMPONENT</strong></td>
<td>An article which is a self-contained element of a complete operating unit and which performs a function necessary to the operation of that unit.</td>
</tr>
<tr>
<td><strong>CRITICAL</strong></td>
<td>Failure conditions which could result in significant system damage or adverse effects on one or more occupants (including fatal injury).</td>
</tr>
<tr>
<td><strong>CRITICALITY</strong></td>
<td>Assignment of relative importance to hardware or systems.</td>
</tr>
<tr>
<td><strong>DEGRADATION</strong></td>
<td>Falling from an initial level to a lower level in quality or performance.</td>
</tr>
<tr>
<td><strong>DEPENDABILITY</strong></td>
<td>It is the degree to which an item is operable and capable of performing its required function at any randomly chosen time during its specified operating time, provided that the item is available at the start of that period.</td>
</tr>
<tr>
<td><strong>DOWN TIME</strong></td>
<td>The total time during which the equipment is not in acceptable operating condition. Down time starts with a failure event and ends at the completion of repair and functional checks/inspections. When logistics delays, travel time, and availability of maintenance staff or spare parts are excluded from down time, and unavailability due to preventive maintenance is also excluded, then mean down time equals to mean time to repair, which is the mean active repair time, or mean corrective maintenance time.</td>
</tr>
<tr>
<td><strong>EQUIPMENT FAILURE</strong></td>
<td>The state in which equipment no longer meets the minimum acceptable specified performance and cannot be restored through operator adjustment of controls.</td>
</tr>
<tr>
<td><strong>EQUIPMENT RELIABILITY</strong></td>
<td>The characteristic which describes the ability of a component, subsystem, or system to perform its specified function without failure and within prescribed limits (mission duration), expressed as a probability (between 0 and 1). Reliability is determined by the equipment mean failure rate and mission duration.</td>
</tr>
<tr>
<td><strong>FAILED COMPONENT</strong></td>
<td>A component which has ceased to perform its intended function.</td>
</tr>
<tr>
<td>----------------------</td>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>FAIL OPERATIONAL</strong></td>
<td>A characteristic design which permits continued operation in spite of occurrence of a discrete failure.</td>
</tr>
<tr>
<td><strong>FAIL OPERATIONAL FAIL SAFE</strong></td>
<td>A system characteristic which permits continued operation on occurrence of a failure while remaining acceptably safe. A second failure results in the system remaining safe, but nonoperational.</td>
</tr>
<tr>
<td><strong>FAIL SAFE (SAFETY)</strong></td>
<td>A characteristic of a system and its elements, the object of which is to ensure that any fault or malfunction will not result in an unsafe condition.</td>
</tr>
<tr>
<td><strong>FAIL SAFE DESIGN</strong></td>
<td>A design principle in which each of the elements which make up a system is analyzed to determine the potential consequence of failure of that element, alone or in combination with any or all other elements of the system, to ensure that a failure or a combination of failures will not result in an unsafe condition.</td>
</tr>
<tr>
<td><strong>FAILURE</strong></td>
<td>An inability to perform an intended function.</td>
</tr>
<tr>
<td><strong>FAILURE ANALYSIS</strong></td>
<td>The logical systematic examination of a system to identify and analyze the probability, causes, and consequences of potential and real failure.</td>
</tr>
<tr>
<td><strong>FAILURE ASSESSMENT</strong></td>
<td>The process by which the cause, effect, responsibility, and cost of an incident (reported Problem) in the transit system, are determined and reported.</td>
</tr>
<tr>
<td><strong>FAILURE, CRITICAL</strong></td>
<td>A failure which could result in major injury or fatality to people or which could result in major damage to any system or loss of a critical function.</td>
</tr>
<tr>
<td><strong>FAILURE MANAGEMENT</strong></td>
<td>Decisions, policies, and planning which identify and eliminate potential failure.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>FAILURE MODE EFFECTS AND CRITICALLY ANALYSIS (FMECA)</strong></td>
<td>An inductive procedure in which potential malfunctions are identified and then analyzed as to their possible effects and criticality.</td>
</tr>
<tr>
<td><strong>FAILURE RATE</strong></td>
<td>Rate at which failures occur as a function of time. If the failure rate is constant, it is frequently expressed as the reciprocal of meantime between-failures (MTBF). Calculated for an article, it is the ratio of the total number of independent article failures to the total article operating hours.</td>
</tr>
<tr>
<td><strong>FAULT</strong></td>
<td>Immediate cause of failure (e.g., maladjustment, misalignment, defect, etc.)</td>
</tr>
<tr>
<td><strong>INDEPENDENT FAILURE</strong></td>
<td>An independent occurrence, failure, or malfunction which causes disruption to or prevents data flow or train movement in accordance with established schedules. A failure induced by the failure of associated items, misuse, or abuse, or improper maintenance is not an independent failure.</td>
</tr>
<tr>
<td><strong>INTERFACE</strong></td>
<td>The junction points within or between systems or subsystems where matching or accommodation must be properly achieved in order to make their operation compatible with the successful operation of all other functional entities.</td>
</tr>
<tr>
<td><strong>MAINTAINABILITY</strong></td>
<td>The quality of the combined features of equipment design and installation that facilitates the accomplishment of inspection, test, checkout, servicing, repair, and overhaul with a minimum of time, skill, and resources in the planned maintenance environments.</td>
</tr>
<tr>
<td><strong>MAINTENANCE</strong></td>
<td>All actions necessary for retaining an item in or restoring it to an operable condition.</td>
</tr>
<tr>
<td><strong>MAINTENANCE, CORRECTIVE</strong></td>
<td>The action taken to restore a failed item of equipment to an operable state.</td>
</tr>
<tr>
<td><strong>MAINTENANCE, PREVENTIVE</strong></td>
<td>The actions performed on an item off-line in an attempt to retain an item in a specified condition by providing scheduled periodic maintenance per manufacturer’s instructions/ maintenance manual or specification to detect and correct incipient failures and minimize faults and failures from occurring during service operations.</td>
</tr>
<tr>
<td><strong>MAINTENANCE, SCHEDULED</strong></td>
<td>Programmed preventive maintenance.</td>
</tr>
<tr>
<td><strong>MAINTENANCE, UNSCHEDULED</strong></td>
<td>Maintenance action initiated by the malfunction of equipment.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>MALFUNCTION</td>
<td>Any anomaly or failure wherein the system, subsystem, or component fails to function as intended.</td>
</tr>
<tr>
<td>MARGINAL</td>
<td>Failure conditions which result in moderate injury, occupational illness, or system damage.</td>
</tr>
<tr>
<td>MEAN CYCLES BETWEEN FAILURES (MCBF)</td>
<td>The arithmetic mean of the number of cycles between successive failures of a repairable device.</td>
</tr>
<tr>
<td>MEAN DOWN TIME (MDT)</td>
<td>The arithmetic mean of the time the device remains in an inoperable state after it has failed.</td>
</tr>
<tr>
<td>MEAN LIFE</td>
<td>The arithmetic mean of time to wear out of all items in the test sample or population.</td>
</tr>
<tr>
<td>MEAN MAINTENANCE TIME</td>
<td>The arithmetic mean of the time required to perform a maintenance action.</td>
</tr>
<tr>
<td>MEAN TIME BETWEEN FAILURES (MTBF)</td>
<td>The arithmetic mean of the time between successive independent failures, which is the mean equipment operating time per independent failure. The MTBF is the reciprocal of the failure rate.</td>
</tr>
<tr>
<td>MEAN TIME BETWEEN SERVICE FAILURES (MTBSF)</td>
<td>The arithmetic mean of the time between failures which interrupt or impact service operations, which is the mean revenue service time per service failure. The MTBSF is the reciprocal of the service failure rate.</td>
</tr>
<tr>
<td>MEAN TIME TO REPAIR (MTTR)</td>
<td>The mean active repair time required, after arrival of the maintenance team, to locate and isolate the fault, make repairs, and perform a functional checkout to verify that the equipment has been restored to operational status. The MTTR is the ratio of the total active corrective maintenance repair time expended on the article during a specific period of time to the total number of failure events requiring corrective maintenance actions during that same time period.</td>
</tr>
<tr>
<td>MINIMUM ACCEPTABLE MTBF</td>
<td>A value so selected that the specified risk of accepting equipment of this value is tolerable.</td>
</tr>
<tr>
<td>OPERATING TIME</td>
<td>The time period between turn-on and turn-off of a system, subsystem, component, or part during which time operation is as specified. Total operating time is the summation of all operating time periods.</td>
</tr>
<tr>
<td>OPERATIONAL PHASE</td>
<td>The post construction phase where designed project function is achieved and maintenance requirements begin.</td>
</tr>
<tr>
<td>QUALITATIVE</td>
<td>Those inductive or deductive analytical approaches which are oriented toward relative, non-measurable and subjective values.</td>
</tr>
<tr>
<td><strong>QUANTITATIVE</strong></td>
<td>Those inductive or deductive analytical approaches which are oriented toward the use of numbers or symbols used to express a measurable quantity.</td>
</tr>
<tr>
<td><strong>REDDUNDANCY</strong></td>
<td>The existence in a system of more than one means of accomplishing a given function.</td>
</tr>
<tr>
<td><strong>RELIABILITY</strong></td>
<td>The probability that the system or subsystem will perform satisfactorily for a given period of time when used under stated conditions.</td>
</tr>
<tr>
<td><strong>RELIABILITY ASSESSMENT</strong></td>
<td>An analytical determination of numerical reliability of a system or portion thereof without actual demonstration testing. Such assessments usually employ mathematical modeling, use of available test results, and some use of estimated reliability figures.</td>
</tr>
<tr>
<td><strong>RELIABILITY GOAL</strong></td>
<td>A preset reliability objective determined by consideration of operational needs, state-of-the-art capability, cost, time, etc. The goal can be a minimum acceptable level, an expected program accomplishment, or an idealistic target.</td>
</tr>
<tr>
<td><strong>REPAIR</strong></td>
<td>The maintenance activity which restores a failed item to an operable state.</td>
</tr>
<tr>
<td><strong>SERVICE FAILURE</strong></td>
<td>An independent failure during revenue service which disrupts or delays the scheduled revenue service of one or more trains for more than four minutes.</td>
</tr>
<tr>
<td><strong>SERVICE FAILURE RATE</strong></td>
<td>The ratio of the total number of service failures to the total revenue service operating hours.</td>
</tr>
<tr>
<td><strong>SUBSYSTEM</strong></td>
<td>A major functional subassembly or grouping of items or equipment which is essential to operational completeness of a system.</td>
</tr>
<tr>
<td><strong>SYSTEM</strong></td>
<td>A composite of people, procedures, and equipment which are integrated to perform a specific operational task or function within a specific environment.</td>
</tr>
<tr>
<td><strong>TIME, UP</strong></td>
<td>The time during which equipment is either operating satisfactorily or is in an operable state and ready to be placed in operation. Up time is initiated by a completion or repair and is terminated by a failure event.</td>
</tr>
</tbody>
</table>
APPENDIX B
REGIONAL CONNECTOR PROJECT
ORGANIZATION CHART
APPENDIX B - Regional Connector Project Org Chart

Excerpts from Regional Connector Project Implementation Plan (December 2010), Figure 2-2 therein, CONNECTOR PARTNERSHIP Team Organization

December 20, 2010

REGIONAL CONNECTOR TRANSIT CORRIDOR PROJECT

January 12, 2012
APPENDIX C
Regional Connector Sample RAMD Specifications For Design-Build Contractor
APPENDIX C - Regional Connector Sample RAMD Specifications for DB Contractor

SECTION XYZ
Reliability, Availability Maintainability Dependability (RAMD) Requirements For Design-Build Contractor

PART 1 – GENERAL

1.01 SUMMARY

A. Description: Section XYZ specifies the general requirements for the DB Contractor to develop and implement a System Reliability, Availability, Maintainability, Dependability Program Plan (RAMDPP). Human factors and quality assurance, although not specified directly herein, shall be considered in the development of the RAMDPP. The Contractor shall develop and implement a RAMDPP, encompassing system reliability and maintainability engineering. The RAMD requirements shall apply to all systems, subsystems and assemblies, software, hardware and firmware provided under the scope of this contract and all interfaces of the Regional Connector Transit Corridor Project (RCTCP). The requirements apply to all suppliers and subcontractors during all phases of the work including final design, manufacture, construction, installation, testing, in-service support/maintenance, warranty, retrofits, and field modifications. This is within the Contractor’s overall scope to:

- Stations (including station amenities)
- LRT Signals
- Communication System, including Telephone system, Supervisory Control and Data Acquisition System, Public Address/Variable Message Signs, Miscellaneous Communications Equipment, Closed Circuit Television System, ROC and Maintenance Facility Ancillary Equipment, Carrier Transmission System
- Traction Electrification System, including Traction Power Substations and Overhead Contact System
- Fare Collection Equipment

B. Among system elements and subsystems the Contractor’s scope of services includes but is not limited to the following:

- Radio
- Cable Transmission System (CTS), (fiber optics)
- Emergency Telephone
- Public Address (PA)
- Variable Message Signs (VMS)
- Closed-Circuit Television (CCTV)
C. The RAMD requirements shall be implemented on systems, subsystems, assemblies and interfaces contained in these contract documents for the RCTCP, to the extent covered under Contractor's scope, and all their interfaces and intercommunications among Contractor's items amongst themselves, interfaces with other Metro LRT system elements and subsystems, and with the operating environment. Transit system element interfaces shall include but not be limited to: Light rail vehicles, automotive vehicles, pedestrians, passengers, employees, the general public, stations, station amenities, track, grade crossings, facilities, systems, power, and the environment in which the RCTCP system operates. Interface requirements shall encompass facilities, structures, systems, equipment, hardware, software, firmware, internet, wired and wireless communications, radio airwaves and spectrum, man/machine interfaces, operations, maintenance, training, rules and procedures.

D. This section specifies the requirements for the Contractor to develop and implement a RAMDPP.

1. The RAMDPP shall describe and provide means for evaluating system reliability, availability and maintainability.

2. The requirements of this Section shall apply to all Contractor’s and its subcontractors’ functions during all phases of the Work, including final design, construction, installation, testing, pre-revenue operations, in-service support, warranty, retrofits and field modifications.

3. The Contractor shall be responsible for verifying that the System elements and subsystems are of the highest achievable level of safety, reliability, and maintainability, that they are designed and constructed in compliance with all applicable, codes, Metro Systems Assurance requirements, industry standards and in accordance with the results of the Contractor’s RAM analyses.

E. Objectives and Criteria:

1. The primary objective of the RAMDPP shall be to optimize the system reliability and maintainability characteristics of the systems, subsystems equipment and assemblies
Reliability, Availability Maintainability, Dependability Plan
Appendix C - Sample RAMD Specifications

provided under this contract, hardware, software and firmware and their interfaces within the existing Metro LRT system and the RCTCP by:

a. Increasing the mean time between failures (MTBF), i.e., reducing failure frequency, or providing active parallel redundancy for reliability-critical subsystems and assemblies, to avoid and minimize high failure frequency, high corrective maintenance cost, and low inherent availability in systems and equipment.

b. Providing a high degree of reliability by maximizing mean time between failures (MTBF) of equipment, systems components and assemblies.

c. Minimizing downtime during maintenance and malfunctions, by minimizing mean time to repair (MTTR) of equipment, systems, components and assemblies.

d. Maximizing functional availability of equipment and systems in safety-critical and reliability-critical functions required to operate on a continuous basis or “on demand” by providing redundancy in critical equipment, components and assemblies or software modules such that the equipment remains fail-operational and fail-safe.

2. A secondary objective of the RAMDPP shall be to minimize the magnitude and seriousness of those events, malfunctions or fault conditions which could result in extensive service delays to trains and patrons and which require Metro to develop failure recovery strategies to minimize delay to trains. These Metro strategies will utilize available alternative measures (acceptable to system safety) which allow the system to continue in revenue operations without incurring a “service failure”. A service failure is defined as a failure resulting in train delay exceeding 3 minutes on a one-way trip.

3. Formulate and document the Contractor’s final design specifications and drawings to satisfy the requirements for systems reliability, availability and maintainability through the design, construction, manufacture, installation, testing, commissioning, and start-up phases of the Contract.

F. During Contractor’s design, manufacture, construction, installation and testing of the systems, employ the objectives, requirements, specifications, and methodology stated in the RAMDPP to accomplish the goals of reliability, availability and maintainability.

G. Apply scientific and engineering principles to identify and analyze potential reliability and availability problems and to recommend the necessary design selection of the most reliable and available system configuration, parts and components selection to increase reliability, and system configuration which is highly maintainable in the shortest time possible during corrective maintenance.
H. List of Abbreviations: The following abbreviations are used in this section:

A Ampere, Availability
ACE Advanced Conceptual Engineering
AREMA American Railroad Engineering and Maintenance of Way Association
BLS Blue Light Stations
BOC Bus Operations Control
CCTV Closed-Circuit Television
CFD Computational Fluid Dynamics
CFM Cubic Feet per Minute
CPJV CONNECTOR PARTNERSHIP Joint Venture
CPTED Crime Prevention Through Environmental Design
CPUC California Public Utilities Commission
CTS Cable Transmission System
DB Design-Build
DC Direct Current
DEIS Draft Environmental Impact Statement
DWP Department of Water and Power
EBPS Emergency Back-up Power System
EDM Electronic Display Monitors
EIS Environmental Impact Statement
EMS Emergency Management System
EPABX Electronic Private Automatic Branch Exchange (Telephone)
ETS Emergency Trip System
EVS Emergency Ventilation Shafts
FA Fire Alarm (and detection)
FAI First Article Inspection
FLS Fire-Life safety
FPM Feet Per Minute
FRP Forced Reduced Performance
HID High Intensity Discharge
HP Horsepower
KV Kilovolts
KVA Kilovolt-amperes
LADWP Los Angeles Department of Water and Power
LAFD Los Angeles fire department
LB-LA Long Beach- Los Angeles
LPA Locally Preferred Alternative
LPSCFT Low-Profile Simple Catenary Fixed Termination
LRT Light Rail Transit
MCC Motor Control Center
MIL-HDBK Military Handbook
MDBF Mean Distance Between Failures
MDT Mean Down Time
MTBF Mean Time Between Failures
MTBSF Mean Time Between Service Failures
MTTF Mean Time To Failure
MTTR Mean Time to Repair
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OCS</td>
<td>Overhead Contact System</td>
</tr>
<tr>
<td>OPE</td>
<td>Over Platform Exhaust</td>
</tr>
<tr>
<td>P</td>
<td>Pole</td>
</tr>
<tr>
<td>PA</td>
<td>Public Address</td>
</tr>
<tr>
<td>PE</td>
<td>Preliminary Engineering</td>
</tr>
<tr>
<td>PIP</td>
<td>Project Implementation Plan</td>
</tr>
<tr>
<td>RAMD</td>
<td>Reliability, Availability, Maintainability, Dependability</td>
</tr>
<tr>
<td>RBD</td>
<td>Reliability Block Diagram</td>
</tr>
<tr>
<td>RCTCP</td>
<td>Regional Connector Transit Corridor Project</td>
</tr>
<tr>
<td>ROC</td>
<td>Rail Operations Control</td>
</tr>
<tr>
<td>SC</td>
<td>Station Cooling</td>
</tr>
<tr>
<td>SCADA</td>
<td>Supervisory Control and Data Acquisition</td>
</tr>
<tr>
<td>SES</td>
<td>Subway Environment Simulation</td>
</tr>
<tr>
<td>SWFT</td>
<td>Single Wire Fixed Termination</td>
</tr>
<tr>
<td>TC&amp;C</td>
<td>Train Control &amp; Communications</td>
</tr>
<tr>
<td>TP</td>
<td>Traction Power</td>
</tr>
<tr>
<td>TPIS</td>
<td>Third Party Intrusion (alarm and detection) Systems</td>
</tr>
<tr>
<td>TPSS</td>
<td>Traction Power Substation</td>
</tr>
<tr>
<td>TVRA</td>
<td>Threat and Vulnerability Risk Assessment</td>
</tr>
<tr>
<td>UFS</td>
<td>Universal Fare System</td>
</tr>
<tr>
<td>UPS</td>
<td>Uninterruptible Power Supply</td>
</tr>
<tr>
<td>V</td>
<td>Volts</td>
</tr>
<tr>
<td>VMS</td>
<td>Variable Message Signs</td>
</tr>
</tbody>
</table>

### 1.01 REFERENCES

The following references are used in this Section:

- Regional Connector, Project Basis of Design Report, Task No. 5.1 (Deliverable No. 5.1.a11), June 2011.
- Regional Connector, Draft Project Implementation Plan, Task No. 2.8 (Deliverable No. 2.8.a11), December 2010.
- MIL STD 756, Reliability Modeling and Prediction.

1.02 SUBMITTALS

A. Reliability, Availability, Maintainability, Dependability Program Plan (RAMDPP): Clearly segregate the plan to identify specific LRT system elements under the Contractor's scope such as those listed in Subsection 1.01 (CDRL-XYZ-1).

B. Monthly System Reliability/Maintainability Progress Reports: Submit monthly system reliability/maintainability progress reports. Include the status of system reliability and maintainability activities based upon the approved milestone chart included in the RAMPP (CDRL-XYZ-2).

C. RAM Analyses Formats: Submit the proposed RAM analyses formats and a preliminary copy of the proposed combined prediction/ allocation of numerical R/M indices (CDRL-XYZ-3).

D. System Reliability Plan: Submit a Reliability Plan for the system elements under the contract scope, including all subsystems and equipment. Include in the plan the methods to be employed to demonstrate how the reliability requirements will be verified. Upon approval of this plan, include it in the RAMDPP specified herein (CDRL-XYZ-4).

E. System Maintainability Plan: Submit a Maintainability Plan for the system elements under the contract scope, including all subsystems and equipment. Include in the plan the methods to be employed to demonstrate how the maintainability requirements will be verified. Upon approval of this plan, include it in the RAMDPP specified herein (CDRL-XYZ-5).

F. Weekly Maintenance Activity Reports: Submit weekly reports to Resident Engineer of maintenance activities (CDRL-XYZ-6).

G. See additional submittals under Part 2- Products.
PART 2 – PRODUCTS

2.01 RELIABILITY, AVAILABILITY, MAINTAINABILITY, DEPENDABILITY PROGRAM PLAN (RAMDPP)

A. Produce an overall RAMD Program Plan (RAMDPP) for evaluating the system designs with regard to system reliability, availability and maintainability, with the objective of prescribing corrective action in a timely and cost-effective manner. Include the process for identification of unreliability, and describe the methods for improving maintainability.

B. Organize the RAMDPP to include specific sections for the disciplines of system reliability, availability and maintainability.

C. Describe the procedures to perform the specific tasks necessary to meet system reliability, availability and maintainability requirements.

D. Clearly define the responsibilities and functions of personnel directly associated with systems reliability, availability and maintainability assurance policies and implementation of the program. Describe the systems RAM assurance organization. Identify and formally document authority delegated to the systems RAM assurance organization and the relationship between that organization and all other organizational components.

E. Identify systems RAM interface requirements among the elements, systems and subsystems included in the Contractor's scope of services on this Contract for the RCTCP. Address the interface requirements between the systems provided in this Contract, and other Metro LRT system elements and subsystems. Address interfaces and intercommunications among Contractor's items amongst themselves, interfaces with other Metro LRT system elements and subsystems, and with the operating environment. Transit system element interfaces shall include but not be limited to: Light rail vehicles, automotive vehicles, pedestrians, passengers, employees, the general public, stations, station amenities, track, facilities, systems, power, and the environment in which the RCTCP system operates. Interface requirements shall encompass facilities, structures, systems, equipment, hardware, software, firmware, internet, wired and wireless communications, radio airwaves and spectrum, man/machine interfaces, operations, maintenance, training, rules and procedures.

F. Rationale for Meeting RAM Criteria: As part of the RAMDPP, this document shall show how the Contractor intends to achieve a high degree of reliability, availability and maintainability, and their inter-relationship. Include design, manufacturing and quality control practices; adherence to and implementation of sound reliability and maintainability principles in design, manufacturing, operation and maintenance; effective control of human factors; and implementation of effective maintenance and repair schedules.

G. Failure Data Collection System: Provide a description of reliability failure data collection systems. Address the provisions for a closed loop data collection system (System Reliability Failure Data Collection System) for collecting, analyzing, and recording all failures that occur during in-plant tests and those that occur at installation or test sites prior to acceptance. The analysis and recording of failures shall differentiate between
those due to design or workmanship and those due to other causes such as error in handling, transporting, storing, and operating the equipment. The failure reporting system shall include provisions to ensure that problems are detected and investigated, and that effective corrective actions are taken on a timely basis to reduce or prevent repetition of the failures.

H. System Reliability, Availability and Maintainability Test Procedures: The Contractor shall plan to conduct Maintainability Demonstration tests on a prototype group of products during the First Article Inspection (FAI) period, and Reliability/Availability tests during a formal Reliability Demonstration Test (RDT) period during the first year of revenue service, during the warranty period. Submit test procedures for the Engineer's approval, 30 days prior to conduct of tests.

I. System Reliability and Availability Test Reports: Generally, within 10 days after each test, submit test results as specified herein and elsewhere in these specifications. In the event of test failure or "reject" decision, analyze the cause of the deficiency and make recommendations for corrective action within 10 working days. After approval, implement the recommendations within 20 working days and then repeat the test of the rejected system. In the event of a second reject decision, or failure of the Engineer to approve recommended action, terminate the test.

J. Final Acceptance Audit: Conduct a final acceptance audit at the completion of all demonstration testing to establish the operational baseline of the system under the Contractor’s scope. The audit shall include a detailed review and analysis of the test results. Document the results of the audit and assign action items to resolve deficiencies. Provide all support equipment and services required by the test plan.

2.02 RELIABILITY PLANS

A. General: Prepare detailed Reliability plans (for each major system under test, e.g., signal system, communications system) in general accordance with applicable provisions of MIL-STD 785B. Upon approval of this plan, include this plan in the RAMDPP. This plan shall include:

1. Task listing and time phasing for each task.
2. Organization and responsibilities of key personnel.
3. Techniques for allocation of quantitative requirements to lower level functional elements.
4. Interfaces between reliability and other closely related programs, and support to efforts such as:
   - Logistic support and maintenance planning.
   - Design.
1. Develop reliability block diagrams that show each equipment element that is essential to the successful performance of each system/subsystem, including element interrelationships. Revise block diagrams to keep current with design iterations.

2. Develop a reliability model consisting of reliability block diagrams and probability of success equations. The model shall show the relationships required for system success. Revise the model to keep current with design iterations.

3. Accomplish reliability apportionment/prediction, including predicted mean time between failures (MTBFs). Conduct the predictions in accordance with established techniques, such as: MIL-HDBK 217E, MIL-STD 756B, or properly documented and verifiable field failure data for identical or similar equipment.

4. Perform a detailed analysis of the ability of the systems provided to achieve the MTBF goals using the demonstration pass/fail criteria specified. Identify the highest failure rate components affecting the MTBF of each assembly or subsystem. Identify actions taken and specific features designed in by the Contractor to mitigate the effect of the failures. The analysis shall also recommend operational and maintenance related strategies that can reduce the
impact of potential service failures, thereby enhancing the system’s ability to maintain service. Document all assumptions made during the analysis.

C. Signal System Reliability/Availability Requirements: Data on identical equipment from other transit properties will be considered for use in meeting these requirements, at the discretion of the Resident Engineer. Requirements have been expressed as minimum acceptable values, in hours.

1. The following items shall be measured in Mean Cycles Between Failures (MCBFs):

<table>
<thead>
<tr>
<th>Item</th>
<th>MCBF Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switch Machine:</td>
<td>25 000.</td>
</tr>
<tr>
<td>Crossing Mechanism:</td>
<td>10 000.</td>
</tr>
<tr>
<td>Signal and Indicator (LED Type)</td>
<td>50 000.</td>
</tr>
<tr>
<td>Indicator (Lamp Type)</td>
<td>10 000.</td>
</tr>
</tbody>
</table>

2. The following items shall be measured in Mean Time (Hours) Between Failures (MTBFs):

<table>
<thead>
<tr>
<th>Item</th>
<th>MTBF Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Crossing Flasher (LED Type)</td>
<td>50 000.</td>
</tr>
<tr>
<td>2) Vital Interlocking Microprocessor</td>
<td>100 000.</td>
</tr>
<tr>
<td>3) Crossing Controller:</td>
<td>10 000.</td>
</tr>
<tr>
<td>4) Event Recorder:</td>
<td>10 000.</td>
</tr>
</tbody>
</table>

D. Communications Reliability/Availability Requirements

1. Reliability of Communications systems/subsystems shall be tied to system availability. A system/subsystem shall be considered “available” as long as it still performs required functions. A system failure, such as SCADA System processor failover to a backup processor that maintains the SCADA functions, shall be still treated as the system being available. Similar treatments shall be given to CTS, Telephone, and PA/VMB systems, whereby failure of such items as a fiber transmitter at a CTS node, failure of a subscriber line card in the EPABX, failure of a single speaker loop/single sign display message board shall not be considered as a System Failure.

2. Inherent Availability percentage shall be determined on the basis of the equation \[\frac{MTBF}{MTBF+MTTR} \times 100\]. Data from manufacturers and/or that was gathered for identical equipment used by other transit properties will be used to develop calculations required to meet the stated requirements. MTTRs shall not include technician travel time or logistics delays but only active repair time at the equipment. Inherent Availability for the Communications subsystem are as follows:
a. SCADA System - Not less than 99.9999%.
b. CTS System - Not less than 99.9995%.
c. Emergency Telephone System - Not less than 99.9995%.
d. PA/VMS System - Not less than 99.99%.
e. CCTV System - Not less than 99.99%.

3. The system and its subsystems shall be able to be restored to full operation within no more than one hour (from arrival of a maintenance technician at the site of the fault or failure) in the event of fault or failure of any subsystem or physical unit (e.g., component, printed circuit board, sub-assembly) except for the following:
   a. Cable that runs from one communications node to another.
   b. Cable that runs from a communications node to external equipment (such as a VMS).
   c. Cable that runs from a communications node to equipment not provided under this Contract.

4. Each make and model of equipment provided shall have an MTBF better than (greater than) at least 49 percent of all equipment (make/model) available in the commercial marketplace meeting both of the following criteria:
   a. That equipment provides essentially equivalent functionality.
   b. That equipment is ranked in the top five for domestic market share (measured by sales dollars) for equipment providing essentially equivalent functionality.

5. Equipment (e.g., Communications Node equipment) that will be installed in Communications Cabinets shall have an expected MTBF, when operating in those cabinets, not less than 85 percent of the expected MTBF when operating in the environment specified in a TC&C room. The Resident Engineer reserves the right to require the Contractor to provide confirming MTBF data.

E. Reliability Demonstration Plans: Provide a plan for formal demonstration of achieved reliability/availability for the systems and equipment as part of the Reliability Plan. Identify the means for obtaining reliability (e.g., counters).

F. RCTCP System-wide Quantitative Inherent Availability Goals: Contractor’s overall system inherent availability goals for the various systems, subsystems, assemblies and interfaces contained in these contract documents for the RCTCP, to the extent included within the system boundaries of the RCTCP and included under the Contractor’s scope up to the point of interface with other existing Metro system elements, at all field locations within the RCTCP and at ROC, shall be as follows:

1. Radio: 99.99%
2. Cable Transmission System (CTS), (fiber optics): 99.9998%
3. Emergency Telephone: 99.9995%
4. Public Address (PA): 99.99%
5. Variable Message Signs (VMS): 99.99%
7. Fire Alarm and detection (FA): 99.999%
8. Third Party Intrusion alarm and detection Systems (TPIS): 99.99%
10. Universal Fare System (UFS): 99.9%
11. Seismic detection: 99.999%
12. Supervisory Control and Data Acquisition (SCADA): 99.9999%
13. Elevators: 99.9%
14. Escalators: 99.9%
15. UPS: 99.99%
16. Traction Power: 99.99%
17. Train Control: 99.99%
18. Emergency Ventilation System: 99.999%
19. Electrical System: 99.999%

G. The Contractor shall apportion and allocate MTBF and MTTR values to the various systems elements and subsystems using a Reliability Block Diagram (RBD) model, which shall support and meet the top level availability goals. The Contractor may use the beneficial effects of redundancy and repair rate (repair rate= reciprocal of MTTR) to reduce the effective failure frequency and thus increase the effective MTBF of system elements and subsystems due to equipment redundancy, and the ability to repair one failed unit in time before the second (redundant) unit fails. The Contractor shall use mathematical models in accordance with the RAMD literature listed in the Reference documentation herein. The Contractor shall demonstrate through analysis and test that the apportioned MTBF values which support the top level inherent availability are achievable and the equipment shall demonstrate such MTBF through analysis and test.

H. Mean time between failures (MTBF) shall be calculated as the total number of equipment operating hours for the entire population of like items, divided by the number of failures (loss of function) requiring unscheduled corrective maintenance action anywhere within the said population of items during said total accrued operating hours by said population of items. A failure shall be defined as loss of function. In redundant systems configuration, the function shall not be deemed “lost” until all the redundant items in the “Cut-set” of redundant items have failed. Thus the Contractor shall benefit from the effects of redundancy and repair rate to reduce the effective failure frequency of the system/ subsystems (i.e., increase the effective MTBF) due to redundancy in configuration. Also, scheduled preventive maintenance to inspect/ repair/ replace items during non-revenue-service hours, shall not be considered chargeable failure for MTBF calculation.

I. Reliability Calculations and Data:

1. Contractor shall submit calculations or other data as requested by Metro, to demonstrate its proposed equipment will meet reliability/availability goals. Contractor shall not furnish any equipment until calculations or data is approved by Metro.
2. Reliability calculations shall be in accordance with MIL-HDBK-217, and shall also use reliability block diagram, reliability model, probability of success equation, and preventive maintenance strategies to achieve required MTBF, or for demonstrated reliability calculations, submit test data in accordance with MIL-STD-781D and MIL-HDBK-781.

3. Contractor may propose alternate method of calculating reliability, such as providing service records for proven equipment, upon approval by Metro.

J. Reliability Demonstration Test:

1. Contractor shall submit a Reliability Test Plan for approval by Metro.

2. Contractor shall perform a reliability demonstration in accordance with the approved Plan and submit a Test Report to verify the specified reliability goal is met. The reliability demonstration shall be conducted during the period commencing with acceptance of each system at the first station plus the warranty period, subsequent to successful completion of field installation and acceptance testing at each location. It is anticipated that the reliability demonstration test (RDT) will last through the first year of revenue service, i.e., 12 months after start of Revenue Operations while the system is under warranty.

2.03 RELIABILITY TEST REPORTS

A. Test Reports

1. The Contractor shall prepare and submit monthly reports to identify the status of system RAMD activities performed throughout the performance of this Contract, including the performance of test activities specified under Commissioning and Testing.

2. In the event of a test failure or “reject” decision, within 10 working days, analyze the cause of the deficiency and make recommendations for corrective action, if the failure or “reject” decision was as a result of a system component failure. After approval, implement the recommendations within 20 working days, and then repeat the test of the rejected system. In the event of a second reject decision, or failure of the Resident Engineer to approve recommended action, terminate the test.

3. Prepare and submit as part of each report, data which shall initially indicate predicted MTBF values and, as data becomes available after the commencement of the Reliability Demonstration Plan, the actual values.
2.04 AVAILABILITY

The Contractor shall demonstrate through analysis and test that the following end-to-end functional availability goals are met.

A. For Safety Critical Functions: The contractor shall demonstrate through analysis and testing that all systems, subsystems, assemblies and equipment, encompassing hardware, software, firmware, including interfaces, which perform safety critical, or safety-related functions in any and all systems specified under this contract, shall meet the following Availability requirement:

The inherent Availability of the safety-related system/ function as measured by the expression:

\[
\text{Availability} = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}}
\]

Where:

MTTR = Mean time to repair (in hours)

MTBF = Mean time between failures (in hours)

And when the function is evaluated, analyzed and tested from end-to-end, across all interfaces i.e., from the point of initiating control-command (e.g., at ROC, or at any field location) to the point of execution of the command at the safety-related device in the field, shall be 99.999% or 0.99999.

This means that the unavailability to successfully execute a safety-related command from ROC (or from any field location) to a safety-related device in the field, when measured from end-to-end across all interfaces, shall be less than one hour in 100,000 hours of operation.

B. The Contractor shall develop and submit to the engineer for approval Availability analysis and test documentation, listing all systems, subsystems, assemblies and equipment, encompassing hardware, software, firmware, including interfaces, which perform safety critical, or safety-related functions in any and all systems specified under this contract. The functions shall be evaluated, analyzed and tested from end-to-end, across all interfaces i.e., from the point of initiating control-command (e.g., at ROC, or at any field location) to the point of execution of the command at the safety-related device in the field. The Contractor shall demonstrate through analysis and testing that each safety-related end-to-end system/function exhibits inherent availability of 99.999%.

Examples of safety-related end-to-end system/function which must exhibit inherent availability of 99.999% include, but are not limited to, the following:

1. Successfully detecting and transmitting fire/smoke alarm from equipment room field location to ROC and successfully receiving and acknowledging the alarm at the ROC Panel.
2. Successfully detecting and transmitting failure conditions from Wayside signaling instrument housing at a field location to ROC and successfully receiving and acknowledging the alarm at the ROC Panel.

3. Successfully commanding a tunnel emergency ventilation fan to operate in a given mode (exhaust or supply) from the Metro ROC.

4. Successfully commanding a tunnel emergency ventilation fan to operate in a given mode (exhaust or supply) from any station Emergency Management Panel (EMP).

5. Successfully commanding a tunnel emergency ventilation fan to operate in a given mode (exhaust or supply) from a station Motor Control Center (MCC).

6. Successfully detecting and transmitting fire/smoke or water flow alarm from a station or any field location to a station Emergency Management Panel (EMP), and to an emergency management workstation at ROC.

7. Successfully detecting and transmitting fire/smoke or water flow alarm from a station or any field location to an outside monitoring Central Supervisory Station (CSS).

8. Successfully commanding a specific Traction Power breaker to open, from the Metro Rail Operation Control Center (ROC), without erroneous inadvertent closing/energization of another TP breaker in the field.

C. For Non-Safety Critical Functions, which are Revenue-Service–Critical: The contractor shall demonstrate through analysis and testing that all systems, subsystems, assemblies and equipment, encompassing hardware, software, firmware, including interfaces, which perform non-safety critical, or non-safety-related functions but which are Revenue-Service Critical (may cause train or passenger delay exceeding 3 minutes, or cause implementation of failure recovery strategies and SOP’s to recover from system failures, fault conditions, loss of control and/or indications) in any and all systems specified under this contract, shall meet the following Availability requirement:

The inherent Availability of the non-safety-related system/ function which is revenue-service-critical as measured by the expression:

$$\text{Availability} = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}}$$

Where:

MTTR = Mean time to repair (in hours)

MTBF = Mean time between failures (in hours)
And when the function is evaluated, analyzed and tested from end-to-end, across all interfaces i.e., from the point of initiating control-command (e.g., at ROC) to the point of execution of the command at the non-safety-related, but revenue-service-critical device in the field, shall be 99.96% or 0.9996.

This means that the unavailability to successfully execute a non-safety-related but revenue-service-critical command from ROC to a non-safety-related but revenue-service-critical device in the field, when measured from end-to-end across all interfaces, shall be less than four hours in 10,000 hours of operation.

D. The Contractor shall develop and submit to the engineer for approval Availability analysis and test documentation, listing all systems, subsystems, assemblies and equipment, encompassing hardware, software, firmware, including interfaces, which perform non-safety critical, or non-safety-related functions, but which are revenue-service-critical (may cause train or passenger delay exceeding 3 minutes, or cause implementation of failure recovery strategies and SOP’s to recover from system failures, fault conditions, loss of control and/or indications) in any and all systems specified under this contract. The functions shall be evaluated, analyzed and tested from end-to-end, across all interfaces i.e., from the point of initiating control-command (e.g., at ROC) to the point of execution of the command at the non-safety-related, but revenue-service-critical device in the field. The contractor shall demonstrate through analysis and testing that each non-safety-related but revenue-service-critical end-to-end system/function exhibits inherent availability of 99.96%.

Examples of non-safety-related but revenue-service-critical end-to-end function which must exhibit inherent availability of 99.96% include, but are not limited to, the following:

1. Successfully completing from the Metro Rail Operation Control Center (ROC) the selection of a divergent route through an interlocking and displaying a wayside “proceed to cross over” to a Metro Light Rail train in the field.

2. Successfully restoring a normal route at an interlocking from the Metro Rail Operation Control Center (ROCC) after a train has crossed over, by selecting a normal route through the interlocking and displaying a wayside “proceed straight” signal to a Metro Light Rail train in the field.

E. For Non-Safety Critical Functions, which are also non-revenue-service−critical: The Contractor shall demonstrate through analysis and testing that all systems, subsystems, assemblies and equipment, encompassing hardware, software, firmware, including interfaces, which perform non-safety critical, or non-safety-related functions and which are non- revenue-service critical (may cause train or passenger delay of less than 3 minutes) in any and all systems specified under this contract, shall meet the following Availability requirement:

The inherent Availability of the non-safety-related system/ function which is non-revenue-service-critical as measured by the expression:

\[
\text{Availability} = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}}
\]
Where:

MTTR = Mean time to repair (in hours)

MTBF = Mean time between failures (in hours)

And when the function is evaluated, analyzed and tested from end-to-end, across all interfaces i.e., from the point of initiating control-command (e.g., at ROC) to the point of execution of the command at the non-safety-related, non-revenue-service-critical device in the field, shall be 99.9%, or 0.999.

This means that the unavailability to successfully execute a non-safety-related and non-revenue-service-critical command from OCC (or from any field location panel) to a non-safety-related and non-revenue-service-critical device in the field, when measured from end-to-end across all interfaces, shall be less than ten hours in 10,000 hours of operation.

F. Revenue service in the RCTCP area is defined as the time period of exposure ("Runtime") during the Metro Light Rail general Revenue Service hours when Metro Light Rail trains are within the physical boundaries of the RCTCP. The Metro Light rail general definition of Revenue Service hours system-wide is the time interval between the time the first revenue service Metro Light Rail Train enters the Mainline, and the time the last revenue service train exits the Metro mainline. The revenue service periods and times are outlined in Metro schedules. The Contractor shall meet the System Availability requirements for all installed systems under this contract irrespective of Metro schedule changes on the mainline or additional special events. However the time of exposure of trains within the RCTCP geographic area shall be taken into consideration.

2.05 MAINTAINABILITY PROGRAM

A. Prepare a description of the Contractor's Maintainability Program as part of the RAMDPP, including:

1. Provisions of Article 2.02.A herein, as they pertain also to system Maintainability.

2. Provisions for early fault detection and rapid fault isolation to the proper service level for minimization of costs and MTTR.

3. Provisions for simplification of fault detection, isolation, and repair so as to minimize the skill levels and training requirements for maintenance personnel by use of maintenance aids or test equipment.


5. Provisions for reduction of the following: complexity of the maintenance, design-dictated maintenance activities and related costs, maintenance down-time and effects on system operation, maintenance costs, potential for maintenance error, and man/machine interface problems.
6. Provisions to evaluate operational and design changes for possible effects upon maintainability requirements.

2.06 GENERAL MAINTAINABILITY REQUIREMENTS

A. General: The design and installation of safety and reliability critical key system elements such as of the Signal and Communications Systems shall provide for ease and speed of troubleshooting and repair for all components.

B. Modular Design

1. Use modular design throughout. Organize electrical and mechanical components in rack-mounted, plug-in assemblies to the greatest degree practicable.

2. Minimize mixing of separate functions within one plug-in assembly.

3. Mount equipment serving similar functions in the same relative location on racks or assemblies.

C. Equipment Maintainability: The design and construction of all systems supplied shall be such to be routinely maintainable by Metro personnel, on site or at Metro maintenance facilities. Replaceable and repairable assemblies and modules shall be provided to facilitate troubleshooting.

1. Equipment Assemblies:

   a. Cable-connected or pull-out modules shall be designed for direct access and quick replacement and shall weigh less than 15 pounds

   b. Assemblies weighing 15 pounds or more shall be provided with roll-out slides, hinges, or other devices to permit moving assemblies to test or maintenance positions without manual lifting.

   c. Packages that weigh more than 15 pounds shall be provided with lifting devices.

   d. Assemblies requiring removal for shop maintenance shall weigh less than 40 pounds

   e. Assemblies requiring removal for preventive maintenance or replacement shall have quick disconnect plug connectors and flexible cabled leads.

   f. Assemblies and subassemblies shall be designed to be handled in normal work positions without damaging or displacing any component parts, and shall require no mechanical readjustment before installation.

   g. All assemblies, subassemblies, and circuit or hardware components shall have permanently affixed labels giving manufacturer and part number. Color coding to designate value and ratings of components shall be used only where it has been accepted as an industry standard.
h. All equipment shall be mounted in racks, cabinets or consoles, and shall be fabricated, finished, and arranged to present a uniform and coordinated appearance.

i. Protective covers shall be provided for all equipment with exposed surfaces that operate in excess of 131°F.

2. Equipment Accessibility: All components, modules, and subassemblies shall be accessible for testing, removal, or replacement without removal of other parts. Where this is not possible, other parts shall be of a pull-out or plug-connected type.

   a. All components requiring adjustment or replacement shall be visible and identifiable.

   b. Access openings shall be covered where required to protect internal parts, safeguard personnel, or restrict access for adjustments not normally performed in the field. Covers shall be labeled to indicate their purpose, or the hazard involved. Hardware or fasteners used to secure covers shall be captive.

   c. Structural braces, supports or enclosure sheets shall not hamper access to components or subassemblies. Overhanging edges or exposed corners that could hamper access or cause injury to personnel shall not be allowed.

   d. All components, modules or subassemblies that may require maintenance access, shall be located with sufficient room for effective use of appropriate tools and test equipment for required maintenance.

3. Graphical User Interfaces

   a. Select lists and mouse inputs shall be provided for specified components requiring a direct interface by maintenance or operations personnel.

   b. All user interfaces shall be subject to approval by Metro.

4. Maintenance Adjustments: Recurring maintenance adjustments shall be minimized by the use of wide-tolerance circuits, stable components, and automatic re-calibration or adaptation. Components that are manually adjustable shall be used only if there is no other choice.

   a. When frequent observations or adjustments are necessary, built-in indicators, meters, or other readouts shall be provided. GO/NO-GO type indicators shall be provided where practicable. Where frequent adjustments are necessary, built-in readouts shall be placed near related devices so that adjustments may be effected by one person.

   b. Adjustable devices shall have locking screws or shall be self-locking to prevent inadvertent operation or drift.
c. Wherever practicable, points requiring preventive maintenance adjustment together shall be located within 12 inches of each other so maintenance can be performed by one person. Interacting adjustments shall be avoided if possible.

d. The replacement of a module or subassembly with a spare unit shall not require adjustment to the associated external input or output circuits or modules. If adjustments are required, such adjustments shall be provided on, and limited to, the device being replaced or repaired.

e. Panels and openings shall be of sufficient size, quantity, and placement to permit ready access from a normal or service work area. Access to replace components or wiring shall not require removal of other assemblies not associated to the component.

f. Use self-retaining fasteners wherever possible.

g. Special-access opening tools shall not be required unless necessary to prevent vandalism.

h. Incorporate latch hold-open devices, where practicable, as an additional safety factor.

i. Components that are most frequently maintained or adjusted inside equipment cabinets shall be the most accessible.

j. Provide means to facilitate handling of heavy or less accessible components.

D. Interchangeability: Provide parts, components, and assemblies performing like functions that are physically and functionally interchangeable. Parts components and assemblies that are not functionally interchangeable shall not be physically interchangeable.

E. Indications and Test Points: Provide indicators and test connectors at points in a circuit that isolate functions necessary for rapid troubleshooting. This shall include but not be limited to oscillator outputs, modulator outputs, amplifier outputs, level detector outputs, and relay driver outputs.

2.07 SIGNAL SYSTEM MAINTAINABILITY PLAN

A. Prepare a detailed Maintainability Plan for the Signal System, as part of the RAMDPP specified herein. The Maintainability Plan shall include:

1. Task listing and time phasing for each task.

2. Organization and responsibilities of key personnel.

3. Interfaces and input from maintainability to efforts such as:
   a. Logistic support and maintenance planning.
b. Design.

c. Standardization.

d. System Engineering.

e. Personnel subsystem program (human engineering, training, and manuals).

f. Methods for ensuring that subcontractors’ and suppliers’ maintainability efforts are consistent with overall plan.

g. Provisions for early fault detection and rapid fault isolation to the proper service level to minimize costs and MTTR.

h. Provisions for simplification of fault detection, isolation, and repair so as to minimize the skill levels and training requirements for maintenance personnel.

i. Provisions for accessibility for maintenance tasks.

j. Provisions for reduction of the complexity of the maintenance, design-dictated maintenance activities and related costs, maintenance down-time and effects on system operation, maintenance costs, potential for maintenance error, and man/machine interface problems.

k. Provisions to evaluate operational and design changes for possible effects upon maintainability requirements.

B. Maintenance Concept: Develop a maintenance concept which is consistent with the overall maintenance concept, taking the following into considerations:

1. System parameters as specified above.

2. Maintenance Assumptions:

   a. Troubleshooting and repair will be done by a high school graduate who has had 2 years of relevant qualifying technical school training and 2 years of experience; has attended the training programs and has all maintenance manuals, as specified in the Contract specifications (Operations and Maintenance Manuals), and has use of the test equipment recommended by the Contractor.

   b. Spare parts recommended by the Contractor will be available.

   c. Perform maintenance at three discrete levels; on-line, off-line, and bench:

      1) On-line maintenance is that performed on an in-place and operational equipment element. Test points or built-in indicators shall facilitate identification of interfaces with other system elements. On-line maintenance shall not disrupt service.
2) Off-line maintenance is that performed on in-place but out-of-service equipment elements.

3) Bench maintenance is that which is performed on out-of-place and service equipment elements. This maintenance is to be performed in a shop area where standard test equipment and fixtures are available. Test equipment and procedures shall allow maintenance to the lowest pluggable component part level.

3. The maintenance concept shall define the repair, corrective, and preventive maintenance program plans, policies, and support requirements for all equipment supplied under this Contract. It shall:
   a. Minimize each level of maintenance consistent with these technical specifications requirements and system reliability goals.
   b. Recommend policies and practices which ensure that, at the time of a failure, qualified maintenance personnel will be promptly notified and will have the necessary documentation, tools, test equipment, and spare parts to effect the repair in a minimum of time.

4. The maintainability concept shall develop recommendations for:
   a. Depth and frequency of maintenance requirements at each level.
   b. Facilities required.
   c. Support equipment and tools required.
   d. Skill levels and numbers of personnel required.
   e. Subsystem, component, and piece part repair policy.
   f. Detailed fault isolation and troubleshooting procedures, diagnostic equipment, and special test equipment.

2.08 COMMUNICATIONS SYSTEM MAINTAINABILITY PLAN

A. Communications System Maintenance Plan: Develop a report for the Communications elements in the Contract.

   1. Include data on all replaceable units (down to and including the Lowest Level Replaceable Unit):
   2. Identify all replaceable units, and state whether it is a Field Replaceable Unit.
   3. If the unit can feasibly be replaced in the field, indicate such and state the expected time from Maintenance Technician arrival at the site until the unit is removed, replaced, restarted, and put back into the operating Communications System.
4. For each replaceable unit, identify the quantity (to be) installed, provide MTBF data, provide the estimated MTTR, and describe any special or unique handling or maintenance procedures, maintenance and tools required, diagnostic and test equipment required to allow the specific faulty or failed replaceable unit to be identified within fifteen minutes. Also provide replacement component procurement lead time and expected number of failures in the one year period after Final Acceptance.

5. Identify data on preventative maintenance:
   a. Identify the recommended preventative maintenance that should be performed on installed equipment.
   b. Based on and relating to quantities and groupings of equipment (to be) installed, state the intervals at which preventative maintenance should be performed, the estimated time to perform preventative maintenance, any special tools or procedures recommended to perform preventative maintenance.
   c. Identify “consumable” equipment or supplies which could be replaced on a regular interval, state the replacement interval, and state the quantity of each consumable required to maintain the system for a one-year period.
   d. Identify unique or unusual maintenance staff skills required to maintain equipment.

B. Operating and Maintenance: Operating and maintenance safety shall be the highest consideration in equipment and subsystem design, construction, and installation.

C. Subsystems and Interfaces:
   1. Interfaces between subsystems shall:
      a. Be designed in a manner to minimize customization.
      b. Be fully defined and documented and shall utilize non-proprietary media and protocols.
   2. Subsystems shall be modular, with replaceable off-the-shelf components. To the extent possible, those components shall be commercially available and conform to industry standards.
   3. Within subsystems, industry standard data communications protocols shall be used between major elements.
   4. Where a subsystem requires a custom or semi-customized solution, or where a choice of system software is available, the underlying system software tools (e.g., operating system) shall be industry-standard commercial off-the-shelf software and serve to help implement an open system where intra-subsystem and external subsystem interfaces are non-proprietary, are fully defined and implement an industry-standard.
D. Minimizing the Effect of Faults: The system shall be designed to:

1. Minimize the possibility of a fault in one subsystem causing a fault or failure of another subsystem.

2. Minimize the effect of faults within each subsystem.

E. Maximizing the Use of Field Replaceable Units: Subsystem products, assemblies, and components shall be selected to:

1. Maximize the percentage of types of units that can be classified as replaceable units.

2. Maximize the percentage of types of units that can be classified as Field Replaceable Units and which can be replaced in the field within 1 hour of arrival of a technician at the site.

F. Health: To the extent possible, the health of all replaceable units shall be monitored by the Communications System, and any fault or failure of a replaceable unit shall be specifically indicated (indication to include at least the identity of the specific replaceable unit which failed or incurred the fault, and visible without needing to remove other equipment) locally, or reported to the Rail Traffic Controller’s console.

G. Coordination with O&M Procedures

1. Design the system and organize the O&M procedures in such a manner that all required preventive maintenance activities can be accomplished without interference with operations.

2. Emphasize in these procedures accessibility, ease of equipment or component removal and replacement, visual indications of component deterioration, and localization of failures.

2.09 SIGNAL SYSTEM SOFTWARE VERIFICATION AND VALIDATION PLAN (SVVP)

A. General: Prepare an SVVP that describes how the Contractor will verify and validate all vital and non-vital software, including application software, and provide the necessary documentation to demonstrate to the satisfaction of the Resident Engineer the plan’s conformance and that the signal system software will comply with the requirements of the Contract.

B. Changes: The SVVP shall provide a method to verify that changes made to the application dependent firmware were confined to the intended logic. This would preclude the need for a system test of the entire content of the application EPROM whenever a change is made to the application dependent firmware.

C. Quality

1. The Contractor will not be required to demonstrate that software not developed specifically for this program, which has been verified and validated on another property or through the manufacturer’s internal processes to the satisfaction of the
Resident Engineer, and which is utilized in an unmodified form in this program, was developed in accordance with the approved Quality Assurance Program. Refer to Contract Quality Assurance and Quality Control requirements for details. Modifications to such software, however, shall not be exempt from this requirement.

2. The SVVP shall be in conformance with the latest issue of IEEE Standard 1012.

PART 3 - EXECUTION

3.01 GENERAL

A. Objectives and Criteria

1. The RAMDPP shall be developed and implemented by the Contractor to:
   a. Minimize the severity and probability of occurrence of safety-critical and reliability-critical/service-affecting failures and fault conditions.
   b. Provide a high degree of reliability.
   c. Minimize downtime during maintenance and malfunctions.

2. Satisfy the RAMD requirements through the design, construction, installation and testing phases of the contract, including start-up and revenue service during a 1-year RDT.

3. Assure that safety and service-critical systems such as the Signals and Communications Systems are of the highest achievable level of safety and reliability.

B. Applicability: The RAMD requirements shall apply to all Contractor and subcontractor functions during all phases of the work, including design, construction, installation, testing (both local and integrated), pre-revenue operations, in-service support, warranty, retrofits and field modifications.

C. Program Plans: Implement and maintain the various aspects of the program, including: system reliability and maintainability program plans, during all phases of the Contract, as specified.

D. Signal System Analyses: Perform reliability analyses, with appropriate updates as specified, during the design phase of the Contract.

E. Signal System Software Verification and Validation Plan

1. Verify that design safety requirements have been met. When required, a combination of analytical and test methods shall be considered. Integrate safety tests into the appropriate test plans developed in accordance with other sections.
2. The Test Program Plan, as specified in Section on Commissioning and Testing, shall include specific safety verifications for:
   b. Vital microprocessor-based system software.
   c. Train detection/loss of detection.

3. Special Test or Analysis Items:
   a. Where necessary, verify that failure modes identified during analyses, which were resolved by rationale or operating/emergency procedures, have been controlled to an acceptable level.
   b. Where complete safety testing in an operational environment is not feasible or could cause system damage, demonstrate and verify safety characteristics in design and procedures by laboratory tests, functional mock-ups, or failure simulation. Use induced or simulated failures to demonstrate an acceptable degree of safety for the failure modes identified as critical by the Contractor's safety analyses. Acceptable safety shall be as defined herein by the acceptable hazard risk index utilizing severity and probability of occurrence.

F. Plan and Procedure Review: Review the Test Program Plan and all test procedures to ensure that:
   1. Testing will be carried out in a safe manner.
   2. Any additional hazard, introduced by testing procedures, instrumentation, and test hardware, is properly identified and minimized.
   3. Safety objectives are achieved and maintained.

G. Design Reviews: Design reviews shall be conducted in accordance with the requirements of the specification Section of Submittal Requirements and Procedures. Applicable aspects of reliability, maintainability, EMI suppression techniques, availability, integrity of operation, and operation in the event of failure shall be covered in each of the design review packages.

3.02 RELIABILITY DEMONSTRATION TESTS

A. Test Duration: The reliability demonstration tests shall be initiated as early as the pre-revenue test period and shall be completed approximately 12 months after commencement of Revenue Operations.

B. Minimum Acceptable MTBF: Refer to Contractor's-developed MTBF requirements during allocation/apportionment of systems availability requirements by allocating MTBF and MTTR to system elements and subsystems/equipment to meet overall system Availability requirements specified herein.
C. Accept/Reject Criteria: Accept/reject criteria shall be as specified herein. All decisions to accept or reject equipment shall be based upon actual operational experience. The test logs maintained by the Resident Engineer and the Contractor shall be analyzed on a daily basis and summarized on a monthly basis to provide:

1. Total accumulated operating time per equipment type.
2. Total accumulated chargeable failures per equipment type with details of each failure.
3. Total accumulated repair and restore time for the chargeable failures.

D. Test Personnel: Identify all Metro special facilities and personnel required to support the testing program.

E. Test Logs: Maintain logs of all equipment test performance and compare them periodically with those maintained by the Resident Engineer. Hours shall be calculated cumulatively for all equipment under test. Failures shall be compiled from the Failure Report forms. The logs shall be maintained for the test period, and contain the following information for each incident:

1. Identification of the equipment, including nomenclature, serial number, manufacturer’s part number, and location.
2. Operating time of each system, including each shutdown and its cause.
3. Date and time of each incident.
4. Failure indication, mode, cause, and effect.
5. Identification of the failed article.
6. Classification of the incident (relevant independent failure or dependent failure).
7. Corrective maintenance or operational procedures required to restore the system to operation.
8. Failures occurring during the various tests shall be recorded on Failure Report form provided by the Resident Engineer, or developed by the Contractor and approved by the Resident Engineer.
9. Consequences of Accept-Reject Decisions: An MTBF accept decision shall terminate the respective test. Document and submit the results as provided herein. In the event of an MTBF reject decision, document and submit the results and then, within 10 working days, analyze the cause of the deficiency and prepare recommendations for corrective action. After approval, implement the recommendations within 20 working days and then repeat the test of the rejected system. In the event of a second reject decision or failure of the Resident Engineer to approve recommended action, terminate the test until the corrective action is implemented.
F. Records Management: Maintain documentation of systems assurance throughout the design, and make it available for examination by the Resident Engineer.

3.03 MAINTENANCE OF SYSTEMS PRIOR TO ACCEPTANCE

A. General: Perform preventative maintenance on completed portions of the Work, and provide weekly reports of activities, in accordance with the requirements of the Special Provisions related to – Maintenance of Systems Prior to Acceptance.

PART 4- MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. RAMD-System Assurance

1. RAMD shall be measured as a lump sum item and includes furnishing all labor and incidentals for doing all the Work involved, including development of the RAMDPP, submittals and reporting, preparation of the Test Plan, and preparation of all qualification, factory, and field test procedures.

2. Measurement of progress shall be based on approval of submittals.

B. Testing: The costs for the performance of qualification, factory, and field testing shall be measured as specified in the Specifications Section for Commissioning and Testing.

4.02 PAYMENT

A. General: The lump sum items for RAMD shall be distributed proportionally, in accordance with the approved Schedule of Values.

B. Bid Items: The Bid Item applicable to this Section has been indicated in Bid Form B – Bid Schedule.

END OF SECTION