METROPOLITAN TRANSIT AUTHORITY OF HARRIS COUNTY, TEXAS

QUAD GATE INSTALLATION FOR INTERSECTION OF WHEELER AVENUE AT UH ENTRANCE #6

EXHIBIT B

TECHNICAL SPECIFICATIONS

100% SUBMITTAL

November 29, 2018
PREPARED BY:

TEI
## SIGNAL SYSTEM TECHNICAL SPECIFICATIONS

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1.01 GENERAL DESCRIPTION

A. The intent of this document is to procure necessary signal designs and components with a proven performance history that will support the operation of the Houston light rail transit system.

B. All signal equipment shall be service proven by use in a similar North American railroad or transit system for a minimum of 5 years.

C. Signal Equipment shall have an expected service life of 30 years.

D. In general, operation of the light rail system will be by line-of-sight operating rules. It shall be the responsibility of the System Installer to provide detailed and final design, application engineering, furnish, install, test, and make safety certifiable all services required to provide for a fully functional signal system, as specified herein and as shown in the Basis of Design Report revision 16, METRO Design Criteria dated February 2007, METRO Directive Drawings, Scope of Services for Phases 1 & 2, Signal System Supplier Assurance Requirements, and the Contract Drawings. To implement operational safety and flexibility, traditional signal system elements shall be employed with other systems and include the following:

1. Signaling Equipment:
   a. Each terminal or junction interlocking and emergency crossovers.
   b. Where operating speed exceeds 40 MPH.
   c. In single track areas.
   d. In areas of exclusive right-of-way, typically one half mile or longer.
   e. Emergency crossover switches, as required, shall be equipped with dual control power operated switches and be controlled as described in specification section 1.12 Dual Operated Powered Emergency Crossovers.
   f. Double rail 100 Hz power frequency track circuits for train detection within interlocking locations where dual controlled powered switch machines are employed, at end terminal locations where train detection is required, and at powered emergency crossover locations. Audio frequency track circuits can be used as appropriate where required.

2. Train to Wayside Communications (TWC):
   a. Automatically request routes through an interlocking.
   b. Cancel established routes through an interlocking
3. Light Rail Vehicle (LRV) Interface:

   a. An automatic system of enforced braking in the event the LRV proceeds past a powered switch interlocking signal displaying a stop aspect. The system shall automatically invoke an emergency brake application on-board the LRV, record the event locally and send an alarm with train number information to the Operations Control Center (OCC).

   b. A system to detect that an LRV has proceeded past a bar signal with an unfavorable (stop) aspect at all traffic intersections. The system shall record the event locally and send an alarm to the OCC. This function is provided by the Traffic Management System and Emtrac.

   c. Design shall include a high water detection system which will send an alarm to the OCC when high water is detected.

4. Highway Grade Crossing Warning System:

   a. Highway grade crossing warning systems, implementing various components, including; gates (traffic gates), flashing lights, grade crossing indicators, cantilevers and bells shall be installed at certain intersections along the alignment. Double rail audio frequency track circuits shall be employed for control of highway grade crossing warning systems. The highway grade crossing warning system shall provide pre-emption to the traffic control system providing traffic signal priority phasing and interlocked with light rail bar signals.

5. Signage:

   a. Static or dynamic signs shall be required to inform motorists of an approaching LRV, over height vehicle detection, and those streets where roads are closed or configured as one way traffic.

   b. All signage must comply with TX-MUTCD Requirements and METRO’s Rules and Procedures for Rail Operations.

   c. All TWC junction box lid covers must be engraved with “TWC” to mark its location.
6. **Wayside Signals:**
   a. Two, Bi-directional bar signals are required at traffic signalized non gated intersections. These Bar signals shall be connected to and controlled by traffic controller case supervised by traffic control system, and provide information to the LRV operator on the current status of the street traffic signal cycle.
   
b. Three aspect wayside interlocking signals shall be located at the entrance to each interlocking equipped with dual control powered switch machines.
   
c. A one aspect, grade crossing indicator, shall be located in advance of a gated highway grade crossing for each direction of travel.
   
d. Powered emergency switches, and manual hand operated switches outside of interlocking limits shall have Switch Point indicator devices that detects the normal and reverse positions of the switch points. The aspect displayed shall be green for normal switch position and amber for reverse switch position.

7. **Automatic Vehicle Location System:**
   a. Automatic Vehicle Location (AVL) is provided by Traffic management and the Emtrac system
   
b. AVL system provided by the Emtrac system shall communicate with the rail vehicle on-board public address and passenger information message signs systems and the station PA/PIS to indicate next stop and via the Wireless Communication System for station announcements.

8. **Power:**
   a. The System Installer shall perform all necessary coordination for AC power services from a traction power substation for a signal house. Signal house power feeds shall include a normal source, and provide a backup generator at all signal house locations.
   
b. The design shall include an emergency supply source capable of 8 hour operation at each interlocking. All gated highway grade crossing locations shall require an emergency supply source capable of 8 hour operations.

9. **Signaling System Microprocessors:**
a. All vital signaling functions shall be controlled by the use of vital signal microprocessors configured in a redundant hot-standby configuration.

b. Non-vital functions shall be controlled by the use of Non-vital microprocessors and do not require redundant configuration.

c. Non-Vital functionality can be combined into the vital signal microprocessor where it is deemed a more practical application.

d. The microprocessors utilized shall be industry standard type, in use for at least 5 years on a North American railroad or transit signal system.

1.02 LIGHT RAIL TRANSIT SIGNAL SYSTEM OPERATION

A. Practical operational line headway of 6.0 minutes at peak to 10.0 minutes at non peak shall be assumed using a 25 second station dwell for intermediate stations. Different headways may be utilized on weekends, overnight hours and holidays to be determined by METRO during the design process.

B. The system is available for operation 7 days a week, 24 hours per day. Planned operation is as follows:

1. Weekday service is proposed to begin at 4:30 AM, with the latest pull-in approximately 12:30 AM.

2. Weekend and holiday service is proposed to begin at 5:30 AM, with the latest pull-in approximately 12:30 AM.

C. On semi-exclusive track way the speed limits are determined by traffic speed limits of the Parallel Street plus 10 MPH, or civil speed restrictions, or as determined by safety analysis or jurisdictional requirement. Speed through curves is limited by the civil geometry design.

D. On exclusive track way the maximum operating speed is determined by the civil geometry design but not greater than 66 mph.

E. Corridors also include:

1. Traffic signal priority/pre-emption for LRV by TWC and AFO track circuits
2. Active signs and other traffic signal options.
3. Crossing gates and flashing lights in exclusive or semi-exclusive rights of way where decreased visibility could impair safety or where the operating speed exceeds 35 MPH.
1.03 SUBMITTALS

A. System installer shall provide a Contract Data Requirement List for all required submittals.

B. System installer shall provide submittals for Signal System products described in each Specification Section, and including but not limited to the following:

1. Functional block diagram of provided equipment based on Engineer's typical design drawings.

2. Labeling Definitions Table: This submittal is a list of symbolic or index labeling definitions used with each site's installation.

3. Test plans, test procedures, documentation, and test reports for signal systems provided in contract.

4. System Design;
   a. The System Design submittal shall include, but not be limited to: block diagrams, double line track plans, and schematic diagrams.
   b. Cabling plans for all signal cables installations.
   c. Detailed design for each signal, switch, track circuit and crossing location.
   d. The System Design shall identify the inter-relationship among all major subsystem elements and the interfaces between existing and new systems and subsystems.

5. Product Data, Shop Drawings and Specifications;
   a. This submittal shall include information about all products and manufacturers to be used in each subsystem at each location.
   b. Includes, but is not limited to a list of proposed manufacturers, qualifications of proposed manufacturers, product technical data and specifications, product manuals and application guides, manufacturers' catalogue sheets, reliability, availability and maintainability information, manufacturers' Quality Assurance Plans, and manufacturers' warranty information.

6. Installation Plan;
   a. The Installation Plan shall include installation survey procedure, grounding plan, site plan, drawings, and all mechanical details necessary to install signal system elements' 
   b. System installer shall provide a submittal for all Signal System products described in each Specification Section, including but not limited to, the following;
      1) Switch machine and layouts.
      2) Embedded earth boxes as required.
3) Signal house and signal case plans and documentation.
4) Local Control panels.
5) Signals and impedance bonds.
6) List of items being recorded
7) Grounding and bonding materials;
8) All equipment associated with supervisory control and data acquisition (SCADA), including fire/smoke and intrusion alarms;
9) UPS requirements

c. System installer shall not begin installation prior to approval of the Installation Plan by the Engineer.

7. Software and Firmware Plan: A functional description of all software and firmware, list of names and version numbers of all commercial products, copies and source code where required.

8. Allocation and Provisioning Plan: A complete listing of the configuration and all settings required for every Signal System element. Includes a listing of all plug-in modules.

1.04 SYSTEM SAFETY

A. Safety shall be the prime consideration in design of the Signaling System. All safety related logic and functions shall be designed using fail-safe or check redundant principles.

B. All circuitry and systems shall be protected from all types and effects of external interference. Design and component selection shall ensure such interference will not cause an unsafe condition.

C. System safety design shall be such that any single independent component or subsystem failure will result in a safe condition. Failures that are not independent will be considered in combination as a single failure and shall not cause an unsafe condition.

D. Component or system failures shall cause a more restrictive signal indication than that permitted with no failure. Built-in fault-detection and alarm-generation capability is required.

E. Component or system failures that are not self-detecting shall not cause unsafe conditions, even if added to other failures. Any number of simultaneous component or system failures attributable to the same cause or related causes shall not cause unsafe conditions.

F. Redundant design by itself shall not be considered an acceptable method of achieving design safety.
G. Only components with high reliability and predictable failure modes or rates that have been proven in conditions similar to the projected service shall be utilized.

1.05 SYSTEMS ASSURANCE

A. See document “Supplier Systems Assurance Requirements – Signaling” for all requirements under this section.

1.06 TRAFFIC SIGNAL PRE-EMPTION AND PRIORITY REQUEST

A. Pre-emption/priority requests at vehicular traffic light intersections shall be designed for both normal and reverse operations and be initiated automatically.

1. Requests shall be initiated automatically as the LRV traverses the right of way and passes over a GPS detection zone, TWC or proximity detector track loop.

B. Pre-emption/priority requests shall allow sufficient time for pedestrians and vehicular traffic to vacate the intersection before a proceed signal aspect is displayed to the LRV operator.

C. Pre-emption/priority traffic signal phases shall automatically be released as the LRV is detected on the leaving side of the intersection, this function is provided by the Emtrac system

1.07 WAYSIDE GRADE CROSSING INDICATOR (GCI)

A. The System Installer shall furnish, install, and test each wayside Grade Crossing indicator at each intersection warned by Highway Grade Crossing Gates. The size of GCI shall be no less than 12 inches in diameter. Light emitting diodes (LED) shall be used to illuminate the GCI.

B. The lunar white aspect will provide confirmation to the LRV operator that Highway Grade Crossing Gates are in the horizontal position. The following aspects and indication shall apply:

1. Dark: No gate activation.

2. Flashing lunar white: Gates have begun to descend (between 10-86 degrees).

3. Steady lunar white: Gates are horizontal (between 0-10 degrees).

C. The discrete GCI signal head shall be provided in advance of the intersection in the direction of travel at safe stopping distance from the crossing.

D. In two track territory wayside grade crossing indicators shall be installed between the two tracks.
E. Specific location of the grade crossing indicators at individual highway grade crossing gate (traffic gate) locations shall be verified by the System Installer prior to beginning of any construction and during final civil design.

1.08 HOUSE, CASE, AND JUNCTION BOX REQUIREMENTS

A. Signal houses and cases shall be 12 gauge aluminum.

B. Houses and cases shall be furnished with backboards and 2” (minimum) of approved thermal insulation on the walls, doors, and ceilings along with door gaskets.

C. Equipment operating on more than 150 volts shall be separated and segregated from other equipment in the same house or case. Conductors located inside the house or case carrying more than 150 volts shall be in metal conduit. Equipment located inside the house or case which requires more than 150 volts to operate shall be enclosed in a separate metal enclosure.

D. Signal houses shall be provided with fluorescent lighting and signal cases shall be provided with incandescent lighting.

E. Signal houses shall be equipped with an HVAC system to maintain a temperature range between 65 and 85 degrees F with all equipment functioning at peak load, plus 10-percent spare equipment. The HVAC unit shall be controlled by an adjustable thermostat. All signal houses must be equipped with a noise control package, a baffle system that reduces the noise produced by the HVAC system. The noise control system must meet the requirements of the local City of Houston community noise ordinance. The noise control system must not interfere with air flow or the proper workings of the HVAC system.

F. Within signal houses that contain batteries, the System Installer shall install a portable, self contained eyewash unit. The unit shall contain a minimum of 32 ounces of liquid. Current OSHA requirements shall apply.

G. Signal houses and cases shall be equipped with 120 VAC duplex convenience outlets. Convenience outlets shall be fused at 15 amperes. All power conductors, power supplies, circuit breakers, fuses and transformers shall be sized to function properly and in accordance with this Specification, with the lights, air conditioning and a 6 ampere load being fed from each duplex outlet in the system.

H. An intrusion alarm shall be installed at each door entrance to signal houses and signal cases. Intrusion alarm will indicate status to OCC.

I. Signal houses shall be equipped with an approved fire detection system that will provide remote indication to the OCC. Detection system shall monitor both heat and smoke levels. Detector shall be UL listed as an automatic smoke and fire detector for open area protection.

J. In ballasted areas junction boxes shall be constructed of stainless steel.
Quad Gate System

completely weather proofed and meet AREMA 2009 Communications and Signals Manual Standards.

1.09 CONDUIT AND CABLE

A. Procurement and installation of concrete encased ductbank or surface trench with lateral conduits will be installed by the Design Build Contractor based upon the System Installer design and requirements.

B. Surface trench may be utilized and installed by Design Build Contractor in the Yards for use by the System Installer for cable installation.

C. Flexible, Schedule 80 PVC, corrosion-resistant, shall be used where necessary for connecting from the main duct bank to the signal house and to all local appliances and junction boxes from the signal house for all underground locations. Short segments of above-ground wiring to switch machines shall use flexible conduit and fittings and conform to the requirements of ANSI/UL 360-1980 (Liquid-Tight Flexible Steel Conduit).

D. Cabling between junction boxes, signals, switch mechanisms, signal houses and cases and other terminal boxes shall be placed in conduit. Cables shall be installed per the manufacture specifications, and appropriately tested for continuity, resistance and insulation requirements.

E. Within signal houses, the System Installer shall furnish and install all cable hanger brackets, straps, bolts, and angles necessary to properly support all signal, communication and signal power cables.

F. During the civil design the System Installer shall verify, to every extent possible, that conduit fill, conduit bend radii, manhole spacing, manhole size, raceways, ducts, and associated hardware are proper for the intended installation. The System Installer shall provide the cable distribution to support the design, procure and install all necessary multi-conductor cable. Cable conductors between instrument housings and field signal equipment shall be 14AWG wire or larger with 5/16 inch of 90 degree C Ethylene Propylene rubber compound insulation. Outer jacket shall be extruded black low density, high molecular weight Polyethylene.

G. Armored cable shall be used where necessary.

H. Cable plan shall provide for 10% spare conductors but not less than 2 spare conductors in each cable.

I. Case and house wiring shall be 16AWG wire or larger with Ethylene Fluoroethylene Copolymer (ETFE) insulation.

J. Other cable size and types shall be as defined in the Contract Drawings.

1.10 WARNING TIMES AT SIGNALIZED INTERSECTIONS
A. It shall be the responsibility of the System Installer to verify the location of devices that are required to initiate a pre-emption request are in accordance with the traffic signal design. The review to be accomplished by the System Installer shall include items such as, but not limited to, all wayside device location, conduit stub ups, conduit locations, conduit fill, manholes and pull boxes.

B. Where traffic intersections are located within controlled interlocking limits, train control signal design must be coordinated and integrated with traffic signal control to allow for safe movement of trains.

C. Operation of the traffic lights shall be designed to provide warning of a LRV traveling at track speed in any direction of travel is provided by Traffic management System.

D. After an LRV clears the intersection, the traffic lights will re-clear. The Signal Installer will furnish an input to the Traffic Control system provided by others.

E. Initiation of Active (normally dark) Warning Signs: Active warning signs shall be designed to operate for 20 seconds ±2 seconds prior to the LRV arriving at the intersection. The Active Warning Sign shall cease to operate once the LRV has cleared the intersection. The Signal Installer will furnish an input to the Traffic Control system, provided by others, for the purposes of initiating and cancelling the active warning sign in train signalized areas.

1.11 HIGHWAY GATED GRADE CROSSING WARNING SYSTEM

A. System Installer shall prepare for review and approval a comprehensive test plan that identifies all subsystem/system functional requirements to be achieved and verified during the testing of a highway crossing.

B. At intersections equipped with Highway Grade Crossing Gates pre-emption of traffic signals shall be initiated prior to operation of the grade crossing. The System Installer shall provide the necessary train detection to actuate this pre-emption sequence, as specified elsewhere in these Specifications.

C. At intersections equipped with traffic signals that will employ Highway Grade Crossing Gates, advance warning times shall be coordinated to ensure Highway Grade Crossing Gate operate in conjunction with the traffic signals.

D. Approach circuits for highway grade crossing warning shall be designed to the basis of a minimum of 21 seconds at operating speed. Where clearance distance exceeds 35 feet, one second shall be added to the warning time for every 10 feet (or fraction of thereof) over 35 feet. Clearance distance is defined in the AREMA 2009 Communications and Signals Manual.

E. Some intersections may require Four-Quadrant Highway Grade Crossing Warning System design.

F. As required by TX-MUTCD and AREMA 2009 Communications and Signals Manual vehicle intrusion detection system must be integrated to work with the Highway Grade Crossing System to prevent any traveling vehicle from being
Quad Gate System

trapped by the Four-Quadrant Highway Grade Crossing System. Any detection by the vehicle intrusion detection system of automobile traffic in the grade crossing during gate activation will immediately raise the exit gate to allow all vehicles to clear railroad crossing for an approaching train.

G. Extended crossing start zones shall be provided in the normal traffic direction to keep Highway Grade Crossing Gate horizontal when two rail vehicles are approaching the crossing. The extended approach shall hold the gates down, if already horizontal, but have no effect if gates are vertical. Extended approaches shall not start or extend through station platforms. Extended starts shall be limited to 10 seconds.

H. Activation of the highway grade crossing gate equipment shall be initiated by audio frequency track circuits.

I. At near side crossings where an extended station dwell would cause unnecessary roadway obstruction, TWC shall be used to raise the gates. The TWC will also be used to re-request the crossing start.

J. Highway Grade Crossings Systems will be equipped with video (IPV) monitoring equipment and is provided by the Communications system.

K. Highway Grade crossings shall have means of emergency control to raise the gates in case of approach circuit malfunction, maintenance or testing the highway grade crossing warning system.

L. Gate mechanism for entrance gates shall be powered-up type. Gate shall have a power down to 45-degree feature. Torque of the arm shall be designed so the arm will descend from vertical to the horizontal position by gravity in case of loss of power for motor drive down.

M. Exit gates in quad-gate configurations shall be powered-down type. Gate shall have a power up to 45-degree feature. Torque of the arm shall be designed so the arm will ascend from horizontal to the vertical position in case of lack of power for motor drive up. At Quad-gate locations, exit gates shall begin to descend only after corresponding presence detectors indicate unoccupied, assuring there are no motor vehicles trapped inside the crossing.

N. Highway grade crossing gates shall be equipped with breakaway sheer pins in case of a motor vehicle run-through while in the horizontal position.

O. No gate arm shall be longer than 28 feet. Where a street is wider than 28 feet, the designed layout shall use a median gate.

P. Highway grade crossings with permitted speeds above 30 mph shall have warning signs “High Speed Trains” with flashing yellow lights facing highway traffic.

Q. The vehicle over-height detection system shall be activated when it detects a motor vehicle or equipment approaching the highway grade crossing where equipment shall extend above the overhead traction wires. The over height detection system shall activate a wayside over-height sign to alert the motor...
vehicle driver of this condition. Alarm status shall be recorded locally.

R. Highway grade crossing gates shall be equipped with Gate Keeper, or an approved equal.

S. Highway grade crossing shall have data recorders that record all vital I/O functions at the crossing.

T. Highway grade crossing gate mechanisms shall be installed on their own pole and foundation.

U. The Highway Grade Crossing Warning System shall be designed to include an emergency power supply source capable of 8 hour operation.

1.12 FACTORY TEST AND INSPECTIONS

A. System Installer shall prepare for review and approval a comprehensive factory test and inspection plan that identifies all subsystem/system functional requirements to be achieved and verified during factory testing and inspection and contain test procedures, test sheets, and test reports.

B. Relays and Plugboards: Both DC vital relays and AC Vital Relays shall be tested in accordance with AREMA 2009 Communications and Signals Manual. The System Installer shall complete and certify the specified record form.

C. Signal House and Cases: The System Installer shall inspect and test the completed signal houses and cases in accordance with the approved test procedure. Signal houses and cases shall be wired complete at the point of assembly, with all equipment installed. An operational and wiring verification test shall be made in accordance with the circuit plans. Functions external to the housing shall be simulated where required. The tests shall include the following:

1. Power Distribution Tests: Power distribution tests shall be performed to ensure the power distribution for the signal house or case under test is complete and functioning as intended. Testing shall verify that each energy bus is fed from its discrete power supply; is free of ground (if applicable), shorts, and opens; and is wired in an enclosed-loop configuration. Tests shall also verify that each power supply is free of internal grounds, operates properly, and is effectively used and that all racks and equipment are supplied energy that is correct both in polarity and magnitude.

Tests shall include but not be limited to the following:

a. Verify fuse and circuit breaker sizes to that on the circuit plans.

b. Energy distribution shall be checked using a resistance test instrument, to verify agreement with the plans.
discrepancies in wire size shall be corrected.

d. Each energy bus shall be tested to all other energy buses to
insure that no bus to bus current path exists.

2. Wiring Verification Test: All circuitry shall be checked for accuracy
against the circuit drawings. Tests may be done with energy on or off and
shall verify the following using the following methods:

a. Point to Point wiring. Test one circuit at a time, by opening the
circuit at each contact in the control wiring of the relay (or other
device) operated by the circuit. This test will be performed without
power, relays not installed, and using jumpers to simulate
contacts.

b. During wire verification test, a wire count on each terminal and
relay contact shall be taken to ensure that only the number of
wires called for on the circuit plans is present at each terminal, or
relay contact. Any discrepancies found shall be corrected.

c. Verify tags and nomenclature where applicable.

d. Verify components are the same as shown on the circuit drawings
and located in proper positions.

3. Vital Circuit Tests:

a. Tests shall be conducted with energy on during simulation testing.

4. Interlocking Tests: After conducting the vital circuit tests, the System
Installer shall simulate all operating conditions to ensure each circuit
function is in accordance with the Specification.

5. Adjustments and corrections of defects in the house wiring shall be made
as necessary to obtain proper operation.

6. Design changes found necessary to obtain proper operation shall be
submitted for approval.

1.13 FIELD TEST PROCEDURES

A. System Installer shall prepare for review and approval a comprehensive test plan
that identifies all subsystem/system functional requirements to be achieved and
verified during field testing and includes test procedures, and test reports.

B. The field tests performed shall cause each installed system and subsystem to be
sequenced through its required operations, including the imposition of simulated
conditions, to demonstrate the installation complies with specified fail-safe design
requirements and operational functions.
C. The quality of the installation shall be demonstrated by field tests for continuity, insulation resistance, resistance of ground connections, circuit breakdown, visual inspection and other tests required by the Specification. These tests shall be performed prior to any operational testing of systems or subsystems.

D. The System Installer test procedures shall consist of pre-printed data sheets or inspection sheets for each test. When completed by the field test personnel and checked for accuracy and completeness, the data sheet shall be submitted as the test report.

E. When tests require specific meter or test instrument readings, the pre-printed data sheet shall show the allowable range of values, for each part of the test. The test report shall also contain a check-off system for each action and a blank space adjacent to the expected value in which to record the test readings.

F. The test report shall also contain a final description sheet on which the System Installer must record discrepancies found and action taken.

G. All test reports shall show the specific test instruments used on each test, with the instruments identified by name, type, serial number, and calibration due date.

H. Any changes made after completion of test procedure shall be retested in accordance with the applicable test procedure.

I. All test reports must have the qualified test engineers names both printed and signed along with the date of the test, for all test reports and documentation.

1.14 GENERAL FIELD TESTING AND INSPECTION

A. System Installer shall prepare for review and approval a comprehensive test plan that identifies all subsystem/system functional requirements to be achieved and verified during the subsequent test phases and includes test procedures, test sheets, and test reports.

B. The System Installer shall perform all tests required to insure the proper and safe operation of the Signal System equipment and prove the adequacy and acceptability of the total installation.

C. Tests to be performed shall cause each system and subsystem to be sequenced through all required operations and include simulated conditions to prove the installation is in compliance with failsafe requirements.

D. After operational testing is complete, signal house log books shall be required for any additional installation, repair and test activities. The System Installer shall, without exception record an entry into the Log Book anytime they enter a signal house or accomplished a task that affects any equipment within a given area of control. The entry shall include name(s), company, date, time, activity accompanied and reasons for entry. Log Book will become the property of the project upon completion of work activities.

E. Prior to operational testing, check the quality of the installation by visual
inspection and by tests of continuity, insulation resistance, resistance of ground connections, vital circuit breakdown, and other tests as required.

F. Typical types of equipment, functions and field tests to be accomplished are as follows but not limited to:

1. Batteries and Power Supplies.
2. Signal Power.
4. Standby Generators.
5. Impedance Bonds.
6. All Insulated Joints
7. Switch Machines.
8. Wayside Signals.
10. 100 Hz Power Frequency Track Circuits.
11. AFO Track Circuits
12. Loss of Shunt Protection.
13. High Water Alarms.
15. Cable Continuity, Loop and Resistance.
17. Ground Resistance.
18. Ground Detectors.
19. Interlocking Operational Testing:
   a. Signal Aspects.
   b. Switch Correspondence.
   c. Switch Circuit Controller and Point Detection.
   d. Switch Obstruction.
   e. Switch Clutch and Overload.
   f. Route Locking.
   g. Time Locking.
   h. Traffic Locking.
   i. Magnetic Trip Stop.
   j. Signal Overrun Protection and Vehicle Interface.
   k. Loss of Shunt Protection.
   l. Local Control PC.
   m. Interface with Traffic Management System at end of line interlocking and junction interlocking
   n. Verify Data Recording.
20. Highway Crossing Warning Systems:

   b. Gate Up and Down Times.
   c. Clearance Times.
   d. Grade Crossing Indicators.
   e. Flashers.
Quad Gate System

22. On-Board Vehicle Announcement System – provided by Traffic Management System, Emtrac/GPS.
23. System Integration.
24. Pre-Revenue.
25. Final Acceptance

1.15 INSTALLATION DRAWING REQUIREMENTS

A. The System Installer shall be responsible to design and deliver for review and approval all site specific and typical installation designs and drawings to facilitate installation of their equipment.

1.16 CIRCUIT DRAWINGS AND SOFTWARE

A. The System Installer shall be responsible to design and deliver for review and approval all detailed control circuit designs and drawings required to facilitate the design of their equipment.

B. This shall include, but not limited to:

1. Site specific logic diagrams.
2. Detail design for each Signal location
3. Selection circuitry.
4. Power circuits.
5. Equipment connection drawings.
6. Equipment arrangement plans.
7. Switch circuitry.
8. Detailed software packages in logic format, such as ladder format.

1.17 MANUALS, TRAINING AND PARTS CATALOG

A. The System Installer shall provide training, described as follows:

1. A thorough explanation of the function of the Signal System and the basic safety principles involved, its various safety features, and the basic levels of required maintenance.
2. Detailed instruction on all system, periodic and special maintenance and adjustment functions required for items such as, but not limited to:
   a. Relay Test and Calibration.
   b. Microprocessors.
   c. Switch Machines.
   d. Track Circuits.
   e. Highway Grade Crossing Warning Equipment.
   f. Train to Wayside Communications.
   g. Brake Enforcement System.

3. Detailed Engineers training and instruction shall be required to facilitate a complete understanding of the system circuit design and software functionality. The course shall provide for software programming training.

B. A plan for the various levels of training shall be submitted. Training shall be separate and distinct from any other activities the System Installer performs pursuant to this Contract. Relay maintenance training shall be conducted by a Relay Quality Control Inspector for the vital relay manufacturer, whose normal and customary duties center on relay inspection and repair. All other training shall be conducted by an experienced signal maintenance instructor, whose normal and customary duties center on signal maintenance instruction.

C. The System Installer shall video record all classroom training sessions and provide to Operations and Maintenance four copies of the recordings in DVD format.

D. Manuals:

   1. Manuals shall be in a reinforced three-ring loose-leaf format with 8-1/2" x 11" text sheets of archival quality. Drawings in the manuals shall be a maximum size of 11" x 17", and shall be fold out sheets bound with the text. Manuals shall not include any superfluous promotional material from any source. Covers shall be resistant to oil, moisture, and wear.

   2. In addition to hard copy, all final manuals and parts catalogs, including drawings, shall be submitted in reproducible and editable electronic media versions. Electronic media versions shall be PC compatible files, using software format which shall be submitted for approval. The electronic media versions shall be revised in accordance with the hard copy manual revisions.

   3. METRO retains the right to reproduce any and all manuals and training materials for its own use.
4. Training Manuals:
   a. The System Installer shall provide training manuals that present a step-by-step introduction to the Signal System function and operation, including a full discussion of those basic safety principles on which the system is based. These manuals shall be suitable for use in the required training program and for future training.

5. Maintenance Manuals:
   a. Maintenance manuals shall be provided with detail procedures for all aspects of Signal System servicing, adjusting, testing, calibration and repair. They shall cover all levels of maintenance from field adjustment, test, and component replacement to shop adjustment, overhaul, and test of components or apparatus. The manual shall contain systematic failure isolation procedures.

E. Standard manufacturer maintenance instructions may be used for individual components or equipment, but specific additional details shall be provided for the integration of overall system maintenance.

F. Overhead Transparencies:
   1. The System Installer shall provide METRO with a complete list of overhead transparencies and a Power Point presentation, created with the latest version of power point, to be supplied for training. This list shall include each lesson outline, hand out, schematic, and drawing parts list contained in the training manuals, maintenance manuals and training program.
   2. The System Installer shall provide five sets of these reproducible and editable transparencies in CD format.

G. Renewal Parts Catalog(s):
   1. The renewal parts catalog shall enumerate and describe every component with its related parts, including the supplier's number, the System Installers, Drawings Apparatus Reference number and provision for entry of the METRO stores number.
   2. Cut-away and exploded drawings shall be used to permit identification of all parts not readily identified by description.
   3. Parts common to different components, as, for instance, bolts, and nuts, shall bear the same number with a reference to the other components in which they are found.
   4. Each part or component shall be identified as being part of the next assembly. Commercially available items such as common standard fastenings, fuses, lamps, and fittings, shall be identified by standard
hardware nomenclature in addition to the System Installers number.

5. A separate list of these items shall be provided in the catalog with adequate information to order these items through commercial channels.

6. An important aspect of the parts catalog shall be the complete itemization of all servicing materials (oils, paints, special compounds, greases, etc.) required and the component requiring its use.

7. This catalog shall provide METRO with the ordering information and procurement information required for all components and subassemblies to the lowest level replaceable component to the end that METRO will not need to request information from the System Installer or the manufacturer at any future date.

8. These lists shall take the form of a reproducible and editable Bill of Material suitable for loose-leaf binding, and be adequately cross-referenced to the related drawings.

1.18 AS-BUILT DOCUMENTATION

A. All drawings utilized for the project shall be provided and must reflect the "as-built" conditions. This documentation shall be provided by the System Installer for review and approval and used to facilitate operation, maintenance, modification, and expansion of the system or any of its individual components. This shall include changes to the Red Line in the downtown section. Final "as-built" documentation to be furnished to METRO in the form of five sets on 11x17 paper copies as well as editable electronic copies of all CAD files.

1.19 VITAL RELAYS

A. Vital relays shall be plug in type and be compliant with the latest AREMA 2009 Communications and Signals Manual.

1. Vital relays shall provide 1 spare independent front-back contact and a minimum of 10% spare contacts.

2. The design shall not use capacitors, diodes or resistors to change timing characteristics.

3. Non vital relays where used, shall be identical.

4. Diodes, capacitors, or resistors cannot be used to change a relay's timing characteristics.
APPENDIX A

CODE REQUIREMENTS

A. The System Installer provided systems, equipment and services shall perform and be suitable for their intended purpose, in accordance with best commercial practices and as a minimum, where not otherwise specifically stated in these Specifications, the equipment shall meet or exceed all applicable standards of the latest editions of the material and design standards, listed below:

1. Department of Transportation Federal Railroad Administration Technical Manual for signal and Train Control Rules, Standards and instructions (FRA)


3. The National Electric Code (NEC)

4. American National Standard Institute (ANSI)

5. National Electrical Manufacturers Association (NEMA)

6. Institute of Electrical & Electronics Engineers (IEEE)

7. Insulated Cable Engineers Association (ICEA)


10. American Disabilities Act (ADA)


12. This system shall comply with the requirements of NFPA 78 – Lightning Protection Code and with standards of the Lightning Protection Institute.

13. System Supplier Assurance Requirements
PART 1 : GENERAL

1.01 DESCRIPTION

A. Work Included

1. The Work of this Section includes, but is not limited to, the general requirements associated with designing, furnishing, installing, testing, and placing into operation the Communication Systems for the Houston METRO Solutions Phase 2 Light Rail Transit Extension (LRT) project.

2. The general requirements specified in this Section apply, in part, to each of the functional areas associated with Communications including but not limited to, the following:

   a. Fiber optic backbone cabling;
   b. Fiber optic and copper horizontal cabling;
   c. Backbone communications network, henceforth known as the Cable Transmission System (CTS);
   d. Telephone system consisting of the following:
      1) IP (Internet Protocol) Passenger Assistance Telephones (PAT);
      2) IP Service Telephones with Direct Inward and Outward Dialing;
      3) IP Service Telephones inside the TPSS and the Communications and Signal House (C&S);
      4) Voice over IP (VoIP) Private Branch Exchange (PBX) equipment.
   e. Public Address / Passenger Information System (PA/PIS);
   f. Master Clock equipment;
   g. Communications Node Uninterruptible Power Supply (UPS);
   h. Station UPS;
   i. IP Video Surveillance System (CCTV);
j. Radio and WIFI communications equipment;
k. Supervisory Control and Data Acquisition (SCADA) System.

B. Where work under this Contract affects operation of existing equipment and/or circuits, adjust and/or recalibrate the existing equipment and circuits as required to maintain proper operation.

C. This Section describes requirements that shall apply to all Communications Systems as specified elsewhere in Sections referenced in Article 1.05 herein.

D. The CTS shall provide a minimum of 100% spare capacity with regard to backbone fiber optic cables

E. In general, communications systems within the C&S and the Communications Interface Cabinet (CIC) at each station shall have 25% spare capacity with regard to the number of ports and bandwidth utilization.

F. Requirements described in this Section shall include, but not be limited to, the following:
   1. General requirements;
   2. Submittals;
   3. Design Reviews;
   4. Environmental;
   5. EMI/EMC;
   6. Reliability;
   7. Software;
   8. Basic Electrical Materials and Methods;
   9. Parts List;
   10. Installation;
   11. Painting;
   12. Staging.

1.02 QUALITY ASSURANCE

A. Contractor’s design, fabrication, inspection, installation and testing shall comply with all applicable Standards and Codes as listed herein.

B. Material and Workmanship Requirements:
1. All equipment and material provided under this section shall be UL listed.

2. All grounding shall be in accordance with local standards, and specifications required by this Contract except as modified herein. Each piece of equipment shall be grounded in accordance with the recommendations of the manufacturer.

3. Discontinued product models, refurbished equipment, products at their end-of-life, or end-of-service shall not be used.

4. All products specified herein shall be subject to Engineer approval based on the Contractor’s ability to demonstrate adherence to the specified requirement and approval of the manufacturer’s quality process.

1.03 CITED REFERENCES

A. Code of Federal Regulations (CFR)

B. Institute of Electrical and Electronic Engineers (IEEE)

C. Military Standards

D. National Electrical Manufacturers Association (NEMA)
   1. NEMA 250 – Enclosures for Electrical Equipment.

E. National Fire Protection Association (NFPA)
   1. 70, National Electrical Code (NEC).
   2. 130, Fixed Guideway Transit Systems.

F. National Transportation Communications for Intelligent Transportation Protocol (NTCIP)
   1. NTCIP-1205 – standard defines the data elements for control of cameras, lenses, and pan/tilts units.

G. Telcordia
   2. GR-63 – NEBS Requirements: Physical Protection.

H. Telecommunications Industry Association/Electronics Industries Alliance (TIA/EIA)
1. 232 – Interface between Data Terminal Equipment (DTE) and Data Circuit Terminating Equipment (DCE) employing serial binary data interchange.
3. 310 – Cabinets, Racks, Panels and Associated Equipment.

I. International Organization for Standardization (ISO)

J. Systems Assurance
   1. Supplier Systems Assurance Requirements

1.04 SUBMITTALS

A. Contractor shall make the following submittals related to the Communications Systems:
   1. Functional block diagram of provided equipment based on Engineer’s design drawings.
   2. Product Data, Shop Drawings and Specifications.
   3. Labeling Definitions Table: This submittal is a list of symbolic or index labeling definitions used with each site’s installation.
   4. Parts List as defined later in this Section.

B. Submittals as defined below shall be made for each communications subsystem as indicated in its Specification Section, and as defined herein.
   1. System Design
      a. The System Design submittal shall include, but not be limited to: block diagrams and schematic diagrams.
      b. The System Design shall identify the inter-relationship among all major subsystem elements and the interfaces between existing and new systems and subsystems.
   2. Product Data, Shop Drawings and Specifications
      a. This submittal shall include information about all products and manufacturers to be used in each subsystem.
      b. Includes, but is not limited to a list of proposed manufacturers, qualifications of proposed manufacturers, product technical data and specifications, product manuals and application guides, manufacturers’ catalogue sheets,
reliability, availability and maintainability information, and manufacturers’ warranty information.

3. Installation Plan
   a. The Installation Plan shall include installation survey procedure, drawings and all mechanical details necessary to install new products.
   b. The Contractor shall provide this submittal for all Communications System products described in each Specification Section, including but not limited to, the following:
      1) Backbone and horizontal cabling;
      2) Communication media converters, adapters, and transceivers;
      3) Data communications network equipment;
      4) Telephone equipment and voice communications switching equipment;
      5) Public address (PA) equipment, and Passenger Information Signs (PIS);
      6) IP Video (IPV) surveillance equipment;
      7) All equipment associated with supervisory control and data acquisition (SCADA), including fire/smoke and intrusion alarms;
      8) Master Clock equipment;
      9) Radio and WIFI communications equipment;
     10) Communications Node uninterruptible power supply (UPS);
     11) Station UPS;
     12) Patch panels, distribution panels, fiber optic pigtails, and connectors;
     13) Main distribution frame (MDF), termination blocks, and protection blocks;
     14) Conduits, innerduct, junction boxes, and pull boxes;
     15) Cabinets, equipment racks, and cable ladder racks.
   c. Contractor shall not begin installation prior to approval of the Installation Plan by the Engineer.
4. Software and Firmware Plan: A functional description of all software and firmware, list of names and version numbers of all commercial products, copies and source code where required.

5. Allocation and Provisioning Plan: A complete listing of the configuration and all settings required for every Communications System element. Includes a listing of all plug-in modules.

C. Submittals defined below shall be made for each site where Communications System equipment is located.

1. Functional Site Block Diagram
   a. Signal levels shall be identified; for example, 0 dBm.
   b. Functional Site Block Diagram shall include SCADA input and output points.

1.05 SYSTEMS ASSURANCE

A. For requirements associated with Communications systems assurance and Systems Assurance Program Plan, Contractor shall refer to the Systems Assurance Supplier Requirements – Communications.

1.06 RELATED WORK

A. In the Specifications, the Related Sections articles are used to list other Sections which are incidental to and included with the Work of the particular Section. The following Sections are those associated with Communications that the general requirements in this Section apply.

B. Section 270500 – Common Work Results for Communications.

C. Section 271100 – Communications Equipment Room Fittings.

D. Section 271300 – Communications Backbone Cabling.

E. Section 271500 – Communications Horizontal Cabling.

F. Section 271600 – Communications Connecting Cords, Devices and Adapters.

G. Section 272100 – Data Communications Network Equipment.

H. Section 273100 – Voice Communications Switching Equipment.

I. Section 273200 – Telephone Equipment.
SECTION 270000 COMMUNICATIONS

J. Section 275100 – Public Address / Passenger Information Signs System (PA/PIS).

K. Section 277000 – Radio and WIFI Systems Equipment.

L. Section 278000 – Uninterruptible Power Supplies.

M. Section 279000 – Communications System Inspection and Testing.

N. Section 282300 – Video Surveillance System.

O. Section 284600 – SCADA.

1.07 PROJECT EXISTING AND PLANNED CONDITIONS

A. The existing METRO Fiber Optic backbone is an OC-48 redundant ring network. There are currently 14 SONET Nodes and 20 Hubs. Together with TXDOT backbone network, it composes an overall backbone network surrounding Highway loop 610, serving both METRO and TXDOT communications needs.

B. Houston METRO LRT is expanding its system by adding 4 Corridors which consists of total 32 new passenger stations as shown in the Contract Drawings.

C. The Operations Control Center (OCC) and the Rail Operations Control Center (ROC) will be the location where METRO personnel will monitor and control all data, voice, and video functions from a central location.

D. The fiber optic backbone (CTS) will be installed to serve the 4 new corridors. The CTS data communications network equipment is described in Section 272100.

PART 2 : PRODUCTS

2.01 GENERAL DESIGN REQUIREMENTS

A. The Communications System shall be maintainable and accessible.

B. All test points, indications and components requiring adjustment or replacement shall be visible and accessible while mounted in their normal position, without disassembly of other components.

1. Test points shall be clearly and permanently labeled and shall be provided wherever required for troubleshooting and routine
maintenance, and be capable of accepting probes and connectors used with standard test equipment.

2. Accessible points shall be provided and labeled where signals need to be injected for testing.

3. Built-in indicators or meters shall be provided where observations or adjustments are necessary. All indicators shall be labeled.

4. All analog audio circuits shall have line, equipment, and monitor jacks at every CIC cabinet to facilitate testing.

C. Assemblies and components that perform identical functions within the Communications System shall be mechanically and electrically interchangeable.

D. Standardized, commercially available components of multiple sources shall be used whenever possible, particularly for items which require replacement at predictable intervals.

E. All equipment and material shall be commercial off the shelf (COTS), standard products of manufacturers regularly engaged in the production of communications equipment and material.

F. All equipment installed under this Contract shall be properly and sufficiently protected from surges caused by lightning strikes and/or power surges.

G. Contractor shall ensure that all outdoor equipment installed under this Contract shall not be located less than 152 mm (6 inches) in proximity to the dynamic LRV clearance envelope.

H. METRO's rail operations shall rely on the Communications System to remotely monitor and control its Signal System, Traction Power system, Fare Collection System, Public Address, Passenger Information Signs, Radio and WIFI, Video Surveillance System, and Telephone Systems.

1. It is critical that all facets of the Communications System be highly available for operation as specified herein and elsewhere in the Contract Documents.

2. Contractor shall protect and save harmless all METRO systems, facilities and property. This includes, but is not limited to, locating and protecting all existing equipment and facilities during execution of the Work.

I. All local wire and cable shall be protected by conduit or other suitable raceway outside of the C&S and CIC as specified in Section 270500.
J. Contractor shall review and be familiar with all Contract Documents, including but not limited to the Contract Drawings.

1. Contractor shall be alert for inaccuracies that may exist on the drawings, including reference drawings, and take necessary precautions to protect and save harmless all existing equipment and facilities.
   a. This includes, but it is not limited to, locating and protecting existing underground utilities and facilities during excavation.

2.02 ENVIRONMENTAL DESIGN REQUIREMENTS

A. Except as otherwise specified in other Sections, all systems and equipment located inside the C&S shall perform reliably, properly and without damage at the following operating conditions:

1. Operating Temperature:
   a. 10 to +35 degrees C (50 to 95 degrees F);

B. Except as otherwise specified in other Sections, equipment located inside C&S shall be mounted within cabinets with cooling as specified in Section 271100, to meet equipment operating conditions.

C. Except as otherwise specified in other Sections, all systems and equipment located outside the C&S shall perform reliably, properly and without damage when subjected to dust, moisture, electromagnetic interference, power fluctuations, vibration, and other adverse conditions as well as under the following conditions, singularly and in any combination:

1. Sunlight
   a. None, to full direct.

2. Ambient Temperature Range
   a. −15 to +65 degrees C.

3. Flood damage
   a. All communications interface cabinets (CIC) shall be placed one foot above the 100 year flood plain unless otherwise directed by METRO.

D. Except as otherwise specified in other Sections, outdoor equipment shall be rated at a minimum of NEMA 4X.
2.03 ELECTROMAGNETIC COMPATIBILITY (EMC) - RELATED DESIGN REQUIREMENTS

A. The Communications System shall be designed to operate in the electromagnetic environment of the METRO LRT system and not cause interference to other systems.

B. Equipment shall be designed, selected, and installed with consideration given to the electromagnetic environment, which includes but is not limited to traction power, AC power distribution systems, vehicle propulsion systems, signal systems, adjacent railroads, electric utility lines, information and data systems, and communications systems, including radio.

C. Equipment installed under this Contract shall operate without being adversely affected by or emitting electromagnetic interference and shall not be adversely affected by nor cause interference to other METRO services, including, but not limited to signal systems, traction power systems, information and data systems, and radio communications.

D. Equipment installed under this Contract shall meet the requirements of the Code of Federal Regulations, Title 47, Part 15.

2.04 POWER REQUIREMENTS

A. Communications System components shall be powered from 120 VAC single phase sources including the UPS within the C&S and the UPS in each CIC cabinet.

B. All communications equipment shall be capable of start-up without re-initialization and with full status memory and process recall utilizing emergency power in the event of power outage.

C. The CIC associated with each station/platform shall each have a Simple Network Management Protocol (SNMP) manageable UPS, and shall have an SNMP manageable thermostat capable of monitoring temperature and humidity inside the CIC.

D. Contractor shall submit plan for powering all Communications System components to the Engineer for approval as part of the System Design.

E. The power supply for all systems components shall be able to be readily disconnected during system maintenance or repair without any risk, and shall not cause disruption to other system components.

2.05 RELIABILITY AND AVAILABILITY
A. Contractor shall design, provide, install, and commission the Communications System as a reliable, available and maintainable system.

B. Reliability and availability of the Communications System shall be calculated by Contractor.
   1. The calculations shall demonstrate that the Communications System reliability and availability shall be 99.9% for the CTS.
   2. Reliability and availability calculations shall be based upon a period of 15 years.

C. Any item furnished as part of the Work shall be considered a system element.
   1. A system element shall be hardware or software.
   2. Examples of system elements are a CTS Backbone switch, a length of fiber optic cable, and a distribution frame.

D. Any circuit that is operated with a parallel circuit to which the application will be transferred upon failure of the circuit is considered to be a redundant circuit. Any circuit that is operated with at least one system element that is a single point of failure is considered to be a non-redundant circuit.
   1. All data, voice, and video communications between the C&S and each station shall be via the CTS, as described in Section 272100.
   2. The CTS shall be a redundant highly available systemwide backbone communications network.
      a. There shall be no single point of failure in the CTS;
      b. The CTS shall meet availability requirements as specified herein.

E. When a system element experiences a cessation of the ability to perform a specific function or functions that are necessary for the proper operation of any circuit using that element, that system element has experienced a failure. A failure is a condition that is beyond the adjustment of controls available to the system’s user during normal operation.

F. For the purposes of the Communications System, Mean Time Between Failures (MTBF) shall be the predicted average time between failures of a population of specific system elements.
   1. Applicable standards include MIL-HDBK 718 and Telcordia GR-332.
   2. Contractor shall state the MTBF for every population of specific elements.
3. Contractor shall present data that justifies its MTBF figure for each population.

G. For purposes of the Communications System, Mean Time to Repair (MTTR) shall be the predicted average time during which a population of system elements with detected failures can be repaired.
   1. MTTR includes diagnosis and physical repair time.
   2. Contractor shall state the MTTR for every population of specific elements. Contractor shall present data that justifies the MTTR figure for each population.

H. For purposes of the Communications System, Mean Logistical Delay Time (MLDT) shall be the predicted average time between detection of a system element failure and the initiation of repair.
   1. Contractor shall coordinate with the Engineer and METRO to obtain MLDT figures to use in Contractor's calculation.

I. Contractor shall convert the MBTF for each system element into reliability estimates.
   1. System element reliability is fifteen years divided by that element's MTBF, expressed as a percentage.

J. Contractor shall convert the MTBFs, MTTRs, and MLDTs for each system element into availability estimates.
   1. System element availability is MTBF divided by the sum of its MTBF, MTTR, and MLDT, described as a percentage.

K. Contractor shall identify each unique type of circuit in the system and estimate its network reliability and availability.
   1. Circuit uniqueness shall be based on both the type and quantity of network elements.
   2. Contractor shall estimate the Communications System reliability and availability estimates using standard probability theory for independent serial and parallel failure events.

2.06 SOFTWARE REQUIREMENTS

A. Software Definition
   1. Forms of Software Defined – Software may exist in multiple forms. For purposes of the Contract, all of the following shall be considered software:
      a. Source code in both electronic and printed form.
b. Run-time executable image files.

c. Object and support libraries in all forms and formats.

d. Configuration data in all forms and formats.

e. All types of documentation associated with the above in all forms, including, but not limited to, listings, manuals, design documentation, etc.

2. Types of Software Defined – Software may be of various types. For purposes of the Contract, all software shall be of one of the following types:

a. Platforms – Platform software is basic software that is utilized as the foundation upon which the remainder of the system is built. Platform software consists of, but is not limited to, the following:

   1) Operating system elements and extensions;
   2) Support libraries;
   3) System services.

b. Tools – Software tools are used to develop, configure or otherwise manage software applications. Software tools consist of, but are not limited to, the following:

   1) System management software;
   2) Language compilers and linkers;
   3) Support utilities;
   4) Revision control system;
   5) Configuration editor;
   6) Debuggers;
   7) Diagnostic tools.

c. Applications – Application software is used to perform or enable the efficient performance of functions that produce specific features and behaviors in the target system. Application software consists of, but is not limited to, the following:

   1) Frameworks – Frameworks are packaged control-system programs that provide a self-contained set of standardized features and functions that enable efficient data acquisition, data management and data presentation. These programs can easily be made to meet the control requirements of an application
through simple configuration and not through software code development or modification.

2) Database Managers – Database managers are programs that provide target features and functions primarily through manipulation of various stored data elements.

3) Specific Functions – Specific function software are programs that are developed to meet one or more specific functions to satisfy the various requirements of the Contract.

4) Stock Functions – Stock function programs are programs that are not specifically developed for this Contract, but provide a specific function within the Communications System, such as e-mail, word processing, spreadsheets, browsers, etc.

5) Data – Data software consists of all remaining information regardless of form that is required to configure, manage, operate or otherwise utilize the system. Data software consists of, but is not limited to, the following:
   a) Configuration data, such as network planning, traffic routing, load balancing, etc. for the Network Management System (NMS) as described in Section 272100.
   b) Tabling data, such as bit assignments that define field device behavior.
   c) Command files, such as startup/shutdown scripts.

3. Classifications of Software Defined – Software may be of various classifications. For purposes of the Contract, all software shall be of one of the following types:
   a. COTS
      1) Software shall be considered COTS if it is in whole or part a standardized package or platform regularly used for the deployment of specific applications. This definition includes service-proven proprietary products that might already have been developed and are owned by Contractor. Such products shall have a distinct life-cycle that provides new and improved, compatible releases over time, shall currently be supported by Contractor, shall be expected to be supported by Contractor over the next eight years,
and shall have a significant and suitable installed base, as determined by the Engineer.

2) To meet the test for COTS, Contractor shall, upon request, supply an affidavit from the manufacturer indicating that the software meets these requirements.

b. Semi-custom – Semi-custom software is software developed in the past for similar projects and modified or extended specifically for this project. Software shall be considered semi-custom if any modifications are implemented to COTS source code. To be considered semi-custom (as opposed to custom), such modifications cannot exceed fifty percent of the total sum of the software.

c. Custom – Custom software is software developed specifically for this project. All project-specific configuration data is included in this category.

B. Communications System Software Coding Standards

1. Software that is poorly structured and documented is not acceptable.

2. All custom and semi-custom software shall be developed in accordance with the accepted software coding standards defined herein.

3. All custom and semi-custom software shall be written in an industry standard high level language.

4. The application shall be fully commented and documented and shall conform to generally accepted standards of excellence within the industry.

5. The networking system software shall satisfy Open System Interconnect (OSI) requirements and utilize industry-standard physical level and link level communications protocols.

6. Each and every function/method in any resultant source code shall include a comment header block.

   a. The header block shall contain, at a minimum, documentation of the function/method’s purpose, and an explicit list of all inputs to and outputs from the procedure.

C. Software Standards and Design Documentation

1. It is anticipated that the Communications System may be comprised of all of the various forms, types and classifications of software previously defined and shall be in the English language.
2. All custom and semi-custom software products shall be designed and implemented in accordance with the standards specified in the IEEE STD 1016 and 730 and MIL-STD-882.

3. All custom and semi-custom software source code shall be provided to METRO and/or entered into an escrow account during execution of the Contract.

4. Contractor shall submit a Software Configuration Management Plan (SCMP) and a Software Quality Assurance Plan (SQAP) as described elsewhere in this Section.

D. Communications System Software Utilization

1. Contractor shall provide all necessary tools, compilers, utilities and other software to allow METRO to reconfigure, extend or otherwise modify custom or semi-custom software as described herein.
   a. Contractor shall clearly indicate the manner in which software shall be modified to make changes in the future.
   b. The system software shall allow for easy expansion or modification of system elements over time.
   c. The system software shall be provided with secure access to Communications systems within the C&S and at the OCC/ROC. Each user at the OCC/ROC or within the C&S shall be required to log on to the system prior to performing any Communications functions. System access shall be verified based upon user profile.
   d. All necessary tools, licenses, manuals, and documentation (paper and electronic form as specified by the Engineer), as well as any and all other information required to operate, maintain and extend the system in the future, by METRO or by Others, shall be provided.
   e. None of the software tools, licenses, manuals, and documentation, or METRO’s use thereof for the Communications System or otherwise will infringe any intellectual property or other rights of any third party.

E. The Contractor shall submit a Software Configuration Management Plan (SCMP). The SCMP shall be developed in accordance IEEE STD 1058.

1. The Contractor shall identify all pertinent software items to be managed and compile the items into a Software Configuration Items List (SCIL). The SCIL shall be subject to the review and approval of the Engineer.

2. The Contractor shall develop the procedures for software configuration management including SCIL management; software
version control; software change control and software build management.

3. The SCMP shall define the software configuration management procedures and guidelines for establishing, controlling, and maintaining the software development environment.

4. The SCMP shall define the processes for release of software to the field. Software releases shall be documented in a Software Version Description Document.
   a. The Software Version Description Document shall be developed and submitted with each release of new and/or modified software to the field, including COTS, Standard and non-COTS software.
   b. The Software Version Description Document shall describe the purpose of the software release, description of the modified/new/deleted software, release numbers and parameters that may need updated to make the new software operable.

5. The SCMP shall include the following:
   a. Definition of the software configuration management procedures.
   b. Guidelines for the use of the configuration management/version control tool as well as the procedures for controlling the files during development. These guidelines shall address the structure of working directories, impose limitations on multiple program copies, and identify the criteria for retrieving and storing versions to control.
   c. The Contractor’s approach to managing all software items documented in the SCIL.
   d. Methods and facilities used to maintain, store, secure and document controlled versions of the identified software developed as well as externally acquired COTS products.
   e. Content requirements, format and the approval cycle of configuration management reports shall be included in the SCMP. Report formats shall be consistent and tool-independent.
   f. Description of the content of the Software Change Report and the frequency of generation of the report.

6. The Contractor shall document modifications to software design artifacts subsequent to the completion of the final design phase within a Software Change Report. The Software Change Report shall be kept current, reflecting all agreed upon changes to the
baselined software design artifacts. The content of the Software Change Report shall include the following:

a. Changes to baselined software requirements (e.g. changes to the Software Requirements Specification).

b. Changes to baselined software design (e.g. changes to the Software Design Document, which includes database documentation and the Interface Design Document).

c. Changes to baselined code.

d. Changes to baselined databases.

e. Revisions to COTS products.

F. The Contractor shall submit a Software Quality Assurance Plan (SQAP). The SQAP shall conform to IEEE STD 730 and IEEE STD 730.1.

1. The Contractor shall develop and document the approach for performing effective software quality assurance and for identifying individuals responsible for performing Software Quality Assurance activities in an SQAP. The SQAP shall be applicable to all software and firmware developed specifically for the Communications Systems provided in response to the Specifications.

2. The SQAP shall address both scheduled and unscheduled audits of software development processes, by the Contractor’s internal Quality Assurance organization, and shall include a process for resolution/tracking of any defects identified by this audit. The SQAP shall describe how the results of internal development reviews and audits are recorded and resolved.

3. The SQAP shall describe how non-conformance is identified and the methods that are used for tracking and resolving non-conformance issues. Note that non-conformances shall include software development process problems, as well as software product anomalies.

4. The SQAP shall include the plan for reporting the Contractor’s and Subcontractor’s software quality assurance activities. Software quality assurance activities shall include software process compliance evaluations and software product reviews. Contractor shall ensure that the SQAP will be adopted and followed by the Subcontractor.

2.07 DESIGN DEFINITION DOCUMENT

A. Contractor shall prepare a Design Definition Document. This document shall include text and drawings and shall state Contractor’s understanding
of the requirements of the Contract Documents. The Design Definition Document shall include, but not be limited to the following:

1. Design approach for the Communications System and subsystems.
2. Overall Communications System layout and design philosophy, total system functional description, system overview and conceptual designs, and system interfaces. The Design Definition Document shall demonstrate that all requirements of the Contract Documents will be met.
3. Reliability and Availability: Provide estimates for Mean Time Between Failure (MTBF), Mean Time To Repair (MTTR), and first year failure rates for all major communications system elements.

2.08 DESIGN REVIEWS

A. There shall be two formal design review meetings prior to the Engineer's acceptance of the final design of the Communications System. The required design reviews are:

1. Preliminary Design Review.
2. Final Design Review.

B. Each design review has a purpose, with specific documents and issues that are to be reviewed, resolved, and approved before proceeding to the next step.

C. Before each design review meeting, the following shall be distributed by the Contractor to the reviewers at least 21 days before the meeting:

1. Date, time, and place of meeting.
2. List of invited attendees.
3. Agenda listing purpose of the meeting, objectives to be achieved, and items to be discussed.
4. Submittals pertaining to the design review.
5. List of any open items to be discussed from previous meeting.

D. Contractor's Systems Assurance organization shall participate in all design reviews.

E. Design review meetings shall be included in the Project Schedule.

F. The Engineer will publish minutes of the design review meetings.

2.09 PRELIMINARY DESIGN REVIEW (PDR)
A. The purpose of the PDR is to:
   1. Assess the progress, consistency, and technical adequacy of the design.
   2. Check the compatibility of the design with functional and performance requirements.
   3. Verify the compatibility of the interfaces between the software, hardware, and final product.

B. The following submittals shall be distributed before the PDR:
   2. Integration Plan.
   4. Labeling Definitions Table.
   5. Complete listing and samples of CAD standards and sample documentation format.
   6. Most recent update of the Project Schedule.
   7. The SQAP and SCMP, as specified herein.
   8. Integration Plan.
   11. Inspection and Test Plan. Refer to Section 279000.
   12. Reliability and availability estimates.
   13. SCADA Point Chart as described in Section 284600.
   14. Design documents for each subsystem developed to the preliminary level of completion. Preliminary level shall mean that all major design decisions are made. The design documents shall include, but not be limited to:
      a. System concept of operation;
      b. System functional requirements;
      c. System major components;
      d. System interfaces diagram;
      e. System interfaces requirements with existing and new systems;
      f. System power requirements;
      g. System quality requirements;
h. System support and maintenance requirements;
i. System Design;
j. Product Data, Shop Drawings and specifications;
k. Functional Site Block Diagram;
l. Arrangement Plans;
m. Installation Plan;
n. Wiring Plan;
o. Power Wiring Plan;
p. Software and Firmware Plan;
q. Allocation and Provisioning Plan.

15. The report associated with the existing radio coverage test for the Phase 2 LRT Extension Project as specified in Section 277000.


C. Contractor is encouraged to submit PDR information incrementally to reduce the duration of the formal meeting. Ideally, the formal PDR meeting should be limited confirmation of previously reviewed, commented on, and approved-in-principle submittals and resolution of open items.

D. At the PDR, the following issues shall be discussed:

1. Contractor’s understanding of the design requirements.
2. Contractor’s familiarity with the existing Communications System, backbone cabling, related systems, and maintenance environment of METRO.
3. Contractor’s strategies, process and schedule that shall be used to develop and implement the design.
4. Site conditions.
5. Contractor’s proposed Quality Assurance Program.
6. Information needs and decisions required.
7. Identify all integration issues to be resolved at the earliest possible opportunity.
8. Overall system design and operation.
9. Hardware components to be supplied under the Contract.
10. System interfaces, both internal and external.
11. How design meets requirements for installation, reliability, availability, and maintainability.
12. Training program, including training materials, facilities, products, classes, and schedule.

13. Special tools and test equipment.


15. Information needs and decisions required.

2.10 FINAL DESIGN REVIEW (FDR)

A. The purpose of the FDR is to verify that the detailed design meets performance and functional requirements before implementation.

B. The following submittals shall be distributed before the FDR. Each submittal shall be developed to the 100 percent level and shall include mechanical and electrical details.

1. Final Integration Plan.
2. Final Staging, Commissioning, and Closeout Plan.
3. Parts List.
4. Final Inspection and Test Plan.
5. Final reliability and availability estimates, verified by Contractor.
6. Final design documents for each subsystem:
   a. System design.
   b. Product Data, Shop Drawings, and specifications.
   c. Functional Site Block Diagrams.
   d. Arrangement Plans.
   e. Installation Plan.
   f. Wiring Plan.
   g. Power Wiring Plan.
   h. Software and Firmware Plan
   i. Allocation and Provisioning Plan.

C. Contractor is encouraged to submit FDR information incrementally to reduce the duration of the formal meeting.

D. At the FDR, the following issues shall be discussed and demonstrated:

1. Complete system satisfies the performance and design requirements.
2. Interfacing to internal and external systems meets requirements.
3. System maintenance, the effects of system maintenance on hardware and software components, and the role of METRO maintenance personnel.

4. Plan for conducting system integration tests.

5. Plan for providing system support.

6. Impact of design decisions on the Project Schedule.

7. Information needs and decisions required.

2.11 POST-FDR CHANGE CONTROL

A. After completing the FDR, system design shall be frozen.

1. From this point on, engineering change control procedures shall be in effect.

2.12 PARTS LIST

A. Contractor shall submit a preliminary parts list at PDR, and a final parts list at FDR, for all equipment furnished under the Contract.

1. The parts list shall also include replaceable components, circuit boards, assemblies, consumable items, meters and instruments, electrical fittings, nameplates, tags and all comparable items.

B. The parts list shall contain component name, drawing reference, description, rating, accuracy class, tolerance, part number, supplier or source and any other essential data.

C. The parts list shall be provided in a matrix form that shows the quantity of each item used at each location.

D. This matrix shall be the basis of the Recommended Spare Parts List.

PART 3 : EXECUTION

3.01 EQUIPMENT INSTALLATION REQUIREMENTS

A. Contractor shall be responsible for all engineering and support services and furnishing all elements of the Communications System, as presented in the Contract Documents.

B. Contractor shall consult the Contract Drawings, for locations of the equipment.
1. If exact location is not given, information shall be obtained from the Engineer prior to installation. Measurements shall be verified in the field.

C. It is the responsibility of the Contractor to find and designate the space required to house all elements of the Communications System.
   1. Contractor shall include as part of the Arrangement Plan and Installation Plan its proposal for allocating space required.

D. Components and equipment shall be installed to provide the maximum possible headroom where mounting heights or other location criteria are not indicated.

E. Items shall be installed level, plumb, parallel, and perpendicular to other building systems and components except where otherwise indicated.

F. Equipment shall be installed to facilitate service, maintenance, and repair or replacement of components.
   1. Connections shall be made for ease of disconnecting, with minimum interference with other installations.

G. Contractor shall obtain Engineer’s approval before relocating any raceways or piping systems installed by others.

H. Contractor shall permanently label all equipment including, but not limited to the following:
   1. Equipment Cabinets.
   2. Equipment interfaces.
   3. Equipment displays.
   4. Cable connections.
   5. Cable ladder racks.

I. Contractor shall provide copies of a table of symbolic or index labeling definitions used at each site.
   1. For each site, one copy shall be mounted on each cabinet, rack, or standalone piece of equipment and one shall be provided to the Engineer.

J. Contractor shall seal all openings in conduits, ducts, equipment rooms, enclosures and junction boxes where cables enter.
   1. A resilient sealing compound made expressly for this purpose shall be installed after the cables are in place.
K. Work shall present a neat and coordinated appearance.

3.02 BASIC ELECTRICAL MATERIALS AND METHODS

A. Communications System equipment installation shall be coordinated with other components in the C&S.

B. Chases, slots and openings in C&S structure shall be arranged during progress of construction to allow for electrical installations.

C. Contractor shall coordinate installation requiring supporting devices and set sleeves in other structural components as they are constructed.

D. Contractor shall sequence, coordinate and integrate installing electrical materials and equipment for efficient flow of the Work.
   1. Installing large equipment requiring positioning shall be coordinated prior to installation.

E. Contractor shall coordinate connecting electrical service to components furnished under other Sections.

F. Contractor shall coordinate connecting electrical systems with exterior utilities and services and shall comply with requirements of governing regulations, franchised service companies and controlling agencies.

G. Contractor shall coordinate requirements for access panels and doors where electrical items requiring access are concealed by finished surfaces.

H. Contractor shall coordinate installing electrical identification after completion of finishing where identification is applied to field-finished surfaces.

3.03 ELECTRICAL SUPPORTING METHODS

A. Contractor shall conform to manufacturer's recommendations for selecting supports.

B. Strength of Supports
   1. Adequate to carry all present and future loads times a safety factor of at least four.
   2. The minimum design load shall be 90 kg (200 lb).

3.04 ELECTRICAL INSTALLATION
A. Raceway Supports

1. Contractor shall comply with NFPA 70 and NFPA 130 and the following requirements:
   a. Conform to manufacturer’s recommendations for selecting and installing supports.
   b. Install individual and multiple raceway hangers and riser clamps to support raceways.
   c. Provide U bolts, clamps, attachments, and other hardware necessary for hanger assembly and for securing hanger rods and conduits.
   d. Support parallel runs of horizontal raceways together on trapeze or bracket-type hangers.
   e. Spare Capacity
      1) Supports for multiple conduits shall be sized so capacity can be increased by a 25 percent minimum in the future.
   f. Support individual horizontal raceways with separate, malleable iron pipe hangers or clamps.
   g. Hanger Rods
      1) Provide 9.5 mm (3/8 inch) diameter or larger threaded steel rods.
   h. In vertical runs, arrange support so the load produced by the weight of the raceway and the enclosed conductors is carried entirely by the conduit supports, with no weight load on raceway terminals.

B. Miscellaneous Supports

1. Metal channel racks shall be installed for mounting cabinets, pull boxes, junction boxes, and other devices except where components are mounted directly to structural features of adequate strength.
2. In open overhead spaces, cast boxes threaded to raceways need not be independently supported, except where used for fixture support; sheet-metal boxes shall be supported directly from the building structure or by bar hangers.
   a. Where bar hangers are used, the bar shall be attached to raceways on opposite sides of the box and the raceway shall be supported with an approved fastener not more than 610 mm (24 inches) from the box.
C. **Sleeves**

1. Contractor shall install sleeves for cable and raceway penetrations of walls, except where core-drilled holes are used.

2. Sleeves shall be installed for cable and raceway penetrations of masonry and fire-rated gypsum walls and of all other fire-rated floor and wall assemblies.

3. Sleeves shall be installed during erection of concrete and masonry walls.

D. **Firestopping**

1. Firestopping shall be applied to cable and raceway penetrations of fire-rated floor and wall assemblies.

2. Firestopping shall be applied to cable and raceway penetrations of the Communications Interface Cabinet (CIC) as specified in Section 271100.

E. **Fastening**

1. Unless otherwise indicated, electrical items and their supporting hardware shall be secure if fastened to the building structure.

2. Fastening shall be performed according to the following:
   a. Fasten by means of wood screws or screw-type nails on wood, toggle bolts on hollow masonry units, concrete inserts or expansion bolts on concrete or solid masonry, and by machine screws, welded threaded studs, or spring-tension clamps on steel.
   b. Threaded studs driven by a powder charge and provided with lock washers and nuts may be used instead of expansion bolts, machine screws, or wood screws.
   c. In partitions of light steel construction, sheet-metal screws shall be used.
   d. Fasteners shall be selected so the load applied to any fastener does not exceed 25 percent of the proof-test load.

### 3.05 PAINTING

A. Contractor shall follow paint manufacturer’s written instructions for surface preparation and for timing and application of successive coats.

B. All exposed electrical equipment, conduit, and fittings shall be painted to match background.
C. No paint shall be applied on wet, damp, frosted or dirty surfaces, or when the temperature is below 12 degrees C (54 degrees F) or when in the opinion of the Engineer conditions are otherwise unsuitable for painting.

D. Surfaces required to be painted that will be inaccessible after installation or erection shall be given two additional coats of paint before installation or erection.

E. If any painted surface is damaged prior to the completion of the Work under this Contract, such damaged surface shall be cleaned, touched-up or completely repainted by Contractor without additional compensation.

F. Contractor shall furnish 3.75 liters (1 gallon) of touch up paint for each finish color at the end of the Work.

3.06 STAGING

A. Installation of Communications System equipment in existing equipment rooms and facilities shall be staged in a manner that minimizes disruption to the use of the room and provides for keeping existing equipment in service as long as necessary.

B. Where sufficient space is not available for new cabinets, Contractor shall arrange for moving existing racks and cabinets to temporary locations, keeping all equipment in service.

1. New cabinets shall then be installed in their permanent locations.
2. New equipment shall then be installed on the new cabinets.
3. Existing equipment that is not being replaced shall then be moved to the new Cabinets.
4. Contractor shall make proper arrangements for taking systems out of service as necessary to complete moves.
5. Old racks and cabinets, and replaced equipment shall be removed once the corresponding system is tested and placed in service.

C. Contractor shall submit for approval to the Engineer a fully detailed Staging, Commissioning, and Closeout Plan for all communications equipment, which shall identify:

1. All proposed equipment installations, equipment relocations, and all proposed changes to existing equipment rooms.
2. All Work that could possibly affect METRO operations.
3. All Work that could affect or be affected by the Work of other Contracts.
D.  All Work performed under this Contract shall be performed according to the approved Staging, Commissioning, and Closeout Plan.

E.  METRO shall be given the option of retaining any electronic equipment that is removed from service under this Contract.

1.  Contractor shall coordinate with the Engineer to determine what equipment is to be retained by METRO.

2.  All equipment removed from service that is not retained by METRO shall be removed from the property and properly disposed of by Contractor.

END OF SECTION
SECTION 270500

COMMON WORK RESULTS FOR COMMUNICATIONS

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section provides an overview of technical requirements, engineering guidelines, technical constraints, and general conditions to be followed by the Contractor throughout the design, furnishing, installing, and commissioning of all Communication elements associated with the Houston METRO Light Rail Transit Expansion (LRT) project.

B. The Contractor shall be responsible for completing an expansion of the existing communications system that performs as intended, is easy to operate and maintain, and includes inherent protection against certain deleterious ambient conditions that are anticipated in a railroad environment. The Contractor shall bear total responsibility for system elements that are provided installed, tested and commissioned under this contract.

C. Technical requirements specific to each communication subsystem shall be found in each of the corresponding subsystem Specification Sections.

1.02 QUALITY ASSURANCE

A. Applicable Standards and Codes

1. The Contractor’s design and installation shall comply with all applicable Standards and Codes as listed herein.

B. Material and Workmanship Requirements

1. All equipment and material provided under this section shall be UL listed.

2. All products specified in this Contract shall be subject to Engineer’s approval based on the Contractor’s ability to demonstrate adherence to the specified requirements and approval of the manufacturer’s quality process.

3. All grounding shall be in accordance with the NEC (National Electric Code), local standards, and specifications required by this Contract except as modified herein. Each piece of equipment shall
be grounded in accordance with the recommendations of the manufacturer.

4. Discontinued product models, refurbished equipment, products at their end-of-life, or end-of-service shall not be used.

1.03 CITED REFERENCES

<table>
<thead>
<tr>
<th>Organization</th>
<th>Spec Number</th>
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<tr>
<td>US Federal Government</td>
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<td>Military Standards</td>
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<tr>
<td>Telecommunications Industry Association</td>
<td>TIA/EIA-606-B</td>
<td>Administration Standards for Commercial Telecommunications Infrastructure</td>
</tr>
<tr>
<td>NFPA</td>
<td>NFPA 70</td>
<td>National Electric Code (NEC)</td>
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1.04 SUBMITTALS

A. As required by Section 270000, “Communications”.

B. The design proposed by the Contractor shall be subject to Engineer's approval. Engineer may disapprove the proposed design if it fails in any way to achieve the result intended by the requirements of these Specifications or is not in accordance with sound engineering principals. If the design or any portion of the design is disapproved by the Engineer, the Contractor shall revise the design until it meets with Engineer's approval in accordance with these Specifications.

C. No Engineer's approval or disapproval, or failure to approve or disapprove shall relieve the Contractor of any responsibilities under this Contract, including the responsibility to provide a sound and practicable system design, suited for the intended purpose outlined in these Specifications.

D. Where requirements posed by individual subsystems, as defined in other sections of these Specifications, are different or greater than those
specified in this subsection, those other requirements shall be deemed to augment the requirements specified herein.

E. Installation Work Plans and Detailed Documentation

1. As required by Section 270000, “Communications”.

2. The submittals required by Section 27000 shall include, as a minimum, the following information pertaining to Common Work Results for Communications (and related subsections):

   a. Cable and conduit schedules shall show exactly where each cable is to be installed. Include and identify raceways, cable trays, conduit, junction boxes, manholes, handholes, and floor boxes.

   b. Names and labels for all equipment shall include every wire, cable, connector, terminal and rack.

   c. Mounting, securing, and installation details shall be shown for all equipment and materials.

   d. All grounding related information, including grounding grids/rods, grounding busbars, and grounding connections shall be clearly shown for all communications equipment.

   e. Clearly indicate the location of all safety and hazard warning signs and labels.

F. Testing and Inspection

1. As Required by Section 279000, “Communications System Inspection and Testing”.

1.05 RELATED WORK

A. Section 270000 - Communications Systems

B. Section 270526 - Grounding and Bonding for Communications Systems

C. Section 270528 - Pathways for Communications Systems

D. Section 270543 - Underground Ducts and Raceways for Communications Systems

E. Section 270553 - Identification for Communications Systems

F. Section 272100 - Data Communications Network Equipment

G. Section 273100 - Voice Communications Switching Equipment

H. Section 273200 - Telephone Equipment
I. Section 275100 - Public Address/Passenger Information Signs System
J. Section 277000 - Radio and Wifi Systems Equipment
K. Section 278000 - Uninterruptible Power Supply
L. Section 279000 - Communications Systems Inspection and Testing
M. Section 282300 - Video Surveillance System
N. Section 284600 - SCADA

1.06 PROJECT CONDITIONS
A. Not Applicable.

1.07 WARRANTY
A. Contractor shall provide warranty for all applicable products.

1.08 COMMISSIONING
A. The Contractor shall deliver materials in manufacturer’s original, unopened, protective packaging.

B. The Contractor shall replace damaged materials and equipment, as determined by the Engineer, at no additional cost to METRO.

PART 2 - PRODUCTS
A. NOT USED.

PART 3 - EXECUTION
3.01 INSTALLATION AND GENERAL DESIGN REQUIREMENTS
A. Information regarding METRO Facilities and space in METRO Facilities is provided in the Contract Drawings.

B. Environmental conditions to which equipment shall be designed is defined in Section 270000, “Communications”.

C. Operations and Maintenance
1. Operating and maintenance safety shall be the highest consideration in equipment and subsystem design, construction, and installation.

2. Human Factors for both operation and maintenance, equipment configuration and positioning shall:
   a. Support the reach and view of a person sized to the 5th percentile female, as defined in MIL-STD-1472.
   b. Fit person the size of the 95th percentile male, as defined in MIL-STD-1472.
   c. User interface equipment and characteristics such as display devices, preferred viewing angles, lettering, control devices and their tactile characteristics, indicators, use of colors, and use of audible indicators shall be consistent with MIL-STD-1472.

3. Where applicable, equipment and design shall comply with all ADA requirements.

D. Continued Operation of the Existing METRO Light Rail System

1. During revenue or non-revenue service hours, any disruption to the existing Communications and Central Control Systems shall be minimized.

2. Track access time is limited and shall be coordinated and approved through METRO’s track allocation process. The Contractor shall follow all METRO’s rules for access to and working in any rail operating territory.

3. Any work that could potentially interfere with the operating system shall be coordinated and pre-approved through METRO’s track allocation request process. The Contractor shall follow all METRO’s rules for access to and working in any rail operating territory.

3.02 TESTING AND INSPECTION

A. As required by Section 279000, “Communications Systems Inspection and Testing”.

B. METRO/HRT reserves the right to:
   1. Witness any and all tests and inspections required by these Specifications.
   2. Inspect test records at any time.
3. Perform additional testing, beyond that specified herein, of any equipment or material at any time to determine conformance with these Specifications. Additional METRO/HRT testing is not to be considered as a replacement for any Contractor required testing.

C. The Contractor shall verify the accuracy of the as-built documentation for each equipment location.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. The Work specified in this Section will not be measured separately for payment.

B. All costs connected herewith shall be considered incidental to the Work specified under Section 270000, “Communications.”

END OF SECTION
SECTION 270526

GROUNDING AND BONDING FOR COMMUNICATIONS SYSTEMS

PART 1 - GENERAL

1.01 DESCRIPTION

A. The Work of this Section consists of designing, furnishing, installing, testing, and commissioning the Grounding and Bonding for all communications system elements associated with the Houston METRO Solution Phase 2 Light Rail Transit (LRT) Extension project.

B. The Bonding and Grounding System shall provide for safety and signal noise protection by ensuring high quality, low resistance to ground connections for all communications related equipment. Note that the equipment and requirements included in this section is not intended be part of the overall LRT Corrosion Control System.

C. The Grounding and Bonding System shall include grounding rods, wire, lugs, and connectors to be provided at locations including, but not limited to, the following:
   1. Communications and Signal House (C&S).
   2. Operations Control Center (OCC) and Rail Operations Center (ROC).
   3. Passenger Stations.
   4. All communication equipment chassis, racks, enclosures, cable trays, Protected Terminal Blocks (PTBs), Main Distribution Frames (MDFs).

D. The Grounding and Bonding equipment described in this Section includes the following:
   1. Facility Lightening Protection;
   2. Facility Surge Protection;
   3. Ground Rods;
   4. Exothermic Welds;
   5. Ground Grid Conductors and Connectors;
   6. Ground Electrode Conductors;
   7. Chassis and Telecommunications Grounding Busbars;
8. Terminal Lugs, Ground Connectors, and Jumpers;
9. Coal Tar Epoxy and Epoxy Resin Encapsulation;
10. Communications and Signal House (C&S) Halo Ground Ring;

E. Requirements for communications cables, connections, and ancillary equipment are described in Section 271500, “Communications Horizontal Cabling” and its subsections.

1.02 QUALITY ASSURANCE

A. Contractor’s design, fabrication, inspection, installation and testing shall comply with all applicable Standards and Codes as listed herein. All equipment and methods shall comply with the latest version of the standards as applicable in paragraph 1.03 in this Section.

B. Material and Workmanship Requirements
   1. All equipment and material provided under this section shall be UL listed.
   2. All grounding shall be in accordance with NEC (National Electric Code), local standards, and specifications required by this Contract except as modified herein. Each piece of equipment shall be grounded in accordance with the recommendations of the manufacturer.
   3. Discontinued product models, refurbished equipment, products at their end-of-life, or end-of-service shall not be used.
   4. All products specified herein shall be subject to Engineer approval based on the Contractor’s ability to demonstrate adherence to the specified requirement and approval of the manufacturer’s quality process.

1.03 CITED REFERENCES

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<th>Organization</th>
<th>Spec Number</th>
<th>Title</th>
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<tr>
<td>ASTM</td>
<td>A666</td>
<td>Standard Specification for Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar.</td>
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<td>Organization</td>
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<td>NFPA</td>
<td>NFPA 780</td>
<td>Standard for Installation of Lightning Protection Systems.</td>
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<tr>
<td>TIA/EIA</td>
<td>J-STD-697-A</td>
<td>Commercial Building Grounding (Earthing) and Bonding Requirements for Telecommunications.</td>
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<tr>
<td>UL</td>
<td>UL 467</td>
<td>Standard for Grounding and Bonding Equipment.</td>
</tr>
</tbody>
</table>
1.04 SUBMITTALS

A. As required in Section 270000, “Communications”, to specifically include:
   1. Installation Plans showing locations of ground rods, connectors, cables, and details of connections, terminations, and access points.

B. As-Built Documentation. Contractor shall submit complete As-Built documentation and drawings for the Grounding and Bonding of all communications systems completed in this Contract.

C. The Contractor shall submit Manufacturer’s technical data sheets and catalog cut sheets for all proposed materials with Manufacturer’s installations recommendations.

D. The Contractor shall submit manufacturer’s warranty information.

1.05 RELATED WORK

A. Section 270000 - Communications Systems
B. Section 270528 - Pathways for Communications Systems
C. Section 270543 - Underground Ducts and Raceways for Communications Systems
D. Section 270553 - Identification for Communications Systems
E. Section 272100 - Data Communications Network Equipment
F. Section 273100 - Voice Communications Switching Equipment
G. Section 273200 - Telephone Equipment
H. Section 275100 - Public Address/Passenger Information Signs System
I. Section 277000 - Radio and WIFI Systems Equipment
J. Section 278000 - Uninterruptible Power Supply
K. Section 279000 - Communications Systems Inspection and Testing
L. Section 282300 - Video Surveillance System
M. Section 284600 - SCADA
1.06 PROJECT CONDITIONS

A. Not Used.

1.07 WARRANTY

A. Contractor shall provide warranty to all applicable products.

1.08 COMMISSIONING

A. The Contractor shall supply and install Grounding and Bonding equipment as shown on the Contract Drawings and as defined herein.

B. The Contractor shall deliver materials in manufacturer’s original, unopened, protective packaging.

C. The Contractor shall replace damaged materials and equipment, as determined by the Engineer, at no additional cost to METRO.

PART 2 - PRODUCTS

2.01 GENERAL DESIGN REQUIREMENTS

A. General Requirements for Grounding and Bonding shall be per UL 467.

B. Facilities Lightning Protection

1. A lightning protection system shall be provided for all outdoor communications equipment and wayside facilities including C&S, Communications Interface Cabinet (CIC), Public Address and Passenger Information Signs (PA/PIS) equipment, Passenger Assistance telephones (PAT), and Internet Protocol Video Camera (IPV). The lightning protection system shall be in accordance with ANSI/NFPA 780, Lightning Protection Code. The lightning protection system shall consist of multiple rooftop/facility/equipment air (lightning) terminals, down conductors, equalizing conductors and ground terminals. This hardware shall surround the communication facilities for the purposes of intercepting, diverting, and dissipating direct lightning strikes.

2. The spacing and interconnection of the lightning protection system with the communication system grounds shall be in accordance with ANSI/NFPA 780. Communication grounds shall be bonded to the lightning protection system grounding within 12 feet of the base of building/platform. Communication conductors shall not be routed
closer than 6 feet from any lightning protection system conductors. The Contractor shall submit an assessment for Lightning Protection System, and bonding requirements as part of an Electromagnetic Interference (EMI) and Electromagnetic Compatibility (EMC) Control and Test Plan to the Engineer.

3. Lightning protection systems and installers shall be certified to the Lightning Protection Institute’s LPI-175 and LPI-176 standards.

C. The C&S grounding system shall connect to TPSS ground grid in the event TPSS site is sufficiently close (within 20 ft) to the C&S.

1. Surge protection. Because the C&S is connected to TPSS ground grid scheme, surge protection is required to prevent the sudden surge from AC ground grid for TPSS system. The providing hardware shall provide for the purposes of intercepting, diverting, and dissipating AC surge strikes.

2.02 GROUND RODS

A. Ground rods shall be copper-clad steel, of a non-rusting type as manufactured by Copperweld Corporation, or an Engineer approved equal. The rod shall be at least 10 feet in length and at least 0.75 inches in diameter.

B. Ground rod clamps shall be made of a cast bronze clamp body with non-ferrous setscrews as manufactured by Copperweld Corporation, or an Engineer approved equivalent.

2.03 EXOTHERMIC WELDS

A. Welding material shall consist of copper exothermic mixture employing tin-metal in an amount to effectively constitute 4.5 to 5.5 percent of the resulting weld. The resulting weld shall be of high conductivity and shall have a minimum tensile strength of 39,000 pounds per square inch (psi).

B. Coating Materials for Thermite Weld Connections shall use black, rubber based compound coating materials, which are soft, permanently pliable, moldable, and unbacked, not less than 1/8 thick, with properties as follows:

1. Solids: 100 percent
2. Density: 12.0 pounds per gallon minimum
3. Penetration: 90-130 ASTM D5
4. Water Absorption: 0.10 percent maximum ASTM D570
5. Dielectric Strength: 500 volts/mil ASTM D570

6. Volume Resistivity: 2,000 megohms-inches ASTM D257, 5,000 megohms-cm ASTM D257.

7. Service Temperature: -40 degrees F to +160 degrees F.

8. Chemical Resistance: Melting point, none; flammability, slow burning (ASTM C653); resists alcohol, water, aqueous hydrochloride and sodium hydroxide; dissolved by carbon tetrachloride, naptha gasoline, mineral spirits, ketones, and benzene.

9. Material should be highly cohesive and adhere strongly to metals, concrete, and itself.

2.04 GROUND GRID CONDUCTORS

A. No. 2 AWG bare solid tinned copper conductor, or as shown on Contract Drawings.

2.05 GROUND ELECTRODE CONDUCTORS

A. Insulated stranded copper conductor, as shown on Contract Drawings, in accordance with these Specifications, for single-conductor cable, 600 volts.

B. Size unless otherwise shown:

1. For use in connecting ground grid to Chassis Main Grounding Busbars (CMGB) and Telecommunications Grounding Busbar (TMGB) in the C&S: Insulated No. 2 AWG or as shown on drawings.

2. For use in connecting ground grid to Chassis Grounding Busbars (CGB) and Telecommunications Grounding Busbars (TGB): Insulated No. 4 AWG or as shown on drawings.

3. For other grounding electrode conductors: In accordance with NEC Table 250-94.

C. Ground Wire Size unless otherwise shown:

1. For use in connecting ground grid to Communication Main Grounding Busbars (CMGB) and Telecommunications Grounding Busbar (TMGB) in the C&S: Insulated No. 2 AWG or as shown on drawings.

2. For use in connecting ground grid to Chassis Grounding Busbars (CGB) and Telecommunications Grounding Busbars (TGB): Insulated No. 4 AWG or as shown on drawings.
3. For other grounding electrode conductors: In accordance with NEC Table 250-94.

4. Equipment Grounding Conductors: Size in accordance with NEC article 250-95, unless otherwise shown on drawings.

2.06 CHASSIS AND TELECOMMUNICATIONS GROUNDING BUSBARS

A. CGB and TGB are located in the C&S shall each be as follows:
   1. Predrilled electro tin plated copper busbar provided with standard NEMA bolt hole sizing and spacing for the type of connectors to be used.
   2. Sized in accordance with immediate requirements of the application and with 50% spare holes for future growth.
   3. Minimum dimensions shall be ¼ inch thick x 2 inches wide and variable length.

B. Busbar Insulators: Fibrous glass reinforced polyester insulator with ½ inch diameter (min) by 2 inches (nominal) length.

2.07 TERMINAL LUGS

A. For No. 4/0 AWG and smaller conductors, use copper compression terminal lugs.

B. For No. 250 MCM and larger, use long barrel, copper, double-compression terminal lugs.

2.08 GROUND GRID CONNECTOR

A. O-Z Gedney, Type KG or approved equivalent.

B. Two-piece, designed for connecting grounding conductor to bus bar.

C. Copper alloy body and silicon bronze bolt, nut, and washer with interlocking clamp.

D. Exothermic Weld: Size and type per manufacturer’s recommendations.

2.09 JUMPERS

A. Jumpers shall be insulated copper braided leaf-type flexible jumper, sized as required by NEC.
2.10 COAL TAR EPOXY

A. Polyamide cured coal tar epoxy, DuPont Corlar 823 CTE, Koppers Company No. 300M, PPG Industries 97-640 or 97-641, or approved equivalent, applied to a dry film thickness of 8 mils. per coat.

2.11 EPOXY RESIN ENCAPSULATION

A. Two-component epoxy resin type with plastic snap mold, as manufactured by Duriron Company, 3-M Company, or approved equivalent.

2.12 COMMUNICATIONS CIRCUIT PROTECTION

A. Copper signal cables shall enter the C&S, Operations Control Center (OCC/ROC), and Communications Interface Cabinet (CIC) at a Main Distribution Frame (MDF). All copper signal cables shall terminate on Protected Terminal Blocks (PTBs) located within the MDF, which shall conform to these specifications. Cable sheaths shall be neatly trimmed and fastened to a No. 8 AWG insulated ground conductor and grounded at the TMGB.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Grounding Connections

1. Weld buried ground connections exothermically, in accordance with manufacturer’s recommendations. Clean and coat with coal tar epoxy applied to 32 mils dry film thickness using multiple coats. Allow drying between coats and before backfilling. Encapsulate with epoxy resin all buried ground connection of grounding electrode conductors running to ground buses.

2. Use terminal lug to connect grounding conductor to equipment enclosure. Secure connector or terminal lug to the conductor so as to engage all strands equally using tools and pressure recommended by the manufacturer.

3. Exothermically weld connection for ground rods in manholes and handholes, or as shown on drawings.

4. Splices in grounding conductors are not permitted.

B. Grounding Busbars
1. Install separate Chassis Main Grounding Busbars (CMGB) and Telecommunications Grounding Busbars (TMGB) in each C&S, as necessary at the OCC/ROC, and other locations as shown on Contract Drawings.

2. Mount CMGB and TMGB on insulators 2 feet above finished floor using cap screws and expandable threaded anchors, unless otherwise shown on Contract Drawings.

3. Provide insulator supports at each end of grounding busbars and at intervals not exceeding 3 feet.

4. Bound the grounding electrode conductors to the grounding Busbar using an approved ground connector in accordance with this Section.

C. Grounding for Personnel Safety

1. In the C&S, bond equipment enclosures and racks, ductworks, conduit, metal cable trays, the MDF ground bolt, PTB grounds, and the C&S halo ground ring to the CMGB (or CGB) using a minimum of No. 6 AWG insulated stranded copper conductor or as shown on Contract Drawings.

2. Wayside metal equipment including, but no limited to, cabinets, poles, pullboxes, equipment enclosures, and junction boxes: bond and ground each item using No. 6 AWG (min) copper conductor to one or more ground rods to provide 5 ohms or less resistance to ground. Wayside metal equipment on bridge structure should be attached to the structure using a No. 6 AWG (minimum) copper conductor.

D. Grounding of Separately Derived AC Power System

1. Bond the safety ground conductor (green wire) to the CMGB using a minimum No. 4 AWG insulated stranded copper wire, or as shown on Contract Drawings. For additional guidance refer to the NEC.

E. Electronic Equipment Signal Grounding

1. Where electronic equipment is provided with separate “SIGNAL” or “TELECOMMUNICATIONS” ground connections, a separate isolated TGB shall be provided in the equipment rack or enclosure. These connections shall be grounded to the TGB using a minimum of No. 10 AWG insulated stranded copper conductor.

2. Within the C&S or other communication room, a separate TMGB shall be provided. All individual equipment rack or enclosure TGBs shall be grounded to this TMGB using a No. 8 AWG (minimum) insulated stranded copper conductor.
3. The TMGB shall be grounded to the same point on the ground grid as the CMGB using the same size (AWG) grounding electrode conductor. Both grounding electrode conductors shall be insulated.

F. Cable Shield Grounding
1. One end of all cable shields shall be grounded to the TMGB (or TGB). Use the following guidelines to determine which end of the cable to ground:
   a. When a cable goes between a C&S and any other facility, ground at the C&S.

G. Fiber Optic Cable Jacket Grounding (Armor)
1. Armored jackets on all fiber optic cables shall be grounded to the CMGB or CGB using a minimum if No. 8 AWG insulated stranded copper conductor.

3.02 TESTING AND INSPECTION:
A. In addition to any requirements listed in Section 279000, “Communications System Inspection and Testing”, the contractor shall:
   1. Inspect installation of all main ground busbars for proper mounting.
   2. Test ground resistance of each ground grid after installation and each ground bus when connected to ground grid, using approved test procedure.
   3. Insure resistance to ground for the C&S Halo, CMGB and TMGB shall not to exceed 4 ohms.
   4. If necessary to meet resistance requirements, Contractor shall install additional ground rods. If resistance requirements can still not be met, install a sacrificial anode after obtaining Engineer approval.
   5. Test metal conduits and raceways, equipment enclosures, metal cable troughs, fences, metal structures, and light poles for resistance to ground not to exceed 4 ohms.

END OF SECTION
SECTION 270528

PATHWAYS FOR COMMUNICATIONS SYSTEMS

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Work includes providing complete conduit and raceway systems as shown on Contract Drawings and as specified. Raceways assembled into duct banks shall also meet the requirements of these Specifications.

B. Underground conduits assembled into systems of concrete encased duct banks, stub-ups and stub-outs shall also meet the requirements of Specification Section 270543, Underground Ducts and Raceways for Communication Systems.

1.02 QUALITY ASSURANCE

A. The Contractor shall perform the Work included in this Section in strict accordance with the requirements of the Contractor's Quality Control Program as approved by the Engineer and in compliance with the requirements of these Specifications.

B. The Contractor shall perform the following in accordance with Contractor's Quality Control Program specified in these Specifications.

1. Material qualification testing and certification for acceptance of materials, components, and assemblies.

2. Job control testing of in-progress Work being performed in shops, factories, and on-site.

3. On-site inspection of specified Work elements.

4. Contractor shall provide conduit sized for the Fiber Optic network and all associated cabling, and to accommodate future growth.

1.03 CITED REFERENCES

<table>
<thead>
<tr>
<th>Organization</th>
<th>Spec Number</th>
<th>Title</th>
</tr>
</thead>
</table>


National Electrical Manufacturers Association (NEMA) NEMA C80.1 Galvanized Rigid Steel Conduit (GRSC).

NEMA NEMA C80.3 Electrical Metallic Tubing - Zinc Coated (EMT).

NEMA NEMA RN1 Polyvinyl-Chloride (PVC) Externally Coated Galvanized Rigid Steel Conduit and Intermediate Metal Conduit.

NEMA NEMA TC2 Electrical Polyvinyl Chloride (PVC) Conduit.

NEMA NEMA TC3 Polyvinyl Chloride (PVC) Fittings for Use with Rigid PVC Conduit and Tubing.

NEMA NEMA TC6&8 Polyvinyl Chloride (PVC) Plastic Utilities Duct for Underground Installations.

NFPA NFPA 70 National Electric Code (NEC).

1.04 SUBMITTALS

A. As required by Section 270000, “Communications”, and including information on, as a minimum:

1. Raceways;

2. Fittings;
3. Metallic joint compounds, caulking and sealing compounds;
4. Pull cords;
5. Raceway tags and labels;
6. Conduit mandrels and brushes;
7. Warning tape;
8. PVC Conduit joint cleaning solvent and cement;
9. Conduit end caps and plugs;

B. Mandrel log sheets shall be submitted seven days after completion.

C. Twenty One days prior to installation, submit Shop Drawings representing planned conduit and/or raceway Work for this Specification Section.

D. Submittals for Concrete Encased (CENC) conduits, duct banks and manholes shall be in accordance with Sections 270543, “Underground Ducts and Raceways for Communications Systems” and Section 270000, “Communications”.

1.05 RELATED WORK

A. Section 270000 - Communications Systems

B. Section 270526 - Grounding and Bonding for Communications Systems

C. Section 270543 - Underground Ducts and Raceways for Communications Systems

D. Section 270553 - Identification for Communications Systems

E. Section 272100 - Data Communications Network Equipment

F. Section 273100 - Voice Communications Switching and Routing Equipment

G. Section 273200 - Telephone Equipment

H. Section 275100 - Public Address/Passenger Information Signs System

I. Section 277000 – Radio and Wi-Fi Systems Equipment

J. Section 279000 - Communications System Inspection and Testing
1.06 PROJECT CONDITIONS

A. Not Used.

PART 2 - PRODUCTS

2.01 DEFINITIONS

A. Conduit: Individual electrical raceway.

B. Duct: Assembly of conduit in configurations shown, either concrete encased or not, with or without reinforcement.

C. Raceway: An enclosed channel of metal or nonmetallic materials designed expressly for holding wires, cables, or bus bars.

D. CENC: Concrete Encased.

2.02 GENERAL

A. Prohibited Materials and Methods

1. Extra-flexible, metallic or non-metallic, non-labeled conduit.

2. Plastic conduit for interior electrical use, except that Polyvinyl Chloride (PVC) conduit may be used for power circuits below basement concrete floors and for ground wires in any location. The transition from PVC to steel shall be made below the floor.

3. Steel Conduit shall not be used outside unless in concrete. Use Galvanized Rigid Steel Conduit (GRSC) outside and wet locations above grade.

4. Aluminum conduit or wiring shall not be used.

5. Use of Incompatible Materials:

a. Aluminum fittings and boxes shall not be used with steel conduit.

b. All materials in a raceway system shall be compatible.

c. Dissimilar Metals. All dissimilar metals shall be properly insulated to prevent galvanic action.

d. When bronze and aluminum components come into contact with dissimilar metals, surfaces shall be kept from direct
contact by painting the dissimilar metal with a heavy coat of a proper primer or asphalt paint.

e. When aluminum components come into contact with cement or lime mortar, exposed aluminum surfaces shall be painted with heavy bodied bituminous paint, water-white methacrylate lacquer, or zinc chromate.

f. Fasteners. All exposed fasteners shall be stainless steel.

6. Multi-use Suspension Systems: Piggy-back suspension systems for conduits and fixtures are prohibited. All suspensions shall be hung independently from structure, or, in limited cases, from trapeze suspension systems.

7. Use of wire ties to support conduit.

8. Use of splices to join communications or electrical wiring within ductbanks and raceways.

2.03 CABLE TRAYS

A. See Section 271100, “Communications Equipment Room Fittings” and Section 271123, “Communications Cable Management and Ladder Rack”.

2.04 GALVANIZED RIGID STEEL CONDUIT (GRSC)

A. Conduit shall comply with ANSI C80.1 and shall be hot-dip galvanized inside and out. Threaded ends shall be galvanized using a zinc metalizing process, which sprays or blasts molten or semi-molten zinc on the threaded area. Minimum size shall be 3/4-inch.

B. Approved manufacturers: LTC, Triangle, Allied or Engineer approved equal.

2.05 INTERMEDIATE METAL CONDUIT (IMC)

A. Shall not be used.

2.06 PVC SCHEDULE 40 CONDUIT (PVC)

A. Conduit shall comply with NEMA TC 2, rigid polyvinyl chloride, Schedule 40. Conduit shall be sunlight resistant and suitable for 90 degrees Celsius (C) conductors and exposed locations. Approved manufacturers: Carlon, PW Pipe, Western Plastics or Engineer approved equal.
2.07 PVC SCHEDULE 80 CONDUIT (PVC 80)
A. Conduit shall comply with NEMA TC 2, rigid polyvinyl chloride, Schedule 80. Conduit shall be sunlight resistant and suitable for 90 degrees C conductors and exposed locations.
B. Approved manufacturers: Carlon, PW Pipe, Western Plastics or Engineer approved equal.

2.08 ALUMINUM CONDUIT
A. Shall not be used.

2.09 ELECTRICAL METALLIC TUBING (EMT)
A. Conduit shall comply with ANSI C80.3.
B. Interior exposed, dry locations only, not subject to damage.

2.10 FLEXIBLE METAL CONDUIT
A. Galvanized flexible steel, listed for dry locations. Minimum size shall be 1/2-inch.
B. Liquid tight: Polyvinyl chloride (PVC) weatherproof cover over galvanized flexible steel conduit, listed for damp and wet locations. Minimum size shall be 1/2-inch.

2.11 GRSC CONDUIT FITTINGS
A. Conduit fittings shall be steel or cast malleable iron and shall be hot-dip or mechanically galvanized. Die-cast zinc fittings shall not be used.
B. Bushings and grounding bushings shall have molded phenolic or "Nylon" insulating collars. Grounding bushings shall have a "lay-in" tin-plated copper lug.
C. Expansion fittings for exposed conduit runs shall be weatherproof with external bonding jumper, providing up to 4 inches longitudinal movement with bushed conduit ends. Manufacturers shall reference the product to ANSI, IEEE, UL, NEMA or any other recognized standards or code.
D. Watertight split couplings or 3-piece ('Ericson') couplings shall be O-Z/Gedney, or Engineer approved equal.
E. Running thread or set screw type fittings shall not be used.
F. Lock nuts 2 inches and smaller shall be heavy galvanized steel. Lock nuts larger than 2 inches shall be galvanized malleable iron.

G. Hubs shall be galvanized steel or galvanized malleable iron, with insulating inserts and sealing rings. Hubs shall provide watertight conduit connections to boxes and enclosures.

H. Conduit outlet bodies shall be cast ferrous alloy, with gasketed ferrous alloy cover, hot-dip or mechanically galvanized. Aluminum alloy conduit bodies shall not be acceptable. "Short" conduit bodies such as SLBs shall not be acceptable. Acceptable manufacturers: O-Z/Gedney, Crouse-Hinds, Appleton, or Engineer approved equal.

2.12 PVC CONDUIT FITTINGS

A. Fittings for PVC conduit shall comply with NEMA TC 3. PVC conduit fittings shall be of the same manufacturer and type as the conduit.

B. Expansion fittings shall allow expansion, with the same characteristics as the PVC conduit and be of the same manufacturer. Manufacturers shall reference the product to ANSI, IEEE, UL, NEMA or any other recognized standards or code.

2.13 EMT FITTINGS

A. Fittings for EMT shall be by the same manufacturer and specifications as for EMT conduit.

B. Fittings shall comply with ANSI C80.3.

2.14 FLEXIBLE METAL CONDUIT FITTINGS

A. Flexible Metal Conduit Fittings: Galvanized malleable iron or steel squeeze-type, setscrew fittings with insulated throat. Acceptable manufacturer: O-Z/Gedney C-8T Series, Thomas and Betts 3112 Series, or Engineer approved equal.

B. Liquid Tight Flexible Metal Conduit Fittings: All fittings shall be galvanized steel compression fittings, with O-rings, conduit ferrule and insulated throat, and shall be oil-tight and water tight. Manufacturers shall reference the product to ANSI, IEEE, UL, NEMA or any other recognized standards or code.

2.15 RACEWAY TAGS AND LABELS

A. Tags and labels shall be made from nonferrous metals, stamped by steel dies, with raceway designations shown on the As-Built Drawings.
2.16 CONDUIT MANDRELS AND BRUSHES

A. Conduit brushes shall utilize round wire bristles for maximum cleaning of sand, grit, and obstructions from the conduit. They shall have a pulling eye on one end, and a smaller twisted eye on the other end, which shall allow for bi-directional pulling. Conduit brushes shall be sized as shown in Table 2.16A.

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<th>Diameter (in)</th>
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B. Conduit mandrels shall be flexible, and manufactured for cleaning out mud, dirt, and light obstacles from ducts before the installation of cable. Mandrels shall be suitable for pulling around tight bends, and use a tapered profile that allows pulling in either direction. Pulling eyes shall be provided on each end. The mandrel shall be fabricated from polyurethane, or an Engineer approved equal material, and shall not damage conduit inner walls. Conduit mandrels shall be sized per Table 2.16B.

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</tr>
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</table>

C. Conduit mandrels and brushes shall not damage any conduit interior coating.

D. Conduit brushes and mandrels shall be manufactured for the purpose by a company regularly engaged in the production of electrical equipment, such as Greenlee Textron, Inc., or Engineer approved equal. Mandrels shall not be fabricated by the Contractor in the shop or field.
2.17 WARNING TAPE

A. Tape shall be installed in accordance with Specification Section 270543, “Underground Ducts and Raceways for Communications Systems” and Contract Drawings.

2.18 PULL CORD

A. Pull cord shall be twisted or braided nylon cordage with a minimum tensile strength of 1,000 pounds.

PART 3 - EXECUTION

3.01 GENERAL INSTALLATION REQUIREMENTS

A. Many raceways shall remain empty, with conductors installed in the future. All raceways installed for future use shall have a nylon pull-cord installed and secured at each end, with tags referenced the same at both ends on the pull-cord.

B. Install raceways with not more than 360 degrees of bend, total, in each raceway run between boxes, manholes, handholes, and raceway terminations.

C. Unless otherwise noted, minimum raceway size shall be 3/4 inch for inside buildings or in a building slab, and one inch for underground raceways governed by this specification section.

D. Install raceways concealed in construction unless shown otherwise on the Contract Drawings.

E. Cut raceway ends square, ream, and extend maximum distance into all couplings and connectors. Tighten all fittings securely.

F. Field-cut threads and reamed ends in metallic conduit shall be protected from corrosion immediately after cutting, reaming and cleaning by application of a zinc-rich coating.

G. Use conductive joint compounds to insure electrical continuity of metallic raceway joints. Manufacturers shall reference the product to ANSI, IEEE, UL, NEMA or any other recognized standards or code.

H. Install manufactured end caps or plugs on all raceway ends immediately after installation to prevent the entrance of liquids, vermin or foreign materials.
I. Bends in GRSC shall be factory ells or field bends. Field bending shall be done using one-shot or segment benders which do not decrease the raceway cross-section. Bending shall be done in accordance with manufacturer's instructions.

1. Unless otherwise indicated, minimum bend radius for raceways within structures shall be in accordance with the National Electrical Code. Exceptions to the National Electrical Code shall not be used to determine conduit bend radius, even if permitted by the NEC, for any part of this Contract unless Engineer approved. Minimum bend radius for raceways installed underground shall be as shown in Table 3.01, except where otherwise indicated.

J. Route raceways to avoid structural obstructions and to minimize crossovers. Should any core drilling or installation of sleeves not shown on drawings be desired by the Contractor, such proposed concrete penetrations shall be submitted to the Engineer for structural review prior to any core drilling or sleeving.

K. Install expansion fittings complete with grounding jumpers where raceways cross expansion joints, construction joints, sawn joints, and where shown.

L. All connections shall be watertight, except for non-liquid tight flexible metal conduit.

M. Install PVC conduit in accordance with manufacturer's instructions. Cut the conduit ends square, deburr, and apply an Engineer approved solvent to clean the joint. Apply Engineer approved cement and allow to set 24 hours before mandrelling, brushing, and installing conductors. Joint cleaning solvent and cement shall be approved by the conduit manufacturer and the Engineer.

N. This paragraph covers bends in PVC conduit runs underground but not in duct banks as governed by this specification section. Minimum bend radius for conduits raceways installed underground shall be as shown in Table 3.01, except where otherwise indicated. Refer to Specification Section 270543, "Underground Ducts and Raceways for Communication Systems" for bends in PVC conduit runs in CENC duct banks, stub-ups and stub-outs. GRSC shall be used for conduit bends 30 degrees or greater in PVC conduit runs underground but not in duct banks. Bends in PVC conduit runs underground but not in duct banks that are less than 30 degrees shall be factory PVC ells or field bend PVC conduit. Use of two PVC ells of less than 30 degrees with short, straight lengths of PVC between ells to make up a bend 30 degrees or greater is not acceptable. Field bends in PVC conduit with a radius of 100 feet or less shall be formed hot using only a heater recommended by the conduit
manufacturer. Use conduit plugs during bending for conduit two inches and larger. Remove plugs only after conduit has cooled. Field bends (sweeps) with radius greater than 100 feet may be formed cold.

O. Route all exposed raceways installed in a building parallel or perpendicular to building lines except where otherwise shown. Form bends in adjacent raceways to match radius and center of bend.

P. Install all ground bushings, and incidentals.

Q. All PVC conduits entering concrete manholes, handholes, or pullboxes shall be terminated with bell-end fittings.

R. End Bells: Flared, smooth surfaced fittings of same material as conduit.

<table>
<thead>
<tr>
<th>Conduit Size (in)</th>
<th>Conduit Radius (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td>1-1/4</td>
<td>18</td>
</tr>
<tr>
<td>1-1/2</td>
<td>18</td>
</tr>
<tr>
<td>2</td>
<td>24</td>
</tr>
<tr>
<td>2-1/2</td>
<td>27</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
</tr>
<tr>
<td>3-1/2</td>
<td>33</td>
</tr>
<tr>
<td>4</td>
<td>36</td>
</tr>
<tr>
<td>5</td>
<td>42</td>
</tr>
<tr>
<td>6</td>
<td>48</td>
</tr>
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3.02 REQUIREMENTS FOR RACEWAY TYPES

A. General

1. Raceway types for specific locations shall be as shown on the drawings. Where conduit types are not called out on the drawings, or specified elsewhere in this Section, the conduit type shall be as specified herein. See Tables 3.02-1 and 3.02-2.
### TABLE 3.02-1
SUMMARY OF CONDUIT TYPES
BY SPECIFIC LOCATION

<table>
<thead>
<tr>
<th>Location</th>
<th>GRSC</th>
<th>EMT</th>
<th>PVC 40</th>
<th>PVC 80</th>
</tr>
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<tbody>
<tr>
<td>Underground Duct banks</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underground direct buried, including under building slabs</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Underground direct buried lighting only, not in a roadway</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stub-ups through concrete slabs</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Embedded in concrete building walls, or in formed concrete</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interior exposed or concealed in construction, dry locations only, not subject to damage</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interior exposed or concealed in construction, dry locations only, subject to damage</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interior exposed or concealed in construction, wet, or damp locations</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exterior exposed above ground in construction, wet, damp, or dry locations, whether, or not subject to damage</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleeves</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under Station Platforms direct buried, not in a roadway</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Under-track Crossings</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Catenary Pole Risers</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct Buried in a roadway</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

### TABLE 3.02-2
SUMMARY OF CONDUIT TYPES
BY APPLICATION

<table>
<thead>
<tr>
<th>Application</th>
<th>Conduit Type</th>
<th>Number* (Size)</th>
<th>Installation Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication System Station – VMS Junction Boxes to VMS</td>
<td>Liquid-tight Flexible Metal</td>
<td>As required, (2 conduits) 1 inch per stanchion</td>
<td>As Required</td>
</tr>
<tr>
<td>Communication System Station – Mounting column/pole to PA Speaker</td>
<td>Liquid-tight Flexible Metal</td>
<td>As required</td>
<td>As Required</td>
</tr>
<tr>
<td>Communication System – Communications and Signal House (CSH)</td>
<td>EMT</td>
<td>As required</td>
<td>Surface Mounted</td>
</tr>
</tbody>
</table>

* If cable fill is greater than 40%, Contractor shall add another conduit.

2. Note: These tables do not address all situations or locations. Conduit types shall meet all the requirements of NEC and these Specifications and Contract Drawings.
3. For the purpose of this Specification raceways are considered 'subject to damage' in any of the following locations:

a. Exposed installations within 48 inches of finished floor or final grade.

b. Exposed installations where the area is subject to vehicular traffic, within 4 feet of established drive lanes or parking areas unless the area is protected by bollards or other structure. Height of affected area shall be 8 feet or maximum height of vehicles whichever is greater.

c. Exposed installations where the area is subject to maintenance activity, including electrical and mechanical equipment rooms. Height of affected area shall be 8 feet above finished floor.

B. For interior, dry installations above ground, exposed or concealed in construction, not embedded in concrete or masonry, and or not subject to damage, provide galvanized rigid steel conduit. For equipment requiring flexible connections, provide flexible metal conduit.

C. For interior, wet or damp installations above ground, provide GRSC. For equipment requiring flexible connections, provide liquid-tight flexible metal conduit.

D. For exterior wet, damp, or dry installations, exposed ground, whether or not subject to damage, provide GRSC. For equipment requiring flexible connections, provide liquid-tight flexible metal conduit.

E. For concrete encased conduits in underground duct banks, provide raceway types specified in Section 270543, “Underground Ducts and Raceways for Communication Systems”.

F. For direct buried underground conduit, provide PVC Schedule 80 or raceway type DB-120 specified in Section 270543, “Underground Ducts and Raceways for Communication Systems”. Conduit shall be encased and embedded in 4 inches of Engineer approved cement based soil stabilizer/ flowable fill or clean sharp sand on all sides of the raceway, as indicated on the drawings.

G. For concrete embedded conduit, such as conduit embedded in concrete building or structure walls, or where the conduit is fully encased in concrete not in a duct bank, or where used in formed concrete, provide GRSC. PVC conduit shall not be used, unless otherwise indicated.

H. For conduits installed in pole foundations, in roadways, and all track crossings, not in duct banks, provide GRSC. PVC conduit shall not be used unless otherwise indicated.
I. For direct buried raceway not in a roadway, for crossing lighting, roadway lighting, pathway lighting, or site lighting, or under station platforms provide schedule 40 PVC conduit, except where schedule 80 PVC conduit is indicated. Conduit shall be encased and embedded in 4 inches of Engineer approved cement based soil stabilizer/flowable fill on all sides of the raceway. PVC raceway is not permitted at burial depths less than 36 inches.

J. For conduit risers on catenary poles, provide GRSC type conduit, ells and fittings unless otherwise indicated.

K. For bridge abutment conduit risers, use GRSC type conduit unless otherwise indicated.

3.03 RACEWAYS INSTALLED UNDERGROUND

A. Install underground raceways in accordance with Specification Section 270543, “Underground Ducts and Raceways for Communications Systems”.

3.04 SLEEVES

A. All sleeves shall be GRSC unless otherwise indicated.

B. Install, in advance of pouring concrete, all sleeves where shown. Sleeves shall terminate flush with the surface of the concrete with a coupling.

3.05 RACEWAYS STUBBED UP THROUGH FLOORS, WALLS, FOOTINGS OR FOUNDATIONS

A. Install at such depth that the exposed raceway is vertical and no curved section of the elbow is visible. End of conduit stub-ups or stub ups shall terminate 3 inches above finished floor or vertical services, unless indicated otherwise.

B. GRSC shall be provided for all raceways installed through floors, walls, footings, or foundations. PVC conduit shall not be stubbed through floors, walls, footings, or foundations. PVC conduit may be terminated in vault walls as shown on the drawings.

C. Fire rated floors, walls, ceilings/roofs: In concrete or masonry, seal around raceway penetration with Dow Corning 3-6548 silicone RTV foam or Engineer approved equal.

D. Where raceways are installed in other openings or block outs, hard pack with mortar made of a mixture of equal parts of sand and cement.
3.06 CONDUIT MANDRELLING AND CLEANING

A. A log shall be kept for all conduits mandrelled. The mandrel log shall contain the following information in tabular format for each conduit mandrelled:

1. Conduit designation;
2. Conduit endpoints;
3. Conduit size;
4. Date mandrelled;
5. Pass/fail for specified mandrel;
6. Install pull cord.

B. After final assembly is in place, all conduit 2 inches and larger shall be thoroughly cleaned and mandrelled prior to installing wires or pull cords. Each conduit shall be mandrelled by pulling a mandrel sized in accordance with these Specifications through the conduits, followed by a steel bristle brush to clean the conduit. At the completion of cleaning and mandrelling, and before final acceptance, a "Nylon" pull cord shall be installed in each empty conduit. The pull cord shall remain accessible from each end at all times.

C. After final assembly is in place, all conduits smaller than 2 inches shall be thoroughly cleaned and mandrelled by one of the following methods:

1. Pulling through the conduits a wire brush and mandrel sized 1/4-inch maximum less than the inside diameter of the conduit for 1-1/2 and 1-1/4 inch conduits, and 1/8 inch maximum less than the inside diameter of the conduit for 1 inch and smaller conduits.

2. Pulling through the conduits a cloth rag or conductor bundle sized 1/4 inch maximum less than the inside diameter of the conduit for 1-1/2 and 1-1/4 inch conduits, and 1/8 inch maximum less than the inside diameter of the conduit for 1 inch and smaller conduits.

3. At the completion of cleaning and mandrelling, and before final acceptance, a "Nylon" pull cord shall be installed in each empty conduit. The pull cord shall remain accessible from each end at all times.

D. If requested by the Engineer, cleaning and mandrelling shall be done in the presence of METRO. Notify METRO seven days in advance of mandrelling.
E. Where raceways are stubbed and capped, the pull cord shall extend through a drilled hole in the cap.

F. Raceways that cannot meet the requirements for mandrelling, shall be deemed defective, and shall be replaced as Engineer approved.

3.07 RACEWAY LABELING

A. Identify each exposed raceway conduit at each end with tags as described below. Tags shall always designate location conduit ends. Tags and labels shall be made from nonferrous metals with raceway designations stamped by steel dies.

B. Conduit numbering shall be decided by the Contractor at time of construction. Use a left to right convention for numbering all conduits.

C. Fasten tags above raceway in manholes using a stainless steel anchor screw. At stub-up locations, band tag to rim of conduit using a stainless steel tie wrap band.

1. MH (manhole no.) - (conduit no.) - (station number or chain marker)
   a) Example: MH110NB - 08 - 552+28.

2. COMM - (conduit number)
   a) Example: COMM – 08.

END OF SECTION
SECTION 270543

UNDERGROUND DUCTS AND RACEWAYS FOR COMMUNICATIONS SYSTEMS

PART 1 - GENERAL

1.01 DESCRIPTION

A. This section specifies the construction of new ducts, manholes, and handholes for electrical and communications facilities.

1.02 QUALITY ASSURANCE

A. Comply with codes and regulations of the jurisdictional Houston METRO Light Rail Transit (LRT).

B. Ladders and steps shall comply with all OSHA Standards.

1.03 REFERENCE STANDARDS

<table>
<thead>
<tr>
<th>Organization</th>
<th>Spec Number</th>
<th>Title</th>
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</thead>
<tbody>
<tr>
<td>American Association of State Highway Transportation Officials, Inc. (AASHTO)</td>
<td>AASHTO HB17</td>
<td>Standard Specifications for Highway Bridges</td>
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<tr>
<td>American National Standards Institute (ANSI)</td>
<td>ANSI A14.3</td>
<td>Ladders - Fixed - Safety Requirements</td>
</tr>
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<td>ANSI</td>
<td>ANSI A14.5</td>
<td>Ladders Portable Reinforced Plastic - Supplement to Safety Requirements</td>
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<td>ANSI</td>
<td>ANSI C80.1</td>
<td>Rigid Steel Conduit - Zinc Coated (GRC)</td>
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<td>ANSI/UL</td>
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<td>Standard for Schedule 40 and 80 Rigid PVC Conduit</td>
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<td>ASTM International</td>
<td>A 36 / A 36M</td>
<td>Standard Specification for Carbon Structural Steel</td>
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<td>-----------------------------------------------</td>
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<tr>
<td>A 48 / A 48M</td>
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<td>A320 / A320M</td>
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<td>Standard Specification for Deformed and Plain Carbon Steel Bars for Concrete Reinforcement</td>
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<td>A615 / A615M</td>
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<td>ASTM International</td>
<td>Standard Specification for Concrete Aggregates</td>
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<td>ASTM International</td>
<td>Standard Practice for Minimum Structural Design Loading for Underground Precast Concrete Utility Structures</td>
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<td>ASTM International</td>
<td>Standard Specification for Pigments for Integrally Colored Concrete</td>
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<td>C 979</td>
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<td>ASTM International</td>
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<td>Organization</td>
<td>Standard/Specification</td>
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<td>------------------------------</td>
<td>----------------------------------------------------------------------------------------</td>
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<tr>
<td>National Electrical</td>
<td>NEMA RN1 Polyvinyl-Chloride (PVC) Externally Coated Galvanized Rigid Steel Conduit and Intermediate Metal Conduit</td>
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<tr>
<td>Manufactures Association (NEMA)</td>
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<tr>
<td>NEMA</td>
<td>NEMA TC2 Electrical Polyvinyl Chloride (PVC) Conduit</td>
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</tr>
<tr>
<td>NFPA</td>
<td>NFPA 70 National Electric Code (NEC)</td>
<td></td>
</tr>
</tbody>
</table>

### 1.04 SUBMITTALS

A. In addition to requirements in Section 270000, “Communications”, the Contractor shall specifically submit:

1. **Shop Drawings:**
   a. Drawings for each cast-in-place manhole.
   b. Drawings for each size and configuration of precast manhole, handhole, systems elements boxes and junction box with details of fabrication, assembly, accessories and joints.
   c. Diagrams showing dimensioned locations for openings and knockout panels for duct penetrations of manhole walls.

B. **Documentation:** Submit calculations to demonstrate compliance with required load-bearing capacity, certified by a Professional Engineer, registered in the State of Texas.

C. **Certification:** Submit certificates on furnished material from manufacturers of materials and as required by Section 270000, “Communications”.

### 1.05 RELATED WORK

A. Section 270000 - Communications Systems

B. Section 270526 - Grounding and Bonding for Communications Systems

C. Section 270528 - Pathways for Communications Systems

D. Section 270553 - Identification for Communications Systems

E. Section 272100 - Data Communications Network Equipment
F. Section 273100 - Voice Communications Switching and Routing Equipment

G. Section 273200 - Telephone Equipment

H. Section 275100 - Public Address/Passenger Information Signs System

I. Section 277000 – Radio and Wi-Fi Systems Equipment

J. Section 279000 - Communications System Inspection and Testing

K. Section 282300 – Video Surveillance System

L. Section 284600 – SCADA

1.06 PROJECT CONDITIONS

A. Not Applicable.

PART 2 - PRODUCTS

2.01 DEFINITIONS

A. Conduit: Individual electrical raceway.

B. Duct: Assembly of conduits in configurations shown, concrete encased, with reinforcement.

C. Raceway: An enclosed channel of metal or nonmetallic materials designed expressly for holding wires, cables, or busbars.

2.02 CONCRETE WORK

A. Concrete formwork: As specified in Section 03100, "Concrete Forming".

B. Reinforcing steel: As specified in Section 03200, "Concrete Reinforcing".

C. Concrete:

1. Cast-In-Place: As specified in Section 03300, "Cast-in-Place Concrete", Mix S-7. Encasement for Underground Ducts shall be Mix M-1.

2. Precast: As specified in Section 03400, "Precast Concrete", Mix S-3 as specified in Section 03300, "Cast-in-Place Concrete".

D. Flowable fill: As specified in Section 02317, "Excavation and Fill".
E. High-density polymer concrete (HDPC) for handholes, junction boxes and pull boxes: Sized as shown on the Manhole Schedule drawings.

1. HDPC or aggregates bound together with polyester resin and/or reinforced with continuous woven glass strands or glass fiber. Precast concrete shall be fire resistant and electrically non-conductive.

2. The precast HDPC concrete mix shall have the following certified, tested minimum characteristics:
   a. Compressive strength (28-day): 10,300 psi.
   b. Tensile strength: 1,800 psi.
   c. Flexural strength: 3,600 psi.
   e. Freeze/thaw resistance (2,500 cycles): No change.
   f. Fire resistance (Maximum): 10 when tested in accordance with ASTM E84; or maximum burning rate of 0.3 inches per minute for each 0.1 inch of thickness when tested in accordance with ASTM D635.
   g. Shear (Minimum): 6,000 psi.

3. Concrete formwork: As specified in Section 03100, “Concrete Formwork”.

4. Quality assurance: As specified in Section 03300, “Cast-In-Place Concrete”.

2.03 CONDUIT AND FITTINGS

A. PVC conduit and fittings:
   1. Concrete encased: ANSI/UL 651 or NEMA TC2; Type-Schedule 40 PVC.
   2. Direct burial: ASTM F512, Type DB-120.

B. Galvanized rigid steel conduit and fittings: ANSI C80.1.

2.04 SPACERS

A. Conduit spacers shall be installed in duct banks at the rate of 3 spacers per 20 linear feet or the equivalent, maximum interval of 78 inch centers along the entire conduit run. Plastic conduit spacers provided shall be
specified for use in duct banks and be standard factory preformed spacers.

### 2.05 END BELLs

A. Flared, smooth-surfaced fittings of same material as conduit; if fittings are of different material, include adapter for connection to conduit.

### 2.06 AGGREGATE

A. Aggregate for Subgrade Foundation where required: ASTM C33, coarse aggregate No. 4 or No. 67.

### 2.07 CHANNEL INSERTS

A. Fiber-reinforced polymer (FRP) channel shall be of pultruded glass-reinforced polyester or vinyl ester resin: ASTM D3917 and ASTM D4385, length and minimum width and depth sizes as shown on drawings, heavy duty, surface-mounted, slotted back with mounting slots on a maximum of 8 inch centers, channel configuration to accommodate standard metal framing fasteners.

### 2.08 CABLE PULLING IRON

A. Fabricated of plain steel reinforcement bar, ASTM A615, Grade 60; welded; size as shown. Hot-dip galvanized after fabrication, ASTM A123.

### 2.09 MANHOLE AND HANDHOLE FRAMES AND COVERS

A. Handhole Frame and Cover: Steel, ASTM A36/A36M; size as shown, with the METRO LRT Logo cast in the cover.

B. Manhole Frame and Cover:

1. METRO LRT manhole, rectangular access cover: Size as shown on drawings.
   a. Covers shall be designed by a registered Civil Engineer licensed in Texas in accordance with HS20 loading requirements of the American Association of State Highway & Transportation Officials (AASHTO) and ASTM C857.
   b. Each Access Door shall be provided with a zinc plated and chromate sealed torsion assist mechanism to reduce the lifting requirements and shall be able to open to a 90 and/or 180-degree position.
   c. Frames and covers shall be hot dipped galvanized per ASTM A123 as last revised to reduce corrosion.
d. Each access door shall be manufactured with a minimum 1/4 inch steel floor plate.

e. Torsion Bars shall be removable or exchanged without removing the covers from the frame assembly.

f. Covers shall have the METRO LRT logo as shown on the Contract Drawings.

g. Covers shall be provided with recessed flush lift handles to assist opening covers.

h. Miscellaneous hardware shall be zinc plated and chromate sealed for corrosion resistance.

i. Countersink hole at bolt locations to prevent bolts from extending more than 1/8 inch above cover. The hole shall have a diameter that is large enough to accommodate the socket for the bolt heads.

2. METRO LRT manhole, round access cover: Size as shown on drawings.

   a. Cast iron, ASTM A48, Class 30, with the METRO LRT logo cast in the cover.

   b. Cast or drilled countersink hole at bolt locations to prevent bolts from extending more than 1/8 inch above cover. The hole shall have a diameter that is large enough to accommodate the socket for the bolt heads.

2.10 MANHOLE STEPS

   A. Unless otherwise shown: Fiberglass or rebar.

   B. As shown on Manhole Schedule drawings, provide at manhole steps a telescoping safety post as specified herein.

2.11 HANDHOLES AND MANHOLES

   A. Unless otherwise shown, Contractor's option of either cast-in-place or precast.

      1. Cast-in-place concrete:

         a. Size and configuration as shown on the detail drawings, the schedules, and as specified.

         b. Manholes shall be designed for AASHTO HS20-44 truck loading.
c. Handholes shall be designed for AASHTO HS20-44 truck loading when indicated on the detail drawings and the schedules.

d. Manhole: Include lifting rings, manhole steps, pulling irons, sump, hole through floor for ground rod. Precast extensions included where required by Utility or by manhole schedule or detail drawings.

2. Precast concrete:
   a. Size and configuration as shown on the detail drawings, the schedules, and as specified.
   b. Designed for AASHTO HS20-44 truck loading.
   c. Manhole: Include lifting rings, manhole steps, pulling irons, sump, hole through floor for ground rod, and seal or sealant for sealing joints between sections. Precast extensions included where required by Utility or by manhole schedule or detail drawings.

2.12 GROUNDING

A. As specified in Section 270526, "Grounding and Bonding for Communications Systems".

2.13 WARNING TAPES

A. Polyethylene non-detectable tape for direct burial, extra stretch, minimum of 7 mil thick and a minimum of 6 inches wide for use in trenches. Approved manufactures are Terra-Tape, Blackburn Manufacturing, Seton, or Engineer approved equal.

B. Provide warning labels on 3 foot centers and be colored as follows:

1. For communication and signals ducts: Orange tape with black printed labeling: "Caution - Communications Cable Buried Below" or "Warning - Communications Cable Buried Below", or Engineer approved standard language. Communication ducts are those that run between Communications/Signal Manholes (CSMH), or run from a CSMH to a Communications and Signal House (C&S), Operations Control Center (OCC/ROC), stub-up, stub-out, handhole, or junction box.

2.14 CONCRETE COLORING AGENT

A. Red Iron Oxide: ASTM C979
1. Include in ductbank concrete encasement mix design, or apply and mix in top layer of ductbank concrete immediately following concrete placement, where indicated on drawings.

2.15 SECURITY BOLTS

A. Two security bolts shall be required to lock down a manhole, handhole, junction box, or pull box cover in order to prevent unauthorized access.

B. The security bolt shall be fabricated to be a direct replacement of existing bolts, where applicable, and shall comply with the following physical specifications:

1. Bolt shall be made from 304 Class 2 or equal stainless steel, conforming to ASTM A320/A320M.

2. Bolt shall be made with a flat pentagonal 0.845 inch head (0.56 inch side), 0.3 inch minimum depth.

3. Bolt shall be torqued by means of a matching tool steel socket, which fits a 1/2 inch drive wrench.

4. Bolt lengths shall be as required to fully engage the threads and shall be held to plus or minus 0.1 inch.

5. Bolt for junction boxes shall be 3/8 inch diameter, 16 threads per inch, class UNC-2A. Bolt for manholes, handholes, and pullboxes shall be 1/2 inch diameter, 13 threads per inch, class UNC-2A.

C. Apply marine grade anti-seize calcium sulfonate lubricant or equal to bolt threads prior to final installation of security bolt.

2.16 LADDERS

A. METRO LRT manhole: Length and type of ladder as shown on Manhole Schedule drawings.

1. Structural steel ladders shall conform to Specification Section 05500, “Metal Fabrications”.

2. Fiberglass ladders shall conform to the requirements of ANSI A14.5, Type 1A - Industrial - Extra Heavy Duty.

3. Fiberglass extension ladders shall conform to the requirements of ANSI A14.5, Type 1A. - Industrial - Extra Heavy Duty.

4. Fixed ladders shall conform to the requirements of ANSI A14.3.
B. As shown on Manhole Schedule drawings, provide at manhole ladders a telescoping safety post as specified herein.

2.17 TELESCOPING SAFETY POST

A. As shown on Manhole Schedule drawings, provide on manhole steps and ladders an aluminum telescoping safety post with stainless steel hardware conforming to OSHA requirements extending not less than 36 inches above the top of the manhole ring or cover.

2.18 PROJECT TOOLS

A. Furnish and deliver to METRO ten sockets for each type of security bolts provided.

B. Furnish fiberglass extension ladders in quantity, length, and type as shown on Manhole Schedule drawings and deliver to METRO as directed.

PART 3 - EXECUTION

3.01 EXCAVATING AND BACKFILLING

A. Ducts and manholes installed on backfill over utilities or structures:
   1. Place and compact backfill up to grade shown for ducts and manholes; ensure the manhole sets level.
   2. Schedule completion of backfilling to allow sufficient time for installation of ducts and manholes.

B. Where shown for subgrade foundation, use layers of coarse aggregate ASTM C33, No. 4 and No. 67 in combinations and proportions as determined by field conditions.

C. Protect and maintain existing utility services.

3.02 PAVEMENTS, SIDEWALKS, CURBS, AND GUTTERS

A. Remove pavements, sidewalks, curbs, and gutters where necessitated by construction of ducts and manholes.

B. Place temporary bituminous pavement when required by the sequence of operations.

C. On completion of distribution systems construction, replace pavements, sidewalks, curbs, and gutters when required by the sequence of operations.
D. Reconstruction of roadway or track slab necessary for the installation of new power switches, insulated joints and related systems elements shall be completed when required by the sequence of operations.

3.03 PLACING DUCTS

A. Depending on encasement necessary for duct formation, place conduits on spacers and, where required, construct concrete base prior to placing bottom tier of conduits.

B. Lay conduits using spacers, on 48 inch centers, to provide tier spacing as shown.

C. Make tight conduit joints by complying with recommendations of conduit manufacturer, using coupling jointing compound or solvent cement.

D. Use non-metallic conduit, unless otherwise shown.

E. Where required, properly place and compact concrete around conduits.

F. Where shown, install reinforcing steel in encasement.

G. If not already in concrete mix, apply and mix concrete coloring agent in top layer of encasement concrete immediately following concrete placement, where shown on drawings.

H. Clear conduit by rod and pull an approved test mandrel from structure to structure.

I. Leave approved nylon or polyester pull line in each conduit, tagged to identify the conduits point of origin, contents, and final destination.

J. Directional Bore:
   1. Where indicated, install conduit by directional bore.
   2. Where concrete casing is required for installation of the 4 inch communication conduits and duct banks, the borehole shall be a minimum of 10 inch diameter. Any voids that develop between communication conduits and walls of the borehole shall be filled with grout.

K. Core-Bore:
   1. Where indicated, install conduit by core-bore.
   2. Where concrete casing is required for installation of the 4 inch and 2 inch communication conduits and duct banks, the core-borehole
shall be a minimum of 10 inch diameter for 4 inch conduit, and 8 inch diameter for 2 inch conduit. Any voids that develop between communication conduits and walls of the core-borehole shall be filled with grout.

3.04 INSTALLATION OF WARNING TAPES

A. After placing a minimum of 6 or a maximum of 12 inches of backfill over the ducts, place the appropriate warning tapes above and parallel to the centerline of the duct for the entire length of the duct trench.

3.05 CONSTRUCTION OF MANHOLES AND HANDHOLES

A. Cast-in-Place:

1. Provide drainage facilities for manholes where shown.
2. Place reinforcing in accordance with approved shop drawings.
3. Provide for location of duct entrances and inserts in walls as shown.
4. Install conduits of material shown.
5. Install end bells on conduits where ducts terminate in manhole and handholes.
6. Build duct formation into walls of manholes and seal around opening.
7. If location of manhole or handhole openings will be obstructed, inform the Engineer immediately.
8. Install frame and cover, adjust to finished grade by using precast neck extenders, grout and, if necessary, brick chimney.
9. Seal conduit openings with approved conduit plugs.
10. Install cable pulling irons and steps as shown.
11. Install ground rods where shown. If soil conditions prevent driving rod to required depth, install alternative grounding system as approved.
12. Paint exterior of manhole, which is below grade, with two coats of epoxy coal tar, 18 mils minimum total dry film thickness.
13. Provide channel inserts along interior walls as shown. Perform pull-out test.


15. Complete grounding of metal components in accordance with Section 270526, “Grounding and Bonding for Communication Systems”.

B. Pre-cast:

1. Provide drainage facilities for manholes where shown.

2. Install conduits of material shown.

3. Install end bells on conduits where ducts terminate in manhole and handholes.

4. Build duct formation into the bulkhead of manholes and seal around opening.

5. If location of manholes or handholes openings will be obstructed inform the Contracting Officer immediately.

6. Install frame and cover, adjust to finished grade by using precast neck extenders, when required.

7. Seal conduit openings with approved conduit plugs.

8. Install cable pulling irons and steps as shown.

9. Install ground rods where shown. If soil conditions prevent driving rod to required depth, install alternative grounding system as approved.

10. When installing sections of precast manholes, prevent damage to joints seals.

11. Provide channel inserts along interior walls as shown. Perform pull-out test.

12. Paint exterior of manhole, which is below grade, with two coats of epoxy coal tar, 18 mils minimum total dry film thickness.

13. Install ladder and telescoping safety post where required by Manhole Schedule drawings.
14. Complete grounding of metal components in accordance with Section 270526, “Grounding and Bonding for Communications Systems”.

3.06 CLEAN-UP

A. Remove debris from manholes and ensure complete installation is left in neat and finished condition.

END OF SECTION
PART 1 : GENERAL

1.01 DESCRIPTION

A. Work Included

1. The Work of this Section consists of designing, furnishing, installing, testing, and commissioning the data communications network equipment, associated with the Houston Metro Solutions Light Rail Transit Extension (LRT) project.

2. The data communications network equipment described in this Section includes the following:
   a. CTS (Communications Transmission System) Backbone Switch;
   b. Station Ethernet Access Switch;
   c. Industrial Ethernet Switch;
   d. Ethernet fiber optic interfaces;
   e. Network Management System (NMS);
   f. CTS Interface Router;
   g. GPS (global positioning system) Master Clock.

B. The data communications network equipment shall implement a system wide backbone communications network that shall be referred to as the Communications Transmission System (CTS) and compatible with existing METRO network equipment and configured to function under all fault condition. Although the CTS will not directly interface into the existing METRO SONET ring, the CTS shall be capable of exchanging data via TCP/IP network connection with the existing METRO wide area network (WAN). See “CTS Interface Router” elsewhere in this section.

C. The CTS shall consist of the following:

1. Core Layer
   a. Layer 2-4 CTS Backbone Switch and associated fiber optic interfaces, arranged in a fault tolerant network configuration as shown in the Contract Drawings.
b. Fiber optic backbone cables routed between the 4 extended corridors.

c. Fiber optic connections between all Communications Nodes (CN) located in selected Communications and Signal Houses (C&S), stations, and Communications Interface Cabinet (CIC) and the Operations Control Center and Rail Operations Center (OCC/BUOCC).

d. Refer to Section 271300 for requirements regarding fiber optic backbone cables, fiber optic patch panels, conduits, inner duct, and terminations.

2. Access Layer

a. The access layer shall consist of the Ethernet Access Switches connecting to the Layer 2-4 CTS Backbone Switches that shall provide 10/100Base-T and to the LRT subsystems.

b. Refer to Section 271100 for requirements regarding copper patch panels.

c. Refer to Section 271300 for requirements regarding fiber optic distribution panels.

d. Refer to Section 271500 for requirements regarding horizontal cabling required to go between CTS and the LRT subsystems located at each station, inside the C&S and outside C&S to include Traction Power substations, passenger platform and other areas local to the station requiring a connection to the CTS.

D. The CTS shall provide data, video and voice communications between the OCC/ROC and facilities in all 4 corridors for LRT subsystems including, but not limited to, the following:

1. Rail Signaling;

2. Automatic Vehicle Location Monitoring and Control System (AVL);

3. SCADA System – PLC communications to C&S;

4. Wireless voice, video, and data to/from LRVs;

5. Fare Collection System;

6. Public Address / Passenger Information Sign System (PA/PIS);

7. Telephone System (Voice over IP);

8. Video surveillance system - IP video.

E. The CTS shall provide interface for voice, data and video.
1. The CTS network equipment shall provide 10 Gigabit uplink interfaces for data, voice and video between Communication Nodes and to the OCC/ROC as shown in the Contract Drawings.

F. Network Management System (NMS)
1. Contractor shall provide computer servers / workstations and software, including a Graphical User Interface (GUI), for operation, administration, and maintenance of the CTS.
2. All network equipment associated with the CTS, as specified herein, shall have the ability to be remotely configured and monitored by the NMS using SNMP.
3. The NMS shall consist of a primary server, keyboard, monitor, and mouse at the OCC with a full-featured enterprise version of NMS software, and a secondary server/workstation at the Backup OCC with a monitor-only version of the same software used on the primary NMS workstation.

G. Requirements for fiber optic cables, terminations, and related equipment are described in Section 271300.

H. Requirements for communications horizontal cabling including copper outside plant and fiber optic cables for short haul interfaces, are described in Section 271500.

I. Requirements for distribution frames, patch panels, equipment cabinets, racks, mounting hardware, and ancillary equipment are described in Section 271100.

1.02 QUALITY ASSURANCE

A. Materials specified shall meet or exceed the requirements of the cited references.

B. Qualifications
1. The Contractor shall provide all product cut sheets as required for the Engineer’s evaluation.

1.03 CITED REFERENCES

A. European (EN) Standards
1. EN50155 - Railway applications. Electronic equipment used on rolling stock

B. International Electrotechnical Commission (IEC)
1. IEC 61850-3 Communication Networks and Systems in Substations

C. International Telecommunications Union (ITU)
   1. G.168 – Echo cancellation
   2. G.711 – Standard for audio companding
   3. G.723.1 – Audio codec
   4. G.726 – Adaptive Differential Pulse Code Modulation (ADCP) speech codec
   5. G.729A – Audio data compression algorithm
   6. H.323 - Protocols to provide audio-visual communication sessions on any packet switched network.

D. Internet Engineering Task Force (IETF) Internet Standards
   1. RFC 768 UDP (User Datagram Protocol)
   2. RFC 791 IP (Internet Protocol)
   3. RFC 792 ICMP (Internet Control Message Protocol)
   4. RFC 793 TCP (Transmission Control Protocol)
   5. RFC 826 ARP (Address Resolution Protocol)
   6. RFC 2131 DHCP
   7. RFC 1112 IGMP (Internet Group Management Protocol)
   8. RFC 1157 SNMP (Simple Network Management Protocol)
   9. RFC 1113 TCP/IP Management Information Base (MIB)
   10. RFC 1305 NTP v3 (Network Time Protocol)
   11. RFC 1493 Bridge MIB
   12. RFC 1583 OSPF (Open Shortest Path First)
   13. RFC 1591 DNS (Domain Name System)
   14. RFC 1657 BGP-4 MIB
   15. RFC 1757 / RFC 2819 RMON (Remote Monitoring)
   16. RFC 1771 / RFC 1772 BGP-4 (Border Gateway Protocol)
   17. RFC 1850 OSPF MIB
   18. RFC 1907 SNMPv2
   19. RFC 1997 BGP-4 Community Attributes
   20. RFC 2131 Dynamic Host Control Protocol (DHCP)
   21. RFC 2233 Interfaces Group MIB
   22. RFC 2236 IGMPV1,v2,V3 for snooping
23. RFC 2328 OSPFv2
24. RFC 2362 PIM (Protocol Independent Multicast)
25. RFC 2453 RIPv2 (Routing Information Protocol)
26. RFC 2460 IPv6 specifications
27. RFC 2461 Neighbor Discovery
28. RFC 2463 ICMPv6
29. RFC 2516 PPPoE (Point-to-Point Protocol over Ethernet)
30. RFC 2571, 2572, 2573, 2574, 2575 and 2576 SNMPv3
31. RFC 2616 HTTP (Hyper Text Transfer Protocol)
32. RFC 3513 IPv6 addressing architecture
33. RFC 3587 Global Unicast Address Format
34. RFC 3768 VRRP (Virtual Redundancy Router Protocol)
35. RFC 2934 PIM MIB
36. RFC 4022 TCP MIB
37. RFC 4113 UDP MIB

E. Institute of Electrical and Electronic Engineers (IEEE)
   1. IEEE 802.1 Local Area Network / Metropolitan Area Network (LAN/MAN) Bridging & Management
   2. IEEE 802.3 Local Area Network protocols (Ethernet)
   4. IEEE 1518 - Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems

F. National Electrical Manufacturers Association (NEMA)
   1. TS2 - Traffic Controller Assemblies with NTCIP Requirements

1.04 SUBMITTALS

A. The Contractor shall provide the following submittals as described in Section 270000 Communications:
   1. System Design.
   2. Arrangement Plan.
   3. Installation Plan.


B. The Contractor shall submit technical data sheets and catalog cuts for each item.

C. The Contractor shall submit manufacturer’s warranty information.

1.05 RELATED WORK

A. Section 270000 – Communications

B. Section 271100 – Communications Equipment Room Fittings

C. Section 271300 – Communications Backbone Cabling

D. Section 271500 – Communications Horizontal Cabling

E. Section 273100 – Voice Communications Switching Equipment

F. Section 275100 – Public Address / Passenger Information Sign System

G. Section 279000 – Communications System Inspection and Testing

H. Section 282300 – Video Surveillance System

I. Section 284600 - Supervisory Control and Data Acquisition

PART 2 : PRODUCTS

2.01 CTS FUNCTIONAL REQUIREMENTS

A. The CTS shall provide the communication interfaces to all LRT subsystems as described elsewhere in this Section.

B. The CTS shall use of data communications network equipment consisting of COTS (commercial off-the-shelf) products with a modular construction.

1. The data communications network equipment shall follow the industry standards as specified elsewhere in this Section.

2. All data communications network equipment shall be new, listed in the manufacturer’s most current catalog, and in current production.

3. The CTS shall provide 10 Gigabit backbone for the use of transmitting data, voice and video (CCTV).
C. The CTS shall be designed and configured to provide separate independent logical networks.
   1. Separate independent logical networks shall be provided by one or more network services including, but not limited to, virtual LANs (VLANs), virtual private networks (VPN), or Secure Sockets Layer (SSL) protocol.
   2. Separate independent logical networks shall be provided for voice, data and video functions including, but not limited to, the following:
      a. Rail Signaling.
      b. Automatic Vehicle Location (AVL).
      c. Supervisory Control and Data Acquisition (SCADA) including Communications RTUs and Traction Power RTUs.
      d. Wireless voice, video, and data to/from LRVs.
      e. Fare Collection System.
      f. Public Address / Passenger Information Sign (PA/PIS) System.
      g. Telephone System, Voice over IP (VoIP).
      h. Video surveillance system - IP video.

D. The CTS shall be provided and installed in a fault tolerant network configuration as shown in the Contract Drawings.
   1. Each portion of the fault tolerant network for North, East, and Southeast corridors shall connect to the OCC/ROC via Node 1 on the Southeast Corridor as shown in Contract Drawing ZM1-0016A. The Uptown corridor network shall be connected to OCC via the Northwest Transit Center, and to the ROC via Node 1 on the Southeast Corridor as shown in Contract Drawing ZM1-0016A.
   2. Each new station in the new extended 4 Corridors shall comprise a single node of the fault tolerant network.
   3. In the event of a failure in a fiber optic link, the fault tolerant network shall automatically achieve network and application convergence within a worst case maximum of 10 seconds.
   4. Communications between the Communications Node and each station shall be independent.
   5. The CTS shall be extended from each Communications Node on each Corridor to the OCC/ROC.
      a. Fiber optic connections between the Communications Nodes and the OCC/ROC shall be via backbone cable as specified in Section 271300.
E. The CTS shall be designed such that any failure or malfunction shall not cause an unsafe condition or produce a failure or malfunction in the train control, traction power, fire alarm, or other LRT subsystems as described elsewhere in this Section.

1. In this context, an unsafe condition shall be defined as follows:
   a. A condition that affects local autonomous operation or prevents local control of train control, traction power, fire alarm, or other LRT subsystems at C&S, TPSS or other points of local control associated with a station.
      1) The train control, traction power, fire alarm, and other LRT subsystems shall be able to be controlled locally at the stations without the CTS operating.
   b. A condition that causes an uncommanded change in state of the train control, traction power or other LRT subsystems.

F. Availability
1. The availability of the CTS for any station to OCC/ROC communications link shall be 99.9% or greater.
   a. The availability shall be defined as the ratio of total time minus downtime due to a failure resulting in loss of communications, to the total time.

G. Maintainability
1. The mean time to repair (MTTR) of a failure in the CTS at any given site shall be less than 30 minutes after an LRT technician arrives on site.

H. Reliability
1. There shall be no single point of failure that interrupts communications within the CTS.

I. Redundancy and Failover
1. The requirements for availability, maintainability, and reliability shall be accomplished through the use of redundant modules provided in the data communications network equipment as specified herein.
2. Each CTS Backbone switch shall be provided with redundant, hot swappable modules including, but not limited to the following:
   a. Power supply;
   b. Cooling fan;
   c. Fiber optic interfaces.
3. Redundant power supplies shall be connected to separate power outlets.

4. Each CTS Backbone switch shall provide automatic failover of a failed module to a non-failed module in 10 seconds or less.

5. A single, highly available, CTS Backbone switch with redundant modules as specified herein, shall be provided at each Communications Node as shown in the Contract Drawings.

J. Scalability

1. The CTS shall be scalable in terms of the number of nodes in the network.

2. The data communications network equipment comprising the CTS shall be scalable with regard to expansion in the number of Ethernet ports, fiber optic interfaces, and bandwidth.

   a. Increase in the number of Ethernet ports, fiber optic interfaces, bandwidth shall be accomplished by adding modules that shall not require a change of the base unit. All CTS Backbone switches and Ethernet Access switches shall have 20% spare ports.

   b. Increase in the number of Ethernet ports, fiber optic interfaces, bandwidth shall only require an incremental cost of the new equipment.

   c. Equipment chassis shall be provided spare slots and/or stacking connectors, power supplies and cooling to allow for a minimum of 20% expansion capability.

   d. Empty slots shall be provided with blank covers.

K. Management

1. Contractor shall provide a NMS, for the LRT Network, consisting of computer servers/workstations and software.

2. The NMS shall be located in the communications equipment room in the OCC/ROC.

3. The NMS shall be capable of communicating with and monitoring all CTS elements and other devices via network interfaces using secure protocols as listed under IETF standards referenced herein.

   a. The NMS shall communicate with and monitor all devices with network (IP) capability including, but not limited to, the following:

      1) CTS Backbone switches;
      2) Ethernet Access switches;
3) PA/PIS station control unit (SCU), VOIP Gateway, and PA/PIS head-end servers at the OCC/ROC.

4) IP video (IPV) CCTV cameras;

5) IP telephones;

6) Ticket vending machines (TVM);

7) Uninterruptible Power Supplies (UPS);

8) Network video recorders (NVR);

9) Peripheral equipment including, but not limited to, computer CPUs, remote terminal units (RTU), terminal servers, device servers, master clock, and media converters.

4. The NMS installed at the OCC and ROC shall include a graphical user interface that provides a means for an authorized user to remotely configure and/or monitor the CTS.

5. The NMS shall provide configuration, fault monitoring, performance, and security management capabilities.

6. The NMS shall automatically monitor CTS performance and all network devices as specified herein.

   a. The NMS shall automatically display and log all alarms and fault conditions occurring in the CTS.

   b. The NMS shall provide the ability for authorized users, at a minimum, to perform the following functions:

      1) Logon to the NMS by entering valid credentials including user name and password;

      2) Configure CTS parameters including, but not limited to, those associated with the following:

         a) Initial network planning;
         b) Traffic routing
         c) Load balancing;
         d) Cryptographic key distribution authorization;
         e) Fault management;
         f) Security management;
         g) Performance management;
         h) Bandwidth management.

      3) View CTS performance data in real time;

      4) View CTS alarm and fault conditions in real time;

      5) Display, search, filter, and print the log of alarm and fault conditions.
A. Each CTS Backbone switch shall be a resilient, modular COTS product providing both switching and routing capabilities.

1. The CTS Backbone switch shall provide OSI (Open Systems Interconnection) layer 2 switching, layer 3 routing, and layer 4 data encapsulation and multiplexing capabilities.

2. The CTS Backbone switch shall provide wire-speed routing and non-blocking switch fabrics.

B. Each CTS Backbone switch shall have a low latency switching fabric providing up to 128 Gbps bandwidth and up to 48 mpps (million packets per second) forwarding rate.

C. Each CTS Backbone switch shall provide Quality of Service (QoS) and traffic filtering capabilities that shall allow bandwidth to be allocated according to applications such as VoIP.

D. Each CTS Backbone switch shall have an integrated firewall and other hardware/software modules that shall provide, at a minimum, the following functions:

1. Address and port filtering that use Access Control Lists (ACLs) to provide security and manage traffic flows;

2. Network address translation (NAT);

3. Virtual Private Networks (VPN);

4. Secure Shell (SSH) protocol;

5. Secure Copy Protocol (SCP).

E. The Contractor shall provide the ability to interconnect pairs of CTS Backbone switches into a highly resilient cluster with increased reliability, performance, and scalability.

1. The pairs of CTS Backbone switches shall function as one logical switch to form a cluster.

F. The CTS Backbone switches at each Communication Node and the OCC/ROC, as shown in the Contract Drawings, shall be provided with redundant fiber optic uplink ports that shall support link aggregation as defined by IEEE 802.3ad.

1. CTS Backbone switches at each CN shall be provided with redundant 10 Gigabit fiber optic ports that shall used for all network communications including voice, data, and video.

2. The CTS Backbone switch shall have the following fiber optic ports:
a. Uplink ports:
   1) 10-Gigabit Ethernet - X2 transceiver.

b. Network Interfaces
   1) 1-Gigabit Ethernet - SFP (small form-factor pluggable).

G. The CTS Backbone switches at each Communication Node and the OCC/ROC shall have a minimum of 2 10-Gigabit fiber optic uplink ports which shall be used to connect to the fault tolerant network as shown in the Contract Drawings.

H. The CTS Backbone switches at each Communication Node and the OCC/ROC shall be provided with a minimum of 12 Gigabit network interface ports.
   1. The 1-Gigabit fiber optic ports shall be used to connect to network drops within the C&S as shown in the Contract Drawings.
   2. The 1-Gigabit fiber optic ports shall be used to connect to network drops outside the C&S including one or more Ethernet Access switches located in the Communications Interface Cabinet (CIC) at each station, as shown in the Contract Drawings.
      a. Contractor shall note that the CTS Backbone switch at a given Communications Node shall provide network drops to the Ethernet Access switches at multiple stations as shown in the Contract Drawings.
   3. Traffic between each communications node in the fault tolerant network, associated with voice, data and video, including CCTV cameras and digital video recorders using MPEG4 or Motion JPEG encoding, and shall be transported via the redundant 10 Gigabit fiber optic interfaces.
      a. All traffic associated with video shall be multicast such that multiple locations in addition to the OCC/ROC may receive video streams.

I. All connections to fiber optic ports shall be made using single mode fiber optic cable as specified in Section 271500.

J. Each CTS Backbone switch shall be provided with non-volatile memory for storage of configuration parameters and application software.

K. Each CTS Backbone switch shall meet, at a minimum, the following system specifications:
   1. Switch bandwidth
      a. 128 Gbps non-blocking.
b. 48 mpps forwarding.

2. MAC Addresses
   a. 6,000.

3. Multicast Addresses
   a. 8,000.

4. Jumbo Frame Support
   a. Up to 9,216 bytes.

5. VLANs
   a. Up to 1,000.

6. Spanning Tree Protocol Instances
   a. Up to 1,500.

7. Unicast Routes
   a. Up to 8,000.

8. Multicast Routes
   a. Up to 1,000.

9. QoS Entries
   a. Up to 500.

10. Fiber optic interfaces
    a. 12 x 1 Gigabit – SFP, 1000Base-LX/LH, 10 km. The Contractor shall provide 1000Base-ZX, 40 km, SFP modules for spans greater than 10 km.
    b. 2 x 10 Gigabit – X2 10GBase-LR, 10 km. The Contractor shall provide 10GBase-ER, 40 km, SFP modules for spans greater than 10 km.

11. Power
    a. 100 to 240 VAC, 60 Hz.

L. Each CTS Backbone switch shall meet, at a minimum, the following mechanical and environmental specifications:

1. Rack mount
   a. 19 inch (483 mm).

2. Operating Temp
   a. 0 to +45 degrees C (32 to 113 degrees F).

3. Humidity
   a. 10 to 95 percent non-condensing.
A. The Contractor shall provide the quantity of 1 Gigabit SFP for each CTS Backbone switch as specified under Provisioning elsewhere in this Section.

B. Each 1 Gigabit SFP shall meet, at a minimum, the following specifications:

1. Standards
   a. 1000Base-LX/LH, IEEE 802.3s
   b. 1000Base-ZX, IEEE 802.3z Ethernet full duplex.

2. Cabling
   a. Single mode fiber.

3. Connectors
   a. LC or approved equivalent.

4. Distance
   a. The Contractor shall provide 1000Base-LX/LH SFP modules with minimum of 10km (6.2 mile) range.
   b. The Contractor shall provide 1000Base-ZX SFP modules, with 40 km (25 mile) minimum range, for spans greater than 10 km.

5. Optical budget
   a. 17 dB minimum.

6. Transmitter Characteristics
   a. Wavelength
      1) 1000Base-LX/LH: 1310 ± 10 nm (nanometers).
      2) 1000Base-ZX: 1550 ±10 nm (nanometers).
   b. Maximum spectral width
      1) 0.2 nm.
   c. Transmit power
      1) 1000Base-LX/LH: -3 to -9.5 dBm.
      2) 1000Base-ZX: +5 to 0.0 dBm.

7. Receiver Characteristics
   a. Wavelength
      1) 1200 to 1620 nm.
   b. Receive power range
      1) 1000Base-LX-LH: -3 to -20 dBm.
2.04 10 GIGABIT ETHERNET FIBER OPTIC INTERFACES

A. The Contractor shall provide the quantity of 10 Gigabit X2 modules for each CTS Backbone switch as specified under Provisioning elsewhere in this Section.

B. Each 10 Gigabit X2 module shall meet, at a minimum, the following transmit specifications:

1. Standards
   a. 10GBase-LR, IEEE 802.3, minimum
   b. 10GBase-ER, IEEE 802.3, as needed for spans greater than 10 km

2. Cabling
   a. Single mode fiber.

3. Connectors
   a. LC or approved equivalent.

4. Distance
   a. 10 km (6.2 mile) minimum
   b. 40 km (25 mile), for spans greater than 10 km.

5. Signaling speed
   a. 10GBASE-ER 10.3125 Gbps.

6. Signaling speed variation from nominal (max)
   a. ±100 ppm for 10BASE-ER.

7. Center wavelength
   a. 1530 to 1565 nm (nanometers).

8. Side mode suppression ratio
   a. 30 dB (minimum).

9. Average launch power
   a. 4.0 dBm (maximum).
   b. -4.7 dBm (minimum).

10. Optical modulation amplitude (OMA)
    a. -1.7 dBm (minimum).

11. Transmitter dispersion penalty (TDP)
a. 3.0 dB (maximum).

12. Launch power in OMA minus TDP
   a. -2.1 dBm (minimum).

13. Extinction ratio
   a. 3.0 dB (minimum).

14. Relative intensity noise OMA
   a. -128 dB/Hz (maximum).

15. Optical return loss tolerance
   a. 21 dB (maximum).

C. Each 10 Gigabit XFP module shall meet, at a minimum, the following receive specifications

1. Standards
   a. 10GBase-ER, IEEE 802.3.

2. Cabling
   a. Single mode fiber.

3. Connectors
   a. LC or approved equivalent.

4. Distance
   a. 40 km (25 mile) minimum.

5. Signaling speed
   a. 10GBASE-ER 10.3125 Gbps.

6. Signaling speed variation from nominal (max)
   a. ±100 ppm for both 10BASE-ER.

7. Center wavelength
   a. 1530 to 1565 nm (nanometers).

8. Average receive power (maximum)
   a. -1.0 dBm.

9. Average receive power (minimum)
   a. -15.8 dBm.

10. Receiver sensitivity in OMA
    a. 0.039 mW, -14.1 dBm (maximum).

11. Stressed receiver sensitivity in OMA
    a. 0.074 mW, -11.3 dBm (maximum).
12. Receiver reflectance
   a. -26 dB (maximum).

13. Vertical eye closure penalty\(^1\)
   a. 2.7 dBm (minimum).

14. Stressed eye jitter\(^2\)
   a. 0.3 unit interval peak-peak (minimum).

15. Receive electrical 3 dB upper cutoff frequency
   a. 12.3 GHz (maximum).

\(^1\) Vertical eye closure penalty is a test condition for measuring stressed receiver sensitivity. It is not a required characteristic of the receiver.

\(^2\) Stressed eye jitter is a test condition for measuring stressed receiver sensitivity. It is not a required characteristic of the receiver.

### 2.05 ETHERNET ACCESS SWITCHES

A. Ethernet Access switches shall be installed in C&S, and CIC cabinets associated with station platforms, as shown in the Contract Drawings.

B. Ethernet Access switches shall allow for setup and management using the NMS as specified herein.

C. Ethernet Access switches shall have a minimum MTBF (mean time between failures) of 180,000 hours.

D. Ethernet Access switches shall have the following minimum port configuration:
   1. Uplink Ports:
      a. 2 x 1-Gigabit Ethernet SFP.
      b. Refer to 1Gigabit Ethernet Fiber Optic Interfaces as specified herein.
   2. Access ports
      a. 24 x 10/100Base-TX.
      b. RJ-45 connector, CAT6 unshielded twisted pair (UTP).

E. Each Ethernet Access switch shall meet, at a minimum, the following system specifications:
   1. Performance
      a. MAC Addresses
      1) Up to 8000.
2. Network Standards
   a. RMON I and II.
   b. SNMP V1, 2c, 3.
   c. 10/100Base-TX, IEEE standard 802.3u.
   d. 1000Base-ZX, IEEE 802.3z Ethernet full duplex.

3. Indicators - System Status LEDs
   a. System.
   b. Link status.
   c. Link duplex.
   d. Link speed.
   e. PoE (power over Ethernet).

4. Indicators - Per Port LEDs
   a. Link integrity.
   b. Disabled.
   c. Activity.
   d. Speed.
   e. Full-duplex.

5. Power
   a. 100 to 240 VAC, 60 Hz.

F. Each Ethernet Access switch shall meet, at a minimum, the following mechanical and environmental specifications:

1. Rack mount
   a. 19 inch (483 mm).

2. Operating Temp
   a. -5 to +45 degrees C (23 to 113 degrees F).

3. Humidity
   a. 10 to 95 percent condensing.
A. Industrial Ethernet switches shall be installed Traction Power Substations (TPSS) and Driver Comfort Stations, as shown in the Contract Drawings.

B. Industrial Ethernet switches shall be rugged switches designed for transportation network solutions.

C. Industrial Ethernet switches shall allow for setup and management using the NMS as specified herein.

D. Industrial Ethernet switches shall have a minimum MTBF (mean time between failures) of 200,000 hours.

E. Industrial Ethernet switches shall have the following minimum port configuration:
   1. Uplink Ports:
      a. Minimum of 2 uplink ports.
      b. Uplink ports shall be one of the following:
         1) 10/100/1000Base-T, RJ-45 connector, CAT6 cabling;
         2) 100Base-FX, multi-mode, MT-RJ connector.
      c. Contractor shall configure and use the 10/100/1000 Base-T uplink port where connection to the Ethernet Access Switch in the C&S House or CIC cabinet is less than 100 meters as shown in the Contract Drawings. Contractor shall provide and install CAT6 unshielded twisted pair (UTP) cable for this connection. See Section 271500 for requirements for CAT6 cable.
      d. Where the connection between the industrial Ethernet switch and the Ethernet Access Switch is greater than 100 meters, the Contractor shall provide and install media converters and multi-mode fiber optic cable, as shown in the Contract Drawings. Contractor shall provide and install multi-mode fiber optic cable for this connection. See Section 271500 for requirements for multi-mode fiber optic cable.
         1) Alternatively, the Contractor may provide and use the 100Base-FX uplink ports in the industrial Ethernet switch and the SFP ports in the Ethernet Access Switch for this connection. If this alternative is used, Contractor shall ensure complete compatibility between the uplink ports in the industrial Ethernet switch and the SFP Ethernet Access Switch.
e. Refer to 1Gigabit Ethernet Fiber Optic Interfaces as specified herein.

2. Access ports
   a. Minimum of 4, 10/100Base-TX.
   b. RJ-45 connector, CAT6 cabling.

F. Each Industrial Ethernet switches shall meet, at a minimum, the following system specifications:
   1. Performance
      a. MAC Addresses
         1) Up to 8000.
      b. Switching Fabric
         1) Up to 13.0 Gbps.
   2. Network Standards
      a. RMON I and II.
      b. SNMP V1, 2c, 3.
      c. VLAN, IEEE 802.1Q
      d. RSTP, IEEE 802.1w
      e. 10/100Base-TX, IEEE standard 802.3u.
      f. Full duplex on 10BASE-T, 100BASE-TX, 1000BASE-T, IEEE 802.3x
   3. Safety Standards
      a. IEC 60950 Information Technology Equipment - Safety.
   4. Indicators - System Status LEDs
      b. Major and minor alarm relay indicators.
   5. Indicators - Per Port LEDs
      a. Link integrity.
      b. Disabled.
      c. Activity.
   6. Power
      a. 120 VAC, 60 Hz – for installation in Driver Comfort Station;
      b. 125 VDC - for installation in TPSS.
G. Each Industrial Ethernet switches shall meet, at a minimum, the following mechanical and environmental specifications:

1. Compact PLC-style form factor
   a. DIN rail mount;
   b. Maximum dimensions: 6.0 x 12.0 x 6.0 inches (H X W x D) including power supply

2. Operating Temp
   a. -40 to +60 degrees C (-40 to 140 degrees F).

3. Humidity
   a. 10 to 95 percent non-condensing.

4. Shock
   a. 20g operational.

2.07 NETWORK MANAGEMENT SYSTEM (NMS)

A. The NMS shall allow remote monitoring and provisioning of equipment associated with the CTS as specified herein.

B. The NMS shall be implemented using one or more COTS (Commercial Off-The-Shelf) software products, based on open standards. The NMS shall be based on a graphical user interface, capable of running on a single computer server and workstation.

C. The hardware/software platform running the full-featured enterprise version of the NMS provided and installed at the OCC, shall be a COTS rack mounted server, and a workstation with the following minimum requirements:

1. Processor
   a. Dual core Intel® Xeon® 2.9 GHz.

2. Front Side Bus
   a. 1066 MHz.

3. Cache
   a. 8MB L2.

4. Memory
   a. 4 GB.

5. Graphics adapter
   a. 512 MB PCI, PCIe, 15-pin VGA connector.
6. Hard drive
   a. 160 GB.

7. Optical drive
   a. 16X DVD-ROM Combo.

8. Network
   a. Dual 10/100/1000Base-T Gigabit Ethernet, RJ45.

9. USB
   a. 2 USB (universal serial bus) 2.0 ports.

10. Operating System

11. Workstation
    a. Base System
       1) Processor: Intel® Xeon®, 2.6 GHz;
       2) Memory: 2 GB;
       3) Hard Drive: 250 GB;
    b. Keyboard
       1) 105 key;
       2) USB interface.
    c. Mouse
       1) USB optical scroll mouse.
    d. Monitor:
       1) Type
          a) 20-inch LCD.
       2) Resolution
          a) Up to 1600 x 1200 UXGA.
       3) Brightness
          a) 250 cd/m²
       4) Contrast ratio
          a) 700:1.
       5) Response time
          a) 15 ms.
       6) Viewing angles
          a) ±85 degrees horizontal and vertical.
D. The Contractor shall provide and install a hardware / software platform running the monitor-only version of the NMS software at the Backup OCC.
   1. The monitor-only version of the NMS software shall be from the same manufacturer as the full-featured enterprise level NMS software running at the OCC.
   2. The hardware platform running the monitor-only NMS software shall be a COTS workstation with the same specifications as the workstation used for the full-featured enterprise level NMS described elsewhere in this Section.

2.08 CTS INTERFACE ROUTER

A. The Contractor shall provide a router that shall be used as an interface between the CTS and the existing METRO wide area network (WAN).

B. The CTS Interface router shall be installed at the OCC (TranStar).

C. CTS Interface router shall have the following minimum port configuration:
   1. Copper Ports
      a. 2 x 10/100Base-T.
      b. RJ-45 connector, CAT6 unshielded twisted pair (UTP).

D. The CTS Interface router shall have a software-based firewall implemented in its processor.
   1. The firewall shall act as an implicit barrier between network interfaces on the METRO WAN and network interfaces within the CTS.
   2. The firewall shall provide stateful, application-based filtering.
   3. The firewall shall provide per-user authentication and authorization.
   4. The firewall shall provide real-time alerts.
   5. The firewall shall be IP version 6 (IPv6) compliant.
   6. The firewall shall provide the IP Security (IPsec) protocol suite for authentication and encryption and shall include the following:
      b. Triple DES.
      c. Advanced Encryption Standard (AES) 128, AES 192, and AES 256

E. The CTS Interface router shall meet, at a minimum, the following mechanical and environmental specifications:
   1. Rack mount
a. 19 inch (483 mm).

2. Operating Temp
   a. 0 to +40 degrees C (32 to 104 degrees F).

3. Humidity
   a. 5 to 95 percent non-condensing.

F. The CTS Interface router shall meet, at a minimum, the following electrical specifications:
   1. Power
      a. 100 to 240 VAC.
      b. 47 to 63 Hz.

2.09 GPS MASTER CLOCK

A. The Contractor shall provide a GPS (global positioning system) based master clock.

B. The GPS master clock, and associated GPS antenna and coax cable, shall be installed at the OCC/ROC.

C. The GPS master clock shall be a network time server that shall distribute time via the network time protocol (NTP) to all equipment connected to the CTS requiring time information.
   1. The GPS master clock shall provide up to 5000 NTP packets per second with less than 10 microsecond time stamp accuracy.
   2. The GPS master clock shall provide 0.5 to 2 ms typical client synchronization accuracy on the CTS.
   3. The GPS master clock shall support NTP v2, v3, and v4.
   4. The GPS master clock shall support NTP unicast, broadcast, and multicast.

D. The GPS master clock shall meet, at a minimum, the following specifications:
   1. Stratum 1 operation via GPS satellites
      a. In Stratum 1 operation, the GPS master clock shall derive its time directly from the atomic clocks aboard the GPS satellite system.
      b. The GPS master clock shall have an integrated 12-channel GPS receiver.
c. Every visible satellite shall be tracked and used to maintain time.

d. Single satellite timing shall be supported.

2. The GPS master clock shall have a minimum of 3 independent 10/100Base-T ports for connection to separate networks.

3. The GPS master clock shall have a display and full numeric keypad. The display shall provide the ability to show the current time and status.

   a. The display shall have a minimum of 256 x 32 resolution, and have variable brightness.
   b. The display shall have user selectable formats with 1, 2 or 4 lines displayed.
   c. The display shall show time in UTC (coordinated universal time), or in local time.

4. The GPS master clock shall be IPv6 and IPv4 compliant.

5. The GPS master clock shall provide the ability for management via network connection using web-based tools.

6. The GPS master clock shall support the following network protocols and services

   a. SSH;
   b. SSL;
   c. SCP;
   d. SNMP v3;
   e. Custom MIB;
   f. HTTPS (Hypertext Transfer Protocol over Secure Socket Layer);
   g. Telnet;
   h. Email alerts for alarms or errors.

7. In the event the GPS signal is lost, GPS master clock shall provide Stratum 2 operation by receiving time from other NTP Servers on the network.

8. The GPS master clock shall have nanosecond time accuracy to UTC.

E. The GPS master clock shall include a 12 volt L1 band GPS antenna with 30m (100 ft) of coaxial cable and lightning arrestor.

**PART 3 : EXECUTION**
3.01 INSTALLATION

A. The Contractor shall install all data communication network equipment in accordance with the manufacturers’ instructions at each location as shown in the Contract Drawings, and as specified herein.

B. Contractor shall provide and install all equipment and material necessary to form a complete and operational CTS.

C. Contractor shall install all rack mounted data communications network equipment in communications equipment cabinets as specified in Section 271100.

D. Contractor shall install all fiber optic connections between CTS Backbone switches in each C&S to the fiber distribution panels (FDP) as shown in the Contract Drawings. Contractor shall refer to Section 271500 for requirements regarding FDPs and fiber cable required for installation of the data communications network equipment defined in this Section.

E. Contractor shall install all copper and fiber connections between Ethernet Access switches in each C&S and CIC cabinet to the copper patch panel and FDP as shown in the Contract Drawings. Contractor shall refer to Section 271500 for requirements regarding FDP, copper patch panels, terminal blocks, protector blocks, and fiber and copper cable required for installation of the data communications network equipment defined in this Section.

F. Installation of all data communications network equipment shall be consistent from site to site to provide uniformity in installations.

G. The Contractor is required to ensure that the installation of new equipment does not adversely affect the operation of any existing systems.

3.02 TESTING

A. Contractor shall notify the Engineer a minimum of two weeks in advance of the testing of the data communications network equipment and the CTS so that the Engineer or the Engineer’s representative may be present for the tests.

B. Following completion of the installation of all data communications network equipment at each site, Contractor shall inspect all equipment and wiring to verify that all mechanical connections are made and properly secured, and all hardware is installed in its proper location and is properly terminated.
1. Contractor shall perform all inspections and tests for the CTS as specified in Section 279000, “Communications System Inspection and Testing”.

C. The Network Management System, including the computer workstation and all software applications, shall be tested as an integrated system. The NMS shall be programmed as specified elsewhere in this Section.

1. All necessary tables or network maps shall be entered and stored in the NMS software.

2. The NMS shall provide remote configuration and status monitoring of all individual nodes connected via 10 Gigabit and 1 Gigabit optical interfaces, from the OCC/ROC.

3. The NMS shall provide remote configuration and status monitoring of all individual devices connected to 10/100Base-TX ports on all Ethernet Access switches, from the OCC/ROC.

4. At the OCC/ROC and at each station C&S, each 10 Gigabit, 1 Gigabit, and 10/100Base-TX interface and subnet, shall be configured, installed, numbered, and labeled according to the Contract Drawings.

5. The NMS shall audibly announce, display, and log all alarms in the OCC/ROC. This shall be tested with simulated error conditions, to verify that all NMS alarms appear on the NMS user interface and logged in the NMS database.

END OF SECTION
a. All ground connections shall use copper conductors with
SECTION 279000

COMMUNICATIONS SYSTEMS INSPECTIONS AND TESTING

PART 1 : GENERAL

1.01 DESCRIPTION

A. Work Included

1. The Work of this Section consists of testing and inspecting the Communication System, associated with the Houston METRO Solutions Phase 2 Light Rail Transit Extension project (LRT), as described in the Contract Documents and as specified herein.

B. Through testing and inspection, Contractor shall verify the Communication System meets Contract specifications and all functional and performance requirements.

1. Contractor shall test and inspect all items of hardware and software that it supplies, and furnish test results to the Engineer.

C. Tests and inspections shall be conducted according to procedures submitted by Contractor and approved by the Engineer.

1. Suppliers’ existing inspection and factory acceptance test (FAT) procedures may be utilized upon the Engineer’s approval.

D. Contractor shall furnish all labor and materials necessary to perform tests, record data, and prepare reports.

E. Changes required to bring the Communications System into compliance shall be at no additional cost to METRO, including costs for additional testing.

F. Upon completion of each test, all test equipment and temporary facilities shall be removed and the system restored to full operational status.

G. Contractor shall coordinate all testing which involves existing LRT facilities, including but not limited to the Main Red line and the Operation Rail Operations Center (ROC), and TranStar, with METRO.
1.02 QUALITY ASSURANCE

A. Materials specified shall meet or exceed the requirements of the cited references.

B. Qualifications:
   1. The Contractor shall provide all product cut sheets as required for the Engineer’s evaluation.

1.03 CITED REFERENCES

A. American National Standards Institute (ANSI)
   1. S1.4 – Specification for Sound Level Meters
   2. S1.13 – Methods for the Measurement of Sound Pressure Levels
   3. S3.5 – Methods For the Calculation Of the Speech Intelligibility Index (SII)

B. International Electrotechnical Commission (IEC)
   1. 60268-16 – The Objective Rating Of Speech Intelligibility by Speech Transmission Index (STI)

C. Telecommunications Industry Association/Electronics Industries Alliance (TIA/EIA)
   1. 455 Series – Fiber Optic Test Procedures
   2. 490 – Standard Test Methods of Measurement for Audio Amplifiers
   3. 526 – Standard Test Procedures for Fiber Optic Systems
   4. 603 – Land Mobile FM or PM Communications Equipment Measurement and Performance Standards
   5. 810-B - Transmission Requirements for Narrowband Voice Over IP and Voice Over PCM Digital Wireline Terminals
   6. 920 - Telecommunications Telephone Terminal Equipment Transmission Requirements For Wideband Digital Wireline Telephones

D. Military Standards
   1. MIL-STD 810 – Environmental Engineering Considerations and Laboratory Tests
1.04 SUBMITTALS

A. The Contractor shall provide the following submittals as described in Part 2 of this Section:

1. Inspection and Test Plan.
2. Factory Inspection and Test Procedures.
3. Field Inspection and Test Procedures.
4. Test Reports.
5. Test Setup Block Diagrams
   a. Contractor shall submit block diagrams depicting test setup for each test, test equipment to be used, procedures, and method for recording data in all cases except where tests are to be performed in full accordance with published standards.

B. The Contractor shall refer to Submittals and 270000 Communications for additional requirements regarding submittals.

1.05 RELATED WORK

A. Section 270000 – Communications
B. Section 270500 – Common Work Results for Communications
C. Section 270800 – Commissioning of Communications
D. Section 271100 – Communications Equipment Room Fittings
E. Section 271300 – Communications Backbone Cabling
F. Section 271500 – Communications Horizontal Cabling
G. Section 271600 – Communications Connecting Cords, Devices and Adapters
H. Section 272100 – Data Communications Network Equipment
I. Section 273100 – Voice Communications Switching Equipment
J. Section 273200 – Telephone Equipment
K. Section 275100 – Public Address and Passenger Information Signs System
L. Section 278000 – Uninterruptible Power Supply
M. Section 282300 – Video Surveillance System
N. Section 281643 – Perimeter Security System
O. Section 284600 – SCADA

PART 2 : PRODUCTS

2.01 STATISTICAL SAMPLING PLANS

A. Sampling plans may be used when tests are destructive, or when quality trend data, inherent characteristics of the product, or the non-critical application of the product indicate that a reduction in testing or inspection can be achieved without jeopardizing quality.

B. Contractor shall provide details on any sampling plans and submit the proposed sampling plan to the Engineer for approval prior to its use.

C. Any sampling plan used shall provide valid confidence and quality levels, as solely determined by the Engineer.

2.02 TEST EQUIPMENT

A. Contractor shall supply all test equipment required for factory and field testing.

2.03 INSPECTION AND TEST PLAN

A. Contractor shall submit an Inspection and Test Plan for the Communication System to the Engineer for approval.

B. The purpose of the Inspection and Test Plan shall be to:
   1. Identify all of the inspections and tests to be performed.
   2. Ensure that testing is in compliance with the overall Quality Assurance Program.
   3. Achieve mutual understanding between Contractor and the Engineer on the range, depth, and other aspects of tests to be conducted.

C. The Inspection and Test Plan shall contain the following as a minimum:
   1. Flow diagram showing the logical sequence of inspections and tests starting with qualification and factory assembly and concluding with system demonstration.
2. List of factory and manufacturer’s recommended field test and inspection procedures, proposed submittal schedule, and proposed test schedule.

3. Outline and format of procedures and test data sheets for each type of test.

4. Requirements (if any) for METRO personnel.

5. Recommendations for witnessing by the Engineer.

6. Organization chart and description of Contractor’s factory and field test organizations.

7. Diagram showing the flow of quality assurance and test data and its use within Contractor’s Engineering and Quality Assurance organizations.

8. A list of all test equipment to be used in testing and calibration of the Communications System.
   a. The list shall include manufacturer and model number of each piece of test equipment and shall include date of calibration/certification, which shall be within 60 days prior to use.

9. Proposed test schedule indicating tests that must be conducted during LRT’s peak operating hours, and tests that could interfere with LRT’s revenue service.

2.04 TEST PROCEDURES

A. Contractor shall submit all test procedures to the Engineer for approval at least 60 days before the scheduled test.

B. No test procedures will be approved by the Engineer prior to approval of Contractor’s Inspection and Test Plan.

C. Test procedures shall include, as a minimum, the following information:
   1. Objective and scope.
   2. Test setup.
   3. Test prerequisites.
   4. Test equipment to be used.
   5. Personnel required for the test.
   6. Estimated duration of the test.
   7. Pass/fail criteria.
   8. Samples of data sheets.
SECTION 279000 COMMUNICATIONS SYSTEM INSPECTION AND TESTING

D. Procedures shall include all inspections, tests and documentation required by the Federal Communications Commission (FCC) and other regulatory agencies as appropriate.

E. Procedures shall include electromagnetic interference compatibility testing and integrated system testing.

F. No material or test equipment will be furnished by LRT for any testing or inspection.

1. Requests for LRT operating personnel shall be submitted to the Engineer no later than 30 days before any testing is to be performed.

G. Supplier’s existing test and inspection procedures may be utilized upon the Engineer’s approval.

2.05 INSPECTION AND TEST REPORTS

A. Contractor, Subcontractors, and Suppliers shall submit to the Engineer signed inspection and/or test reports for every inspection and/or test performed no later than 10 days after completion.

B. Test reports shall contain, as a minimum, the following information:

1. All data obtained during tests.
2. Analysis of the data.
3. Conclusions relating to the pass/fail criteria outlined in the test procedure.
4. Discrepancies found and corrective action taken.
5. Date of test.
6. Signature of person conducting the test.
7. Space for signature of witness.
8. Specific test equipment used by name, type, serial number, and calibration details.
9. Tested equipment item by serial number.
10. Statements of remediation done to pass tests, retest criteria, and retest results.

a. Test equipment of the same model and, if at all possible, the same serial number shall be used during retesting to ensure consistency.

b. Changes made by Contractor in order to pass tests shall be at no additional cost to METRO.
C. Inspection reports shall contain, as a minimum, the following information:

1. Complete description of facilities inspected.
2. Complete description of observations.
3. Discrepancies found and corrective action taken.
4. Suggested actions, including but not limited to leased facilities ready for disconnection.
5. Date of inspection.
6. Signature of person conducting inspection.
7. Space for signature of witness.

D. All factory and field inspection and test reports shall be documented on approved forms and submitted as project record.

2.06 FACTORY INSPECTIONS AND TESTS

A. Contractor shall inspect and test each item to be provided under the Contract. The following inspections and tests shall be included:

1. Receiving inspection of raw materials or component parts at the factory.
   a. These inspection measures shall be used to preclude the use of incorrect or deficient products and to ensure that only products which are acceptable and in compliance with the Contract Documents are used and installed.
   b. All product certifications and Test Reports used as the basis for acceptance by Contractor shall be preserved.
2. In process inspections of production operations.
3. Factory qualifications testing, if applicable, as described in Article 2.07.
4. First article inspection test, if applicable, as described in Article 2.08.
5. Environmental testing, if applicable, as described in Article 2.09.
6. Factory acceptance tests, as described in Article 2.10.

B. General Requirements for Factory Inspections and Tests

1. Design tests: All subsystems, equipment, and components shall be tested at the factory on the first assembled equipment or system component to demonstrate compliance with specifications and/or industry standards.
2. Production tests
a. All systems, subsystems, and equipment shall be 100 percent factory inspected and tested to verify the quality and correctness of the manufacturing and assembly process.

3. The Engineer shall have the right to witness inspections or tests in Contractor’s, Subcontractor’s, or Suppliers’ plants.

4. Contractor shall obtain the Engineer’s approval of test results prior to making any shipment from its or its Suppliers’ plants.

5. When approved by the Engineer, Suppliers’ existing factory test procedures may be used.

C. Rack Wiring

1. All factory-installed rack wiring shall be tested before shipment.

2. Contractor shall perform point-to-point tests to verify the continuity and connection of each conductor.

D. Operational Testing

1. All equipment shall be operationally tested as a complete functional assembly prior to shipment.

2. Contractor shall test each function by simulating operating conditions.

E. Notification of Testing

1. In order to have the opportunity to witness testing, the Engineer shall be notified in writing a minimum of 2 weeks in advance of each test.

2. When tests are to be conducted continuously as a production-line routine, Contractor shall inform Engineer in writing at least 2 weeks in advance of the date of testing and the expected duration.

2.07 FACTORY QUALIFICATIONS TESTING

A. Qualification testing is required for new or modified components, systems, or equipment to verify that environmental and design requirements of the Contract are met.

B. Qualifications testing may not be required for service-proven components, systems, or equipment based upon service records or previous qualification test records approved by the Engineer.

C. Qualifications testing shall include environmental testing (temperature, humidity, vibration, etc.) as well as testing under normal and abnormal conditions.
2.08 FIRST ARTICLE INSPECTION (FAI)

A. Contractor shall perform a comprehensive FAI on the first production item of any component or system that requires qualification testing as specified herein.

B. FAI shall be required even for service-proven equipment if the equipment has been modified.

C. FAI shall include all interfaces to assure the complete and proper operation of the equipment.

D. FAI shall require approval of the Engineer before additional systems are manufactured or installed.

2.09 ENVIRONMENTAL TESTING

A. All equipment shall be proven to operate properly over the temperature, humidity, and mechanical vibration and shock range defined in these specifications.

B. Environmental testing shall be in conformance with MIL-STD 810.

C. Service-proven equipment may not require environmental testing, but shall require evidence of proper performance in previous tests or similar operating environment, subject to Engineer approval.

2.10 FACTORY ACCEPTANCE TESTS (FAT)

A. Prior to shipments, Contractor shall test all products to be delivered for installation into the Work or otherwise delivered to the Engineer to assure completion and conformance to the requirements in the Contract Documents.

1. The Contractor shall assemble and test all the major hardware, software components and subsystems.
   a. A 72-hour burn-in shall be performed for each piece of equipment.
      1) Subsequent to burn-in, diagnostic testing, utilizing standard manufacturer supplied tests, shall be performed for all equipment and each communications port.
   b. All equipment configuration, management, and diagnostic functions shall be exercised and demonstrated as operational.
c. The performance of the components and subsystems shall be demonstrated while operating under peak loading conditions.

1) Simulated peak loading shall be defined in the written test procedures.

2. For FAT, all hardware and software shall be assembled and tested at the Contractor's, Subcontractor's, or Suppliers' facility, using simulated inputs and outputs (i.e. data, voice, video, controls, and indications), special test equipment, and software to confirm that the Communications System meets all the Specification requirements.

3. The Contractor shall define the factory test bed configuration(s) within the test procedures for FAT.

4. The Contractor shall supply test procedures for FAT, subject to review and approval by the Engineer, as specified elsewhere in this Section.

5. At a minimum, the specified components of the FAT shall include but not be limited to:

a. Review of documentation from all testing and quality checks to support initiation of the FAT.

b. Demonstration of communication between components within each subsystem comprising the Communications System including, but not limited to, the following:

1) The backbone communications network (i.e. the CTS), including fiber optic and copper cabling interfaces;

2) Telephone system and voice communications switching equipment providing voice over IP (VoIP) functionality;

3) Public Address / Passenger Information Signs System (PA/PIS);

4) Uninterruptible Power Supplies;

5) Video Surveillance System;

6) Supervisory Control and Data Acquisition (SCADA) System.

c. Demonstration of control functionality;

d. Demonstration of response to controls;

e. Verification of changes in state of indications;

f. Demonstration of user interfaces;
SECTION 279000 COMMUNICATIONS SYSTEM INSPECTION AND TESTING

PART 3 : EXECUTION

3.01 FIELD INCOMING INSPECTIONS AND TESTS

A. Contractor shall perform receiving inspection for incoming products at each worksite, including each station in the LRT Extension and the Operations Control Center (OCC) and the Backup OCC at the existing METRO TransStar And Rail Operations Center (ROC) facilities respectively (OCC/ROC).

   1. Inspection shall preclude the use of incorrect or deficient products and ensure that only products which are acceptable and in compliance with the Contract Documents are used and installed.

   2. All product certifications and Test Reports used as the basis for acceptance by Contractor shall be preserved.

B. Contractor shall maintain a receiving inspection log for all items received at the worksite. Contractor shall submit the content of the log for the Engineer’s approval.

3.02 FIELD INSPECTIONS AND TESTS

A. Contractor shall verify the quality of the installation by inspections and tests including, but not limited to, the following:

   1. Missing components and parts;
   2. Correct serial numbers;
   3. Damage to equipment;
   4. Conformance to standards, methods, and quality;
   5. Current location, positioning, mounting, orientation, and labeling;
   6. Correct and secure external connections;
   7. Correct and secure routing of internal connections;
   8. Correct and secure routing of cables and wires;
   9. Proper grounding;
   10. Tests of continuity and resistance of ground connections;
11. Verification of all configuration data and settings;
12. Correct labeling.

B. All tests required shall be performed to ensure the proper operation of all Communications System equipment and to prove the adequacy and acceptability of the total installation.

C. Contractor shall obtain recommended field inspections and tests from all Suppliers for all equipment to be used in this Contract.
   1. These manufacturers’ recommended field inspections and tests shall be contained in the Inspection and Test Plan.

D. Procedures for all tests shall be submitted for approval to the Engineer at least 60 days before the scheduled test.

E. The Engineer shall have the right to witness all field inspections and tests.
   1. The Engineer shall be notified in writing a minimum of 2 weeks in advance of each inspection or test.

F. Test Reports from Contractor and Suppliers shall be submitted within 10 days after performing tests.

G. Test Reports shall include any pass/fail history along with any corrective action taken to bring test into compliance, including recommended changes and retesting.

H. Contractor shall make every effort not to interfere with existing LRT systems during tests and inspections.
   1. Operational tests shall be performed during off-peak hours to the maximum extent possible.
   2. If interference with existing LRT systems is unavoidable, arrangements must be made with METRO a minimum of 2 weeks in advance of the test.

I. During all field inspections and testing, Contractor shall be available to make repairs of any failed equipment within 1 hour after discovery of the failure.

3.03 FIELD EQUIPMENT AND SUBSYSTEM TESTING

A. Tests to be performed shall cause each subsystem to be sequenced through all required operations and include simulated conditions as necessary to prove the installation is in compliance with requirements specified in the Contract Documents.
B. The following equipment field tests shall be performed for all installed equipment. Additional field tests for each subsystem, as specified in subsequent Sections, shall not be construed to limit or otherwise relieve the Contractor of the responsibility for performing comprehensive field testing of the following:

1. Basic equipment operation;
2. Functional and performance testing;
3. All external interfaces such as mechanical, electrical, and functional;
4. Operation in the presence of equipment and software failures;
5. Operation in the presence of power failure and restart;
6. Subsystem testing shall include:
   a. Tests for proper local operation;
   b. Tests to confirm the installed equipment or subsystem meets performance requirements;
   c. Validation of all data used to configure or operate the subsystem.

3.04 SUPPORT FOR THE SYSTEM INTEGRATION TEST

A. Upon turn-up, interface, and integration of all required individual subsystems required for the Contract, the Contractor shall provide technical support for the System Integration Test (SIT).

1. Technical support shall include providing engineer, technician, and installation staff as well as tools, appliances, fixtures, expendable materials, supplies, and test equipment as needed to perform the SIT procedures or develop and implement corrective actions on the Contractor's elements.

B. SIT shall involve the interaction of the Communications System operating with one or more other subsystems and will be required through the System Final Acceptance.

C. SIT shall include testing of all communications subsystems added to, modified, or integrated as a result of this Contract and integrated or interfaced to any other contract. Subsystem SIT testing shall include:

1. CTS node integration;
2. Proper transport and operation of Signaling controls and indications;
3. Proper transport and operation of Traction Power Substation (TPSS) controls and indications;
4. Proper transport and operation of Fare Collection data and indications;
5. Proper transport and operation of SCADA controls and indications, including fire/smoke and intrusion alarm indications, between field locations and the OCC/ROC;
6. Proper local and remote operation of PA and PIS messaging, including interaction with trains;
7. Proper operation of all telephone circuits between field locations and the OCC/ROC;
8. Proper local and remote operation of all IP CCTV cameras, and network video recorder associated with the Video Surveillance System.

3.05 INSPECTIONS AND TESTS FOR FINAL ACCEPTANCE

A. Final acceptance inspections and tests for each portion of the Communications System shall be performed subsequent to the SIT for that portion.
1. At this stage of the Contract all the defects and open items relevant to the Communications System and identified up to that time shall be closed prior to final inspection and acceptance test.

B. Final acceptance inspections and tests as outlined in these Specifications shall demonstrate to the Engineer that the Communications System is operating in accordance with the requirements of the Contract Documents.

C. “Complete Testing” shall be performed for all equipment that exhibited faults during the SIT.
1. “Complete Testing” shall be testing that is equivalent to the field and functional testing performed on the equipment when first installed as required by these Specifications and Engineer approved test procedures, including submission of test results and test reports.
2. Complete Testing shall be performed by the Contractor for all equipment that was replaced under warranty.
   a. For all subsystems and equipment that have changed after initial installation and testing the Contractor shall perform complete testing of such equipment.
D. The Contractor shall verify the accuracy of the as-built documentation for each equipment location.

3.06 TRAINS FOR TESTING

A. METRO will provide trains and crews to support the testing as necessary, subject to approval by the Engineer.

1. Trains shall be scheduled 30 days in advance.

3.07 FIBER OPTIC CABLE INSPECTIONS AND TESTS

A. Testing of fiber optic cabling, as described in Sections 271300 and 271500, shall be in conformance with TIA/EIA Standard 455, Fiber Optic Test Procedures.

B. Factory Inspections and Tests

1. Contractor shall ensure that each finished and installed fiber optic cable segment is traceable to the test date on file for each step in the manufacturing process.

2. Physical tests shall be made on samples selected at random at the place of production.
   a. Each test sample shall be taken from the accessible end of different reels.
   b. Each reel selected and the corresponding sample shall be identified.
   c. The number and lengths of samples shall be as specified for the individual test.

3. Optical tests shall be made on the entire length of each continuous fiber provided within each fiber optic cable.
   a. Each test shall be completed during manufacture as required, and again prior to shipping, after the cable is secured to the reel in final shipping packaged form.

4. All optical fibers shall be 100 percent attenuation tested at the factory for compliance with performance specifications described herein.
   a. The attenuation of each fiber shall be provided in a report provided with each cable reel.

5. The manufacturer shall provide, at the point of production, apparatus and labor for making any or all of the following tests under the supervision of the Engineer, to include, but not be limited to tensile strength, impact resistance (crushing and flexing), optical
SECTION 279000 COMMUNICATIONS SYSTEM INSPECTION AND TESTING

C. Field Inspections and Tests

1. All fibers shall be 100 percent attenuation tested in the field before pulling the fiber optic cable in place to assure no damage was incurred in shipment.

2. Upon completion of installation and termination of fiber optic cable, a visual inspection shall be made of all portions of the installation, recording all defects noted.

3. Upon completion of installation and termination of fiber optic cable, all fibers within each cable shall be tested as terminated on each fiber distribution panel.

4. Contractor shall notify the Engineer in writing at least 2 weeks in advance of testing so that the Engineer may be present for the tests.

5. Tests shall include but not be limited to the following:
   a. Cable length.
   b. Propagation delay.
   c. Optical loss.
   d. Point discontinuities.
   e. Optical spectral dispersion.
   f. OTDR.

6. All OTDR records and all other graphical test records shall be labeled and identified. The output shall be either photographic or computer printed/plotted.

7. Tests shall be conducted for both directions of transmission.
   a. All OTDR tests shall be made with an OTDR approved by the Engineer.

3.08 COPPER CABLE INSPECTIONS AND TESTS

A. Contractor shall perform inspections and testing of copper cabling, as described in Section 271500.

B. Factory Inspections and Tests

1. Tests shall include, but not be limited to:
   a. Tensile strength.
   b. Impact resistance, crushing and flexing.
c. Attenuation.

d. Mutual capacitance.
e. Insulation resistance.

f. Conductor resistance.
g. Conductor imbalance.
h. Crosstalk.
i. High voltage.
j. Shield continuity.

2. All copper data cabling, video cabling, and patch cords shall be tested with a Time Domain Reflectometer (TDR). The results shall be documented and submitted as project record.

C. Field Inspections and Tests

1. Installed Field Tests

a. Testing of copper data cable installed outside the Communications and Signal Houses (C&S), shall be performed before and after installation, and after complete termination of the cable.

2. Testing shall be performed on the copper conductors, as terminated on the Main Distributions Frames (MDFs).

3. Tests shall include, but not be limited to, the following:

a. Attenuation at 1 MHz, 100 MHz, and 250 MHz between terminations.

b. Conductor to conductor resistance.

c. Insulation resistance.

1) Prior to the test, disconnect power sources, direct connection to ground circuits, and any equipment that may be damaged by the voltages of the test instrument unless connection incorporates an isolation link.

2) Connection to ground for the test shall be the most convenient previously verified low resistance connection to ground available.

3) Test all wire and cable installed at the job site for insulation resistance between the conductor and ground, using a direct resistance reading instrument having a self-contained or generating test voltage of 500 to 1000 VDC.
4) Minimum insulation resistance to ground for circuits shall be 100 megohms. Wires and cable shall be replaced when insulation resistances are below these values. Actual resistance readings shall be recorded on test forms and submitted as project documentation.

d. TDR Test, conducted for both directions of transmission records.

4. All TDR records and all other graphical test records shall be labeled and identified. The output shall be either photographic or computer printed/ plotted.

5. Tests shall be conducted for both directions of transmission. All TDR tests shall be made with a TDR approved by the Engineer.

### 3.09 GROUND RESISTANCE TEST

A. Contractor shall test communication equipment room ground buses to ensure the resistance between each bus and the single point ground source is not greater than 4 ohms.

B. Fall of potential 3 point method shall be used to measure the resistance between ground rods and the surrounding earth.

C. Resistance between a ground rod driven at least 2439 mm (8 feet) from the point under test and each housing or junction box shall be less than 15 ohms. No chemical salts are permitted to achieve the required ground resistance.

D. All connections to the ground bus shall be tested to verify proper and adequate connections.

E. Contractor shall submit proposed test method and test equipment to be used for ground resistance test.

### 3.10 CABLE TRANSMISSION SYSTEM INSPECTIONS AND TESTS

A. System Level Factory Test

1. A System Level Factory Test of the CTS shall be performed by the Contractor.

2. Each component of the CTS listed below, shall be included in the test to demonstrate all interfaces between components and proper operation of components.

   a. The System Level Factory Test shall include the following:
1) A CTS Backbone Switch at from a minimum of two Communications Nodes (in each C&S);

2) Ethernet Access Switches at a minimum of two Communication Nodes (at each C&S) and a minimum of two Communications Interface Cabinet (CIC);

3) The CTS Backbone/Core Switches at the OCC and ROC;

4) All redundant 1 Gigabit and 10 Gigabit fiber optic interfaces (i.e. uplink ports) on all CTS Core, Backbone and Ethernet Access Switches used for testing;

5) All 10/100 Base-T ports on all CTS Ethernet Access Switches used for testing.

3. Inspection and Test Plan shall include a complete description of the LRT System Level Factory Test.

B. Field Inspection and Test

1. The CTS shall be tested as a system upon completion of installation. Tests shall include but not be limited to demonstrating and testing the following:

   a. Each 10/100Base-T and 1000Base-LX network access port at each station and at each Communications Node shall be tested end to end between the station and the OCC/ROC.

   b. Each access port shall be tested end to end with sufficient test equipment to test all functionality of the port.

   c. Full functionality of each ERS including but not be limited to the following:

      1) Performance requirements as specified in Section 272100;

      2) Redundancy and automatic failover of the following:

          a) Switch fabrics;

          b) CPUs;

          c) Power supplies;

          d) Cooling fans;

          e) Fiber optic interfaces.

      3) All routing functions as specified in Section 272100;

      4) Each VLAN;

      5) Link aggregation;

      6) Load balancing;

      7) Front panel indications.
d. Full functionality of the NMS including but not be limited to the following:

1) Communications with every CTS Backbone Switch and Ethernet Access Switch;
2) Communications with each device connected to access ports;
3) Display and logging of all alarms and faults;
4) Real time inventory access;
5) Access and password protection;
6) Software versions.

3.11 UNINTERRUPTIBLE POWER SUPPLY (UPS) INSPECTIONS AND TESTS

A. Field Inspections and Tests

1. Upon completion of installation of UPS, they shall be tested as a system, before being used to power other Communications subsystems.
   a. The UPS tests shall be conducted with a test load that is approximately equal to their rated loads.

2. UPS tests shall include but not be limited to the following:
   a. Proper operation under normal conditions (i.e. normal mode);
   b. Simulation of a main utility power failure (i.e. emergency mode)
      1) Verification of backup time;
   c. Return of main utility power after failure (i.e. recharge mode);
   d. Turning off the inverter (i.e. bypass mode);
   e. Maintenance bypass mode;
   f. The following shall be recorded for each of the above conditions:
      1) Audible noise.
      2) Voltage regulation over load range.
      3) Dynamic response to step change from 20 percent to 100 percent of the full rated load.
   g. External Monitoring and Communications Interfaces
      1) Status and alarm indications with contact closure outputs.
2) Status and alarm indications monitored using simple network management protocol (SNMP) via network interface.

h. Battery capacity and recharge time.

3.12 TELEPHONE SYSTEM INSPECTIONS AND TESTS

A. Field Inspections and Tests

1. Following completion of the installation of all telephones at each site, as specified in Section 273200, and voice communications switching equipment as specified in Section 273100, Contractor shall inspect all equipment and wiring to verify that all mechanical connections are made and properly secured, and all hardware is installed in its proper location and is properly terminated.

2. Testing shall be accomplished from the wiring frame in the site communication room as well as testing from any local termination in the vicinity of an instrument. Testing shall include but not be limited to the following:

   a. Conductor and shield continuity from each telephone location to protector block on MDF.

   b. Isolation verification of all installation wiring.

3. Upon completion of installation and integration with LRT extension and existing LRT PBX at the OCC/ROC, end to end tests shall be conducted for every phone installed under this contract.

   a. Telephones shall be tested for full functionality and voice quality as specified in Section 273200.

3.13 PA / VARIABLE MESSAGE SIGN INSPECTIONS AND TESTS

A. Testing of PA amplifiers shall be in conformance with EIA Standard 490.

B. Field Inspection and Tests

1. Contractor shall test the PIS/PA equipment in each station once installation is complete and the Engineer has approved the inspection certification. System testing shall address at minimum:

   a. Functional testing of each equipment item installed.

   b. Each individual speaker output shall be tested by measuring the sound pressure level generated by the speaker.

      1) Contractor shall verify that the speaker meets (recommend 95 */dB) at 1 meter (3.3 ft) on centerline axis with the speaker adjusted for 1 watt input power.
SECTION 279000 COMMUNICATIONS SYSTEM INSPECTION AND TESTING

2) The equipment used to test and document the sound pressure level shall be an industry recognized, ANSI S1.4 compliant, Sound Pressure Level meter, and audio spectrum analyzer for white noise generation.

c. Balancing and adjusting speaker levels throughout the system to demonstrate an average sound pressure level of 6 dBA ±2 dBA above ambient noise levels, at ear level [1.5 m (4.9 ft.) above floor level], throughout the station areas.

d. Speech Intelligibility Performance Requirements

1) Average Performance Level
   a) The Contractor shall ensure that the PA/PIS as a whole provides a Speech Transmission Index (STI) averaging 0.60 over at least 90 percent of the target coverage areas on a per zone basis.
   b) Contractor shall note that this average level of speech intelligibility corresponds to an Articulation Index (AI) of 0.67, and is equal to 0.78 on the Common Intelligibility Scale (CIS).

2) Minimum Performance Level
   a) The Contractor shall ensure that the PA/ PIS as a whole meets or exceeds the NFPA 72 standard for minimum intelligibility.
   b) The Contractor shall ensure that the PA/ PIS as a whole provides a minimum STI of 0.50 over 100% of the target coverage areas on a per zone basis.
   c) Contractor shall note that this level of speech intelligibility corresponds to an Articulation Index (AI) of 0.50, and is equal to 0.70 on the Common Intelligibility Scale (CIS).

e. Demonstration of live ad-hoc announcements from the test microphone in the C&S.

f. Demonstration of pre-recorded auto announce train arrival messages triggered by track circuits.

g. Demonstration of all system control functions available at the following locations:
   1) Stations;
   2) OCC/ROC.

h. Demonstration of summary report for all PA/ PIS alarms and fault conditions.
3.14 SCADA INSPECTIONS AND TESTS

A. Integration testing of the complete SCADA system shall follow completion of all work regarding the SCADA system, including system testing at all stations in the LRT Extension, and at the OCC/ROC.

1. Integration testing shall consist of exercising the overall SCADA system from the OCC/ROC and locally within the C&S to verify its operation.

B. Field Inspection and Tests

1. Testing shall include but not be limited to the following:
   a. Interface with RTU and IP telephone at the TPSS;
   b. Failure and status alarms on equipment in the C&S as defined in Section 284600;
   c. Miscellaneous station (facility) command and indications as defined in Section 284600.

3.15 VIDEO SURVEILLANCE SYSTEM INSPECTIONS AND TESTS

A. Integration testing of the complete Video Surveillance System shall follow completion of all work regarding the Video Surveillance System, including system testing at each station in the LRT Extension, and at the OCC/ROC.

1. Integration testing shall consist of exercising the overall Video Surveillance System from all onboard vehicles, at each passenger station, and from the OCC/ROC, to verify its operation.

B. Field Inspection and Tests

1. Inspection of installation at all locations.

2. Testing shall include but not be limited to the following:
   a. Manufacturer suggested field tests of all components;
   b. Quality of picture on all monitors from all cameras and network video recorders (NVR);
   c. PTZ functionality;
   d. Full functionality of all major components:
      1) User interface on workstations at the at the OCC/ROC;
      2) NVR, including but not limited to recording, searching, and playback of video;
      3) Cameras;
SECTION 279000 COMMUNICATIONS SYSTEM INSPECTION AND TESTING

4) PTZ drives;

5) Communication of video and PTZ data via the CTS.

END OF SECTION
PART 1 : GENERAL

1.01 DESCRIPTION

A. Work Included

1. The Work of this Section consists of designing, furnishing, installing, testing and commissioning a Video Surveillance System, a subsystem of the Communications System, as described in the Contract Documents and as specified herein, associated with the Houston METRO Light Rail Transit (LRT) expansion project. The Video Surveillance System shall be an Internet Protocol Video (IPV) System.

2. This Section describes the requirements of the IPV System that shall provide for the control, monitoring, and management of real-time and recorded video from fixed and pan/tilt/zoom (PTZ) digital IP cameras located at the following locations:

   a. Passenger stations;
   b. Selected street crossings;
      1) Images from LRVs are transmitted to wayside access points via wireless IEEE 802.11;
      2) The images from LRVs shall be sent from the wireless access points to Communications nodes.
   c. Traction Power Substations (TPSS)
   d. Communications and Signal (C&S) Houses

B. The IPV System shall include network video recorders (NVRs), consisting of industrial grade rack mount servers with internal storage and associated network video and camera management software applications, installed in each Communications Node.

C. Each NVR shall include communication interfaces to the Communications transmission system (CTS) consisting of a fiber optic, wireless, and copper backbone as specified in Section 272100.
1. Communication interfaces from each NVR to the CTS shall be via dual redundant 10/100Base-T Ethernet.

1.02 QUALITY ASSURANCE

A. Materials specified shall meet or exceed the requirements of the cited references.

B. Qualifications

1. The Contractor shall provide all product cut sheets as required for the Engineer’s evaluation.

2. Contractor shall utilize supervision and labor experienced in performing the Work required herein in a skillful and satisfactory manner, and according to the project schedule.

3. IPV System equipment shall have been satisfactorily used in projects of similar size and complexity for no less than two years.

1.03 CITED REFERENCES

A. Institute of Electrical and Electronic Engineers (IEEE)

1. 802.1 - Local Area Network / Metropolitan Area Network (LAN/MAN) Bridging & Management

2. 802.3 - Local Area Network protocols

B. Internet Engineering Task Force (IETF) Internet Standards

1. RFC 768 UDP (User Datagram Protocol )

2. RFC 783 TFTP (Trivial File Transfer Protocol)

3. RFC 791 IP (Internet Protocol)

4. RFC 792 ICMP (Internet Control Message Protocol)

5. RFC 793 TCP (Transmission Control Protocol)

6. RFC 826 ARP (Address Resolution Protocol)

7. RFC 854 Telnet Protocol

8. RFC 951 / RFC 2131 BootP / DHCP

9. RFC 1112 IGMP (Internet Group Management Protocol)

10. RFC 1157 SNMP (Simple Network Management Protocol)

11. RFC 1213 TCP/IP Management Information Base (MIB)

12. RFC 1215 Traps

13. RFC 1305 NTP v3 (Network Time Protocol)
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<td>RFC 2362 PIM-SM (Protocol Independent Multicast – Sparse Mode)</td>
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<td>RFC 2385 BGP-4 MD5 authentication</td>
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<td>a. RTP: A Transport Protocol for Real-Time Applications</td>
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<td>RFC 2934 PIM MIB</td>
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44. RFC 4022 TCP MIB
45. RFC 4113 UDP MIB

C. National Television Systems Committee (NTSC)
   1. 3.58 – National Television System Committee

D. International Organization for Standardization (ISO) / International Electrotechnical Commission (IEC)
   1. ISO/IEC 14496-2 Coding of audio-visual objects part 2 visual; includes standard for MPEG-4 (Moving Pictures Experts Group)

E. International Telecommunications Union (ITU)
   1. Recommendation BT470.7 - Conventional Analog Television Systems (i.e. NTSC)

F. Military Standards

   1. 60529 - Degrees of Protection Provided by Enclosures (IP Code)

H. National Electrical Manufacturers Association (NEMA)
   1. 250 - Enclosures for Electrical Equipment (1000 Volts Maximum)

1.04 SUBMITTALS

A. The Contractor shall provide the following submittals for the IPV System, as described in Section 270000 Communications:
   1. System Design;
   2. Functional Site Block Diagram;
   3. Arrangement Plan;
   4. Installation Plan;
   5. Wiring Plan;
   6. Power Wiring Plan;
   7. Allocation and Provisioning Plan;
   8. Operation and Maintenance (O&M), and Programming Manuals.
B. The Contractor shall submit technical data sheets and catalog cuts for each item.

C. The Contractor shall submit manufacturer’s warranty information.

D. The Contractor shall submit an IPV System Chart, with text description of each camera to be monitored and controlled by the IPV System. The IPV System Chart shall include, at a minimum, the following information:
   1. Camera ID - alphanumeric designation;
   2. Camera name - specific location (e.g. station name, mounting position, view, direction);
   3. Camera type - fixed, PTZ, LRV;
   4. Camera network parameters - IP address, protocols (TCP/IP, UDP, unicast, multicast IGMP, DNS, DHCP, RTP, NTP);
   5. Camera image stream parameters - resolution, frames per second (fps), compression, data rate;
   6. Camera presets - preset locations;
   7. Camera alarms/events - configured alarm and event triggers.

1.05 RELATED WORK

A. Section 03300 – Structural Concrete
B. Section 03310 – Portland Cement Concrete
C. Section 270000 – Communications
D. Section 270543 – Underground Ducts and Raceways for Communications Systems
E. Section 271100 – Communications Equipment Room Fittings
F. Section 271300 – Communications Backbone Cabling
G. Section 271500 – Communications Horizontal Cabling
H. Section 271600 – Communications Connecting Cords, Devices And Adapters
I. Section 272100 – Data Communications Network Equipment
J. Section 278000 – Uninterruptible Power Supplies
K. Section 279000 – Communications Systems Inspections and Testing
1.06 PROJECT CONDITIONS

A. This section will describe the existing Main street corridor video surveillance system. RFI will be generated to METRO to request the existing system document.

B. The Operations Control Center (OCC) is located at the existing Houston METRO TranStar facility.

C. The Backup OCC is located at the existing Houston METRO Rail Operations

PART 2 : PRODUCTS

2.01 GENERAL

A. The IPV System shall be capable of integrating multiple COTS products with a consistent user interface. COTS products shall include, but are not limited to:

1. IP cameras, fixed;
2. IP cameras, PTZ;
3. IP cameras in TPSS and C&S Houses;
4. Camera enclosures and mounts;
5. NVRs;
6. IPV clients;
   a. Workstations - remotely located at the OCC, and the Backup OCC.

B. Fixed and PTZ IP cameras at each station shall have 10/100Base-T network connections to the Ethernet Access switch located in the CIC cabinet at each station. The Ethernet Access switch shall have redundant uplink ports to the CTS for connection to NVRs located in the Communications and Signal House (C&S) at the Communications Node associated with the station. Refer to Section 272100 for requirements regarding the Ethernet Access switch.

C. The IP camera inside the TPSS shall have 10/100Base-T network connection to the industrial Ethernet switch inside the TPSS. The industrial Ethernet switches shall be connected by uplink ports to the Ethernet Access Switch located in the C&S House at the Communications
Node closest to the TPSS. Refer to Section 272100 for requirements regarding the industrial Ethernet switch.

D. The IP camera inside the C&S House shall have 10/100Base-T network connection to the Ethernet Access Switch inside the C&S House.

E. The IPV System shall provide monitoring, control, and management functions including from IPV clients, but not limited to, the following:

1. Viewing Video
   a. Selecting one or more of the following video sources for simultaneous viewing:
      1) Real-time video from PTZ cameras
      2) Recorded video from NVRs.
   b. PTZ
   c. Variable speed control
   d. Omni-directional control
   e. Select and move to presets

2. Video Compression
   a. The IPV System shall support IP cameras and NVRs using MPEG-4 and M-JPEG compression.

3. Digital Recording
   a. Search and playback of recorded video, as specified elsewhere in this Section;
   b. Automatic (maintenance free) daily archiving of recorded video;
   c. Export video clips or individual images on disk as audio video interleave (AVI) files.

4. Viewing and Playback Functions
   a. The IPV System shall provide the following viewing and playback functions from client workstations:
      1) Provide a logon function for operators to enter their username and password for access control into the IPV System.
      2) A graphical user interface (GUI) showing a premises diagram or map of each location containing cameras, and the ability to navigate between locations and select cameras with a drag and drop of the camera icon into one or more display icons.
The GUI shall provide the ability to zoom in and out the maps, and the ability to move within the maps using the mouse.

The GUI shall provide the ability to show one or more camera windows. Each camera window shall be able to be defined as a live/playback camera, a map, a fixed image, or an alarm window.

The GUI shall provide the ability to select cameras using “drag and drop” from a camera list.

The GUI shall provide the ability to dynamically change the grid view of cameras selected from pull down menu.

The GUI shall provide the ability to arrange grid views and cameras in logical hierarchy of Groups and Views.

3) Ability to perform immediate playback (i.e. view recorded video) on any camera, and go back to live real-time viewing in one click of the mouse.

4) Ability to perform investigative analysis including the following features/functions:
   a) Scrollable events timeline;
   b) Zoom in and out on the time line motion based histogram;
   c) Synchronous playback from multiple cameras associated with multiple NVRs.

5) Cameras recorded on multiple NVRs throughout the IPV System shall be able to be viewed on the same client workstation monitor.

6) The GUI shall provide the ability to create unlimited number of views and screen grids, arranged into groups.
   a) The GUI shall provide the ability to toggle between views using the keyboard or mouse.

7) The GUI shall provide full PTZ control, including sending a camera to any of the 25 presets. PTZ control shall be done via keyboard and mouse commands.

8) The GUI shall provide the ability for synchronized playback of multiple cameras with forward and backward commands, fast forward, fast backward, forward playback, reverse playback, playback speed control and frame-by-frame commands.
9) The GUI shall provide the ability to search for recorded video using a "Go-To" time and date function.

10) The GUI shall provide the ability to search for recorded video using the Alarm / Event list.

11) The GUI shall provide the ability to search for recorded video by activity in a designated area of the image.

12) Preview a clip of any alarm/event sequence of a popup window.

13) Print a still picture from any camera, with the ability for the operator to enter comments.

5. The IPV System shall provide an option for enabling tamper-proof log files storing all user activity.

   a. A separate log file shall be maintained for the activity associated with each NVR.

6. Configuration

   a. The IPV System shall provide the ability for authorized users such as the System Administrator to configure IPV System parameters including, but not limited to, the following:

      1) Camera and NVR names, locations, IP addresses;
      2) Image resolutions;
      3) Compression levels;
      4) Network bandwidth;
      5) PTZ preset positions;
      6) Alarm/event triggers;
      7) Automatic functions.

7. Camera Alarms

   a. The IPV System shall provide the ability to configure and enable camera alarm inputs from security and access control system devices including door contacts and motion sensors.

   b. The IPV System shall provide the ability to define specific camera PTZ moves to a preset position in response to an alarm.

8. Video Loss Detection

   a. The IPV System shall be capable of detecting the loss of video from each camera, and displaying a specific alarm on
the user interface associated with the IPV System client workstations.

9. The IPV System software shall run under the Windows™ operating system on both servers (NVRs) and clients (workstations).

10. The Contractor shall provide secure access to the IPV System functions from client workstations, by requiring user authentication including logon and password protection.
   a. The IPV System shall provide the option of using Active Directory™ services to authenticate users.
   b. The IPV System shall provide the ability for authorized users such as the System Administrator to define user profile and user rights in relation to viewing certain cameras and the use of PTZ on a per camera basis.

11. The IPV System shall provide context sensitive help accessible via function key on the client workstations.

12. The IPV System shall include the ability for data exchange and network integration using industry standards and protocols for communications including, but not limited to, the following:
   a. TCP/IP, IEEE 802.3 Ethernet

F. IPV System Capacity

1. The Contractor shall provide an IPV System, including fixed and PTZ IP cameras, NVRs, IPV clients, and all associated software licenses, as indicated in the Contract Drawings.

2. The IPV System shall be scalable such that any number of cameras can be added in the future through the addition of NVRs and all associated NVR and individual camera software licenses.

2.02 CAMERA COVERAGE

A. The Contractor shall provide camera coverage for the following typical areas as shown in Table 282300-1:
### Table 282300-1 Typical Camera Coverage Areas - Stations

<table>
<thead>
<tr>
<th>Area</th>
<th>Camera #</th>
<th>View</th>
<th>Camera Type</th>
<th>Mounting Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Platform Station (2-sided), Split Platform Station</td>
<td>1</td>
<td>Platform</td>
<td>PTZ, Auto Iris</td>
<td>End signage stanchions outside columns</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Platform, TVMs</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Platform, TVMs</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Platform</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B. Refer to the Contract Drawings for typical camera mounting locations, coverage area, and viewing angles.

### 2.03 FIXED IP CAMERAS

A. The Fixed IP cameras shall be high resolution security cameras designed for day / night operation.
   1. The fixed IP camera shall provide color video in high light (daytime) conditions, and infrared (IR) sensitive black/white (B/W) video at night.

B. Fixed IP cameras shall have a solid state progressive scan CCD (charged coupled device) image sensor.

C. The fixed IP cameras shall have automatic iris control and manually controlled variable focal length.

D. Fixed IP cameras shall provide compressed digital video packets via Ethernet network connection to the NVR associated with the camera.
   1. The NVR shall record all video from fixed IP cameras, as specified elsewhere in this Section.
   2. The NVR shall provide the ability to view live, real-time, video from the fixed IP cameras.
   3. The NVR shall provide the ability to view recorded video from the fixed IP cameras.

E. Fixed IP cameras shall meet, at a minimum, the following requirements:
   1. Image Sensor
      a. 1/3 inch (8.5 mm) progressive scan color CCD.
   2. Lens
a. F1.0 varifocal 3.0 to 8.0 mm;
b. Range: 1.0 ft (0.3 m) to infinity;
c. DC iris control;
d. CS mount.

3. Field of View
   a. Horizontal Plane: 55° or greater;
   b. Vertical Plane: 40° or greater.

4. Minimum Illumination
   a. Color: 0.65 lux at F1.0;
   b. B/W: 0.08 lux at F1.0.

5. Video Compression
   a. Motion JPEG (M-JPEG)
   b. MPEG-4:
      1) Profiles: advanced simple profile (ASP), simple profile (SP);
      2) ISO/IEC 14496-2;
      3) Number of compression levels: 10.

6. Resolution
   a. Up to 640 x 480;
   b. Number of selections: 3 minimum;

7. Frame Rate
   a. Up to 30 fps at 640 x 480.

8. Video Streaming
   a. Configurable frame rate and bandwidth;
   b. Constant and variable bit rate.

9. Image Settings
   a. Rotation: none, 90°, 180°, 270°;
   b. Configurable color level, brightness, sharpness, contrast, white balance, exposure control, and backlight compensation;
   c. Overlays: time, date, privacy mask, text.

10. Shutter Speed
    a. 2.0 to 1/25000 second.
11. Security
   a. IP address filtering;
   b. HTTPS (hypertext transfer protocol over secure sockets layer) encryption;

12. Alarm and Event Management
   a. Alarm/event triggered by video motion detection, and external input (e.g. door contact, tamper switch);
   b. Notification via TCP, email, HTTP, external output;
   c. 8 MB of pre and post alarm buffer.

13. Supported Protocols
   a. IPv4/v6,
   b. HTTP, HTTPS, SSL/TLS,
   c. TCP, ICMP, SNMPv1/v2c/v3
   d. (MIB-II), RTSP, RTP, UDP,
   e. IGMP, RTCP, SMTP, FTP, DHCP, UPnP,
   f. ARP, DNS, NTP.

14. Connectors
   a. 10Base-T/100Base-Tx Ethernet, 8P8C (8 position 8 contact) connector (i.e. "like RJ-45");
   b. Terminal block: 2 alarm inputs, 1 output; Alarm output shall be connected to an indication point on the SCADA RTU in the CIC cabinet associated with the station platform.

15. Power
   a. Voltage: 24 VDC;
   b. Power: 6 W maximum.

16. Dimensions
   a. Refer to maximum dimensions for fixed IP cameras as stated under Camera Enclosures and Mounts specified elsewhere in this Section.

2.04 PTZ IP CAMERAS

A. The PTZ IP cameras shall be high resolution security cameras designed for day / night operation.
1. The PTZ IP camera shall provide color video in high light (daytime) conditions, and IR sensitive black/white (B/W) video at night.

B. PTZ IP cameras shall have a solid state progressive scan CCD (charged coupled device) image sensor.

C. The PTZ IP cameras shall have automatic iris control.

D. PTZ IP cameras shall provide compressed digital video packets via Ethernet network connection to the NVR associated with the camera.
   1. The NVR shall record all video from PTZ IP cameras, as specified elsewhere in this Section.
   2. The NVR shall provide the ability to view live, real-time, video from the PTZ IP cameras.
   3. The NVR shall provide the ability to view recorded video from the PTZ IP cameras.

E. PTZ IP cameras shall meet, at a minimum, the following requirements:
   1. Image Sensor
      a. 1/4 inch (6.4 mm) progressive scan color CCD.
   2. Lens
      a. F1.4 - 4.2;
      b. Autofocus;
      c. Auto day / night;
      d. 3.4 to 119 mm wide to telephoto;
   3. Field of view
      a. 2º to 55º horizontal.
   4. Minimum Illumination
      a. Color: 0.5 lux at 30IRE;
      b. B/W: 0.008 lux at 30IRE.
   5. Pan range
      a. 360º endless.
   6. Tilt range
      a. 0º to 180º
   7. Maximum speed
      a. Pan: 0.05 to 450 º / sec;
      b. Tilt: 0.05 to 450 º / sec;
8. Zoom
   a. Optical: 35x;
   b. Digital: 12x.

9. Video Compression
   a. Motion JPEG (M-JPEG)
   b. MPEG-4:
      1) Profiles: advanced simple profile (ASP), simple profile (SP);
      2) ISO/IEC 14496-2;
      3) Number of compression levels: 10.

10. Resolution
    a. Up to 640 x 480;
    b. Number of selections: 3 minimum.

11. Frame Rate
    a. Up to 30 fps at 640 x 480.

12. Video Streaming
    a. Configurable frame rate and bandwidth;
    b. Constant and variable bit rate.

13. Image Settings
    a. Rotation: none, 90°, 180°, 270°;
    b. Configurable color level, brightness, sharpness, contrast, white balance, exposure control, and backlight compensation;
    c. Overlays: time, date, privacy mask, text.

14. Shutter Speed
    a. 1.0 to 1/30000 second.

15. PTZ Control
    a. Preset positions: 25;
    b. Move to preset on external alarm input.

16. Security
    a. IP address filtering;
    b. HTTPS encryption;
17. Alarm and Event Management
   a. Alarm/event triggered by video motion detection and external inputs (e.g. door contact, tamper switch);
   b. Notification via TCP, email, HTTP, external output;
   c. 36 MB of pre and post alarm buffer.

18. Supported Protocols
   a. Pv4/v6,
   b. HTTP, HTTPS, SSL/TLS, QoS,
   c. TCP, ICMP, SNMPv1/v2c/v3
   d. (MIB-II), RTSP, RTP, UDP,
   e. IGMP, RTCP, SMTP, FTP, DHCP, UPnP,
   f. ARP, DNS, NTP.

19. Connectors
   a. 10Base-T/100Base-Tx Ethernet, 8P8C (8 position 8 contact) connector (i.e. "like RJ-45");
   b. Terminal block: 4 alarm inputs, 1 output; Alarm output shall be connected to an indication point on the SCADA RTU in the CIC cabinet associated with the station platform.

20. Power
   a. Voltage: 24 VDC;
   b. Power: 20 W maximum.

21. Dimensions
   a. Refer to maximum dimensions for fixed IP cameras as stated under Camera Enclosures and Mounts specified elsewhere in this Section.

2.05 CAMERA ENCLOSURES AND MOUNTS

A. Enclosures
   1. Enclosures for both fixed and PTZ IP cameras shall provide, at a minimum, the following:
      a. Vandal Resistance
      b. Environmental Protection
         1) Enclosures shall be sealed, weatherproof, and rated at minimum ingress protection of IP65 against dirt, dust, water, and salt water air.
2) Enclosures shall meet the requirements of NEMA 250 type 4x.

c. Thermal Management
1) Enclosures that have an integrated, solid-state, thermal electric cooling system that shall actively cool the interior of the enclosure without air exchange into the sealed enclosure in order to control humidity, and prevent fogging and corrosion.

2) The thermal electric cooling system shall have the capacity to generate up to a 25° C (45° F) differential with the outside environment.

3) The thermal electric cooling system shall be thermostatically controlled, and shall have the following:
   a) Activation threshold: 38° C (100° F);
   b) Deactivation threshold: 27° C (80° F).

4) The thermal electric cooling system shall provide the ability for IP cameras to operate in the following conditions:
   a) Temperature: -1° to 70° C;
   b) Humidity: 20% to 100%.

d. Enclosure Power
1) Voltage: 120 VAC, 47 - 63 Hz;

2) Current: 1.8 A, including thermal management system and camera power.

3) For cameras at stations, the enclosure power including thermal management system and camera power shall derive power from the uninterruptable power supply (UPS) within the CIC cabinet. Refer to the Contract Drawing and Specification 278000 for requirements associated with the UPS.

e. Camera Power
1) The enclosure shall include an internal power supply for the IP camera;

2) Voltage: 24 VDC;

3) Current: 1.0 A.

2. Fixed IP Camera Enclosure
a. Construction
1) The fixed IP camera enclosure body shall be constructed of extruded aluminum, minimum 0.08
inch (2 mm) thickness, with a white powder coat finish;
2) The fixed IP camera enclosure end-caps shall be injection molded polycarbonate;
3) The front end-cap shall have a clear, high impact, glass lens, minimum 0.0625 inch (1.6 mm) thickness.

b. Maximum Camera Dimensions
1) Length: 10 inch (254 mm);
2) Width: 3.5 inch (89 mm);
3) Height: 3.5 inch (89 mm).

3. PTZ IP Camera Enclosure
a. Construction
1) The PTZ IP camera enclosure shall be constructed of white, impact resistant, polycarbonate thermoplastic;
2) The PTZ IP camera enclosure shall have a tinted, high impact acrylic dome lens, minimum 0.0625 inch (1.6 mm) thickness. The tinted lens shall have a light attenuation factor of not more that 1 f-stop.

b. Maximum Camera Dimensions
1) Length: 9.375 inch (238 mm);
2) Width: 6.5 inch (165 mm);
3) Height: 6.5 inch (165 mm).

B. Mounts
1. Construction
   a. Material: 0.125 inch (3.2 mm) thick aluminum;
   b. Finish: epoxy painted per MIL-P-53022-Type 1;
   c. Load: up to 150 lb.
2. Pole Mount
   a. Pole size: .75 inch (19 mm) minimum;
   b. Pole mounts shall be provided with a tilt angle correction plate to correct the angle of the camera enclosure up to 10 degrees for non plum poles.

C. Tamper Provisions
1. Fastening Hardware
a. All fastening hardware (screws, nuts, washers, etc.), hinges, latches used in the outdoor portions of the IPV System, including fixed and PTZ IP camera enclosures and mounts shall be stainless steel.

b. All exposed screws shall be tamper resistant.

2. Tamper Switches

2.06 TPSS AND C&S HOUSE IP CAMERA

A. The TPSS and C&S House IP camera shall be a PTZ network camera.

B. The TPSS and C&S House IP camera shall be mounted on the wall or ceiling inside each TPSS, and on the wall in each C&S House as shown in the Contract Drawings. The TPSS and C&S House IP camera shall be configured to provide a view of someone entering the substation or C&S House via the doors.

C. The TPSS and C&S House IP cameras shall provide compressed digital video packets via Ethernet network connection to the NVR associated with the camera.

   1. The NVR shall record all video from TPSS C&S House IP cameras, as specified elsewhere in this Section.

   2. The NVR shall provide the ability to view live, real-time, video from the TPSS IP C&S House cameras.

   3. The NVR shall provide the ability to view recorded video from the TPSS C&S House IP cameras.

D. TPSS and C&S House IP cameras shall meet all of the requirements of the PTZ IP Camera as specified elsewhere in this Section.

E. TPSS and C&S House IP cameras shall be provided with a standard indoor dome enclosure, and shall not be provided with the PTZ IP Camera Enclosure (as specified elsewhere in this Section) which is intended for outdoor operation.

F. The TPSS and C&S House IP camera shall be provided with 120 VAC power adapter and a junction box on which to mount the camera.

G. Contractor shall provide all power and data cabling to the TPSS and C&S House IP camera.

H. TPSS C&S House IP cameras shall automatically pan/tilt/zoom to a preset position to provide a view of each entry door.
1. A separate PTZ preset position shall be pre-programmed for each entry door.

2. The automatic pan/tilt/zoom to the preset position shall be triggered by a camera alarm input associated with each entry door, as shown in the Contract Drawings.

3. Contractor shall provide all necessary cabling and terminations between door magnetic switches and camera alarm contacts.
   a. Contractor shall be aware door magnetic switches shall also be connected to the intrusion panel within the TPSS or C&S House.
   b. Contractor shall ensure that the operation between the magnetic door switches and intrusion panel is not affected by the connection of the magnetic door switches to the camera alarm inputs.
      1) In the event the magnetic door switches form a closed loop system with the intrusion panel, do not have multiple contacts (i.e. double-pole, double-throw) or are otherwise incompatible with the PTZ camera alarm inputs, Contractor shall provide and install a separate magnetic door switch for each door to meet the requirements as specified in this article.

2.07 ETHERNET ACCESS SWITCH

A. Contractor shall refer to Section 272100 for detailed requirements regarding the Ethernet Access switches.

2.08 NETWORK VIDEO RECORDERS (NVR)

A. Functional Requirements:
   1. The NVRs shall be IPV servers consisting of industrial grade rack mount servers, internal hard drives, and associated IPV server software applications.
   2. Each NVR shall provide the ability to view live real-time video for all associated cameras, as shown in the Contract Drawings.
      a. Real time video for each camera shall be able to be viewed at 30 frames per second (fps), up to 640 x 480 resolution in NTSC format, using M-JPEG or MPEG-4 encoding and compression.
   3. Each NVR shall provide a minimum of 72 hours of continuous recording for all associated cameras.
Video shall be recorded at a minimum of 15 fps, 24 hours/day, up to 640 x 480 resolution in NTSC format, using MPEG-4 encoding and compression.

4. Each NVR shall be capable of supporting the following resolutions per camera, in NTSC format:
   a. 160 x 120;
   b. 320 x 240;
   c. 640 x 480.

5. Each NVR shall have the ability to configure the frame rate to record and store images, on a per camera basis, from 1 to 30 fps.

6. Each NVR shall support simultaneous viewing by clients.

7. To avoid improper use and configuration, the NVR shall provide the ability to define individual users by username and password.

8. Each NVR shall provide motion detection capabilities with all the functions as described below. Each NVR shall provide the ability for authorized users such as the System Administrator, to configure one, several, or any non-conflicting combinations of the following functions, on a per camera basis:
   a. Automatically freeze the live video of a camera with no motion in its field of view.
   b. Stop recording camera images with no motion in its field of view.
   c. Start recording images up to 999 seconds before a motion is detected in the cameras field of view and continue recording for up to 999 seconds after the motion stopped in the cameras field of view.
   d. Adjust the motion level sensitivity from 0 to 10,000 units, in 1 unit increments.
   e. Adjust the low light noise levels from 0 to 256 units, in 1 unit increments to avoid false motion detection.
   f. Define up to 1024 inclusion / exclusion motion detection zones per camera.
   g. Automatically change recorded frame rate when motion is detected.

9. All NVRs shall communicate with all IP cameras and client workstations over communications transmission system (CTS) providing Gigabit Ethernet services over fiber optic interfaces as specified in Section 272100.
a. Communication interfaces to the NVRs shall be dual redundant 10/100/1000Base-T Ethernet.

b. Each NVR shall communicate with IP addressable cameras to receive video streams and send PTZ commands.

c. Each NVR shall support both IP address filtering and HTTPS (Hypertext Transfer Protocol over Secure Socket Layer) to secure transmission of video and configuration data.

10. Upon power-up, each NVR shall automatically perform the following operations such that no manual operations are required to resume the IPV System functions in the event of a power failure:

a. Boot-up;

b. Auto logon;

c. Run the IPV server software applications.

B. Minimum Hardware Requirements

1. CPU
   a. Dual core Xeon® processor;
   b. 2.6 GHz;
   c. 1333MHz front side bus;
   d. 8 MB L2 cache.

2. Operating System
   a. Windows Server.

3. Memory
   a. 4 GB.

4. Storage
   a. 2 Serial Advanced Technology Attachment (SATA) hard drives;
   b. 7200 RPM;
   c. 2.0 TB total storage available for video image data.

5. Network Interface
   a. Number of ports:
      1) 2.
   b. 10/100/1000Base-T Ethernet;
   c. TCP/IP offload engine enabled;
   d. TIA/EIA-568B wiring interface;
e. 8P8C (8 position 8 contact) connector (i.e. "like RJ-45").

6. Graphics Adapter
   a. 32 MB memory.

7. Input/Output Interfaces
   a. 1 PCI-E;
   b. 1 PCI-x;
   c. 4 USB (universal serial bus);
   d. RS-232, 9-pin, D connector;
   e. 1 video;
   f. 2 PS/2, keyboard and mouse;
   g. Contact Closure
      1) Inputs: 8;
      2) Type: non-polarized, optically isolated from each input and from the server;
      3) Voltage: 3 to 30 V, DC or AC RMS (40 - 10000 Hz);
      4) Isolation: 500V.

8. Removable Media
   a. 8x DVD+RW, 24x CD-RW.

9. Operating conditions:
   a. Temperature
      1) -20 to +60 degrees C (-4 to +140 degrees F);
      2) MIL-STD-810F, Methods 501.4 and 502.4.
   b. Humidity
      1) 5% to 95% non-condensing;
      2) MIL-STD-810F, Method 507.4.
   c. Vibration
      1) Up to 1.04 grms;
      2) 10 - 500 Hz;
      3) MIL-STD-810F, Method 514.5.
   d. Shock
      1) 20g;
      2) 11 m/s;
      3) MIL-STD-810F, Method 516.5.
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10. Power:
   a. 120VAC, 60Hz;
   b. Cord: NEMA 5-15P, 15 amp, 10ft (3048 mm).

11. Enclosure
   a. 1U height;
   b. 19-inch (483 mm) rack mount;
   c. Industrial grade rails;
   d. Corrosion resistant steel.

2.09 IPV CLIENTS

A. IPV clients shall consist of computer workstations.

B. The Contractor shall provide IPV client workstations and associated software applications at the following locations:
   1. Operations Control Center (OCC) – 2 workstations;
   2. Backup OCC – 2 workstations.

C. IPV client workstation software applications shall provide all of the viewing and playback functions as specified elsewhere in this Section.

D. IPV client workstation shall, at a minimum, meet the following requirements:
   1. CPU
      a. Core®2 Duo processor;
      b. 2.66 GHz;
      c. 1066 MHz front side bus;
      d. 8 MB L2 cache.
   2. Operating System
      a. Windows XP Professional x64.
   3. Memory
      a. 2 GB.
   4. Storage
      a. Serial Advanced Technology Attachment (SATA) hard drive;
      b. 10000 RPM;
      c. 250 GB total storage.
5. Network Interface
   a. Number of ports:
      1) 2.
   b. 10/100Base-T Ethernet;
   c. TIA/EIA-568B wiring interface;
   d. 8P8C (8 position 8 contact) connector (i.e. "like RJ-45").

6. Graphics Adapter
   a. Number of channels:
      1) 2.
   b. Memory:
      1) 256 MB video RAM per channel (512 MB total).

7. Monitor
   a. Number provided:
      1) 1, with option for adding 2nd monitor.
   b. Type:
      1) Color TFT (thin film transistor) active matrix LCD (liquid crystal display).
   c. Display Area:
      1) 510 mm (20.1 inch) diagonal.
   d. Resolution:
      1) Up to 1600 x 1200 pixels @ 60Hz.
   e. Pixel Pitch:
      1) 0.25 mm (0.01 inch).
   f. Contrast Ratio:
      1) 800:1.
   g. Viewing Angle:
      1) ± 89 degrees horizontal, ± 89 degrees vertical.
   h. Brightness:
      1) 300 cd/m².
   i. Video Inputs:
      1) DVI-D digital.
   j. Max Sync Rate (V x H):
      1) 76 Hz x 81 kHz.
k. Response Time:
   1) 16 ms.

l. Power:
   1) 120 VAC;
   2) 50/60 Hz.

m. Controls:
   1) Power;
   2) Image adjust;
   3) Contrast;
   4) Brightness;
   5) Color;
   6) Input select.

8. Keyboard
   a. The Contractor shall provide a standard 104 key keyboard with the IPV client workstation. They keyboard shall have a USB connector.

9. Mouse
   a. The Contractor shall provide a 2-button optical mouse with the IPV client workstation. The mouse shall have a USB connector.

10. Input/Output Interfaces
    a. 1 PCI-E slot;
    b. 2 PCI 2.2 slot (5V, 32 bit, 33 MHz);
    c. 8 USB (universal serial bus);
    d. 1 RS-232 serial interface;
    e. 2 DVI-D (digital visual interface) video;
    f. 2 PS/2, keyboard and mouse.

11. Removable Media
    a. 16x DVD+/-RW.

12. Operating conditions
    a. Temperature
       1) 5 to 40 degrees C (40 to +104 degrees F).
    b. Humidity
       1) 5% to 95% non-condensing.
13. Power
   a. 120VAC, 60Hz.

2.10 IPV SYSTEM TEST EQUIPMENT

A. The Contractor shall provide a minimum of two portable IPV System test sets.
   1. The IPV System test set shall consist of an industrial, rugged, laptop computer with associated client workstation software, and network communication data cables.
   2. Each IPV System test set shall be resistant to vibration and shock consistent with being transported in the trunks of cars.

B. The IPV System test sets shall provide the ability to perform the following:
   1. Verify operation and functionality of fixed and PTZ IP cameras.
   2. Verify operation and functionality of NVRs.
   3. Verify the ability for an operator to manually select and view video, and perform PTZ from each IPV client workstation.
   4. Display IPV System alarm/event logs.

C. The IPV System test sets shall meet, at a minimum, the following requirements:
   1. Rugged Laptop Computer
      a. Magnesium alloy case with handle;
      b. Spill resistant keyboard and touchpad;
      c. CPU
         1) Core®2 Duo processor;
         2) 2.4 GHz;
         3) 1067MHz front side bus;
         4) 3 MB L2 cache.
      d. Operating System
         1) Windows XP Professional x64.
      e. Memory
         1) 2 GB.
      f. Storage
         1) 80 GB hard drive;
         2) Shock mounted and quick release.
g. Network Interfaces
   1) 1 port, 10/100Base-T Ethernet;
   2) Wireless, WiFi, IEEE 802.11a/b/g.

h. Display
   1) Size: 13.3 inch (338 mm);
   2) Type: color TFT LCD with touchscreen;
   3) Resolution: up to 2048 x 1536;
   4) Brightness: 460 cd/m².
   5) 256 MB video RAM.

i. Expansion slots
   1) PC card Type II x 1;
   2) Secure digital high capacity (SDHC) card x 1.

j. Interfaces
   1) External video: 15-pin D connector;
   2) Headphones/speaker: mini-jack stereo;
   3) Microphone/line-in: mini-jack stereo;
   4) Docking / port replicator: 65-pin;
   5) Serial: 9-pin, D connector;
   6) USB: 2.0 x 2;
   7) Network: 10/100Base-T, RJ-45.

k. Power supply
   1) Battery type: lithium ion, 11.1V, 7800mAh;
   2) Battery operation: 6 hours (typical);
   3) Battery charging time: 4 hours (typical);
   4) AC adapter: 100 - 240 VAC, 50/60Hz.

2. Network communication data cables - refer to Section 271500.

2.11 PROVISIONING

A. Cameras
   1. See Table 282300-1 listing cameras and locations at typical single platform and split platform stations, and typical street crossings.

B. NVRs
1. Contractor shall provide a minimum of one NVR in a C&S House associated with for each new Corridor (North, East, Southeast, and Uptown).
   a. Contractor shall provide additional NVRs as necessary to handle the number of cameras as specified herein, and to meet IP Video storage requirements specified herein.

C. IPV Clients
   1. Table listing all client workstation locations will be provided.

PART 3 : EXECUTION

3.01 PREPARATION

A. The Contractor shall be responsible for field verification of dimensions and coordination of conduit entry and all other mounting conditions.

B. After the system equipment has been delivered, an onsite inspection will be made by the Engineer. If any equipment has been damaged or for any reason does not comply with the requirements of this Section, the Contractor will be notified in writing, and shall be required to replace the equipment at his own cost and expense, even though the equipment has been previously inspected, tested and approved for shipment. After such satisfactory replacement, the system shall be installed by the Contractor.

3.02 INSTALLATION

A. The Contractor shall install all IPV System equipment in accordance with the manufacturers' instructions at each location as shown in the Contract Drawings, and as specified herein.

B. Contractor shall install all fixed and PTZ IP cameras, including all mounts, enclosures, and power, communications, and I/O connections, at each station platform and gated intersection as shown in the Contract Drawings.

C. Contractor shall install all NVRs, including power, communications, and I/O connections, in each Communications Node as shown in the Contract Drawings.

D. Contractor shall refer to Section 271500 for requirements regarding terminal blocks, protector blocks, conduits, raceways, cable trays, wire, and cables required for installation of the IPV System equipment defined in this Section.
E. Contractor shall install all data cabling between IP camera and NVR communications ports to the TCP/IP network equipment associated with the communications transmission system (CTS) as described in Section 272100.

1. Contractor shall refer to Section 271100 for requirements regarding communications equipment cabinets, copper distribution frames, patch panels.

2. Contractor shall refer to Section 271500 for requirements regarding copper and fiber optic horizontal data cabling.

F. Contractor shall provide and install all mounting hardware associated with the IPV System equipment specified herein.

G. Installation of all IPV System equipment shall be consistent from site to site to provide uniformity in installations.

H. The Contractor is required to ensure that the installation of new equipment does not adversely affect the operation of any existing systems.

3.03 TESTING

A. Factory Inspections and Tests

1. Contractor shall perform all factory inspections and tests as required in Section 279000.

B. Following completion of the installation of all IPV System equipment at each site, Contractor shall inspect all equipment and wiring to verify that all mechanical connections are made and properly secured, and all hardware is installed in its proper location and is properly terminated.

1. Data sheets containing evidence of such inspection, certified as correct by Contractor, shall be delivered to the Engineer for approval.

2. Contractor shall receive approval of such inspection certification before applying power to the IPV System equipment covered by such certification.

C. Field Inspections and Tests

1. Contractor shall perform all field inspections and tests for the IPV System as required in Section 279000.

2. Verify all automatic actions including archiving, patrolling sequences, move to presets, scheduled functions, and all alarm /event functions, as specified herein.
3.04 HARDWARE DOCUMENTATION

A. IPV System Manuals

1. The Contractor shall provide IPV System Operation, Maintenance (O&M) and Programming Manuals as specified in Article 1.04 herein.

END OF SECTION
SECTION 284600

SCADA

PART 1 : GENERAL

1.01 DESCRIPTION

A. Work Included

1. The Work of this Section consists of designing, furnishing, testing and commissioning the Supervisory Control and Data Acquisition (SCADA), as described in the Contract Documents and as specified herein.

2. This Section describes the requirements of the SCADA System that shall monitor failure alarms, and points on station equipment including communication devices.

3. This Section includes work for the Contractor to provide the communications interfaces between each remote terminal unit (RTU) and the OCC/ROC, and other systems.

B. The SCADA System shall include a RTU installed in each Communications and Signal House (C&S), Communications Interface Cabinet (CIC), Driver Comfort Station, and at the ROC, that shall monitor failure alarms on equipment, miscellaneous station indications, and intrusion alarms.

1. Control and monitoring of C&S and CIC equipment indications shall include but not be limited to the following subsystems and functions:

   a. Intrusions – C&S House, TPSS, Driver Comfort Station, CIC, TVM;
   b. Environmental - high temperature, high water alarms;
   c. Fire/smoke alarm;
   d. Uninterruptible Power Supplies (UPS);
   e. Cable Transmission System (CTS);
   f. CCTV Camera alarms;
   g. PA/PIS alarms.

C. The SCADA equipment described in this Section includes the following:
1. RTUs, including chassis / backplane, power supply, CPU, communication interfaces, and input/output (I/O) modules.

2. A preliminary table showing cabling and connections between the RTU in the C&S, CIC, and Driver Comfort Station and equipment alarm outputs and miscellaneous station equipment as listed in Table 284600-1 herein;

D. Each SCADA RTU shall include communication interfaces to the CTS as specified in Section 272100.

1. Communication interfaces to the CTS shall be 10/100Base-T or 100Base-FX Ethernet.

a. Contractor shall be responsible for providing Ethernet fiber optic media converters, industrial Ethernet switches, and/or device servers as necessary, as specified in Sections 272100 and 271600.

1.02 QUALITY ASSURANCE

A. Materials specified shall meet or exceed the requirements of the cited references.

B. Qualifications

1. The Contractor shall provide all product cut sheets as required for the Engineer’s evaluation.

2. Contractor shall utilize supervision and labor experienced in performing the Work required herein in a skillful and satisfactory manner, and according to the project schedule.

3. SCADA System equipment shall have been satisfactorily used in projects of similar size and complexity for no less than two years.

1.03 CITED REFERENCES

A. American Public Transportation Association

1. 34 - Standard for Supervisory Control and Data Acquisition (SCADA) System Inspection, Testing, and Maintenance

B. Institute of Electrical and Electronic Engineers (IEEE)

1. 802.1 - Local Area Network / Metropolitan Area Network (LAN/MAN) Bridging & Management

2. 802.3 - Local Area Network protocols

C. National Electrical Manufacturers Association (NEMA)
   1. Standard 250 - Enclosures for Electrical Equipment

D. International Electrotechnical Commission (IEC)
   1. Standard 60529 - Degrees of Protection Provided by Enclosures

E. Underwriters Laboratory (UL)
   1. 1638 - Standard for Safety Visual Signaling Appliances, Private Mode Emergency and General Utility Signaling

1.04 SUBMITTALS

A. The Contractor shall provide the following submittals, as described in Section 270000 Communications:
   1. System Design;
   2. Functional Site Block Diagram;
   3. Arrangement Plan;
   4. Installation Plan;
   5. Wiring Plan;
   6. Power Wiring Plan;
   7. Allocation and Provisioning Plan;
   8. Operation and Maintenance (O&M), and Programming Manuals.

B. The Contractor shall submit technical data sheets and catalog cuts for each item.

C. The Contractor shall submit manufacturer’s warranty information.

D. The Contractor shall submit a SCADA Point Chart, with text description of each point to be monitored or controlled by the SCADA System. The SCADA Point Chart shall include, at a minimum, the following information:
   1. Point description of specific equipment to be monitored or controlled;
   2. Type of point (e.g. control, indication, analog);
   3. Subsystem of point (e.g. Comm Alarm, Station Alarm);
   4. Location of point (e.g. Elgin TPSS, Graceland C&S);
   5. RTU communication port address;
6. RTU I/O module and register address;
7. Register value (i.e. logic sense and meaning for discrete points, range and scale factor for analog points).

E. The Contractor shall submit a SCADA Interface Design Document (IDD) that shall include, at a minimum, the following information:
1. A detailed description of the communications protocol for each message sent and received between the SCADA RTUs and a future supervisory computer system, provided by others, at the OCC/ROC. The description of the communications protocol shall include, at a minimum, the following:
   a. Identification of the open industrial network protocol that shall be used;
   b. The byte-for-byte message format and checksum;
   c. The polling sequence and timing of messages;
   d. Handshaking and acknowledgement of each message;
   e. Description of time of day synchronization with the supervisory computer system at the OCC/ROC;
   f. Description of communications failures, timeouts, and recovery procedures;
   g. Description of data security features.
2. A detailed listing of each RTU, its communication data rate, port or network address, and physical port assignment within network equipment associated with the CTS provided and installed at the OCC/ROC under this Contract as described in Section 272100.

1.05 RELATED WORK

A. Section 270000 – Communications
B. Section 271100 – Communications Equipment Room Fittings
C. Section 271300 – Communications Backbone Cabling
D. Section 271500 – Communications Horizontal Cabling
E. Section 271600 – Communications Connecting Cords, Devices And Adapters
F. Section 272100 – Data Communications Network Equipment
G. Section 275100 – Public Address/Passenger Information Signs Systems
PART 2 : PRODUCTS

2.01 REMOTE TERMINAL UNITS (RTUs)

A. Functional Requirements:

1. All RTUs shall communicate with a redundant supervisory control system at the OCC/ROC over CTS.
   a. Communication interfaces to the CTS shall be 10/100Base-T or 100Base-FX Ethernet.
      1) Contractor shall provide Ethernet fiber optic media converters and/or device servers as necessary, as specified in Section 271600 and as shown in the Contract Drawings.
      2) The Contractor shall provide all copper or fiber optic data cabling and connectors between the CTS equipment located in the C&S, CIC, Driver Comfort Station and each RTU.
         a) Contractor shall refer to Section 271500 for requirements regarding copper and fiber optic horizontal data cabling.
   b. The RTUs shall communicate with a future supervisory control system at the OCC/ROC using an open industrial network protocol for industrial automation applications. Contractor shall document the communications protocol in the SCADA System IDD submittal, as specified in this Section and to be reviewed and approved by the Engineer. Potential communications protocols include:
      1) Modbus/TCP;
      2) Fieldbus;
      3) Profinet;
      4) Ethernet/IP;
      5) Engineer approved equivalent.
   c. The RTUs shall have the ability for remote configuration and provide diagnostic information via the network using Simple Network Management Protocol (SNMP).
d. The inputs from the remote devices C&S, CIC, Driver Comfort Station and miscellaneous station equipment shall be discrete indication points and analog measurements.

e. The outputs to the remote devices shall be control points.

f. The RTUs shall operate independently of the future supervisory control system at the OCC/ROC such that the RTUs shall continue to operate regardless on any action or inaction by users of the supervisory control system.

B. Operational Requirements

1. The RTUs shall contain, but not be limited to, chassis/backplane, CPU and memory, power supplies, communication modules, input/output (I/O) modules, interposing relays, ground detectors, terminal blocks, fuse blocks and switches as required.

a. Fusing also shall be furnished to protect the lines and equipment in the event of accidental contact with 120 VAC or 600 VDC.

b. The Contractor shall provide I/O cabling and wiring between device signal terminal blocks and RTU I/O systems. Device signal terminal blocks shall include, at a minimum, the following:

   1) Terminals for alarm and status outputs on communications, UPS, and other miscellaneous station equipment.

   2) All intrusion alarms as specified herein.

2. RTUs shall be from the same manufacturer and shall be of the same product family;

3. RTUs shall be the same model and revision level, with common modules interchangeable between RTUs;

4. The RTUs shall support programmable calculation and control algorithms. These shall be written on a portable laptop computer using a script editor. These shall be compiled and loaded into non-volatile memory in the RTU.

5. As a minimum, the calculation and control routines shall support the following mathematical and logical functions: add, subtract, multiply, divide, assign, log, exponential, sine, cosine, tan, arcsine, arccosine, arctan, equal to, not equal to, greater than or equal to, less than, less than or equal to, square root, absolute value, reciprocal, AND, OR, NOT, and XOR.

6. The available database (e.g. RTU memory registers) for the above shall include: indication values, analog values, local accumulator
values, setpoint values from the supervisory computer system at the OCC/ROC, controls requested from the supervisory computer system at the OCC/ROC, date and time variables, and communications failure.

7. Functions shall include: set indication value, set analog value, set accumulator value, set setpoint control value, execute local controls, and start local timer.

8. A maximum of 1.5 second shall elapse from the first possible detection by a RTU of a read request for the current state of any input(s) or internal alarms, until the results are available for display and recording by the supervisory computer system at the OCC/ROC.
   a. The 1.5 second includes the time for the RTU to receive the read request via the CTS, process it, and transmit the results to the OCC/ROC via the CTS.

9. A maximum of 1.5 second shall elapse from the first possible detection by a RTU of a control request to change the state of any outputs, until the requested logic state of the output appears at the terminals of the I/O module associated with the output.
   a. The 1.5 second includes the time for the RTU to receive the write request via the CTS, process it, and set the requested logic state of the output appears at the terminals of the I/O module.

10. No characteristic of the provided RTU equipment, addressing and firmware/software shall prevent the future addition of, and operation with, up to 100% additional RTUs (over the amount provided in this Contract).

11. Each individual RTU shall be provided with a minimum of 50% spare capacity in terms of memory, and I/O points.
   a. No characteristic of each individual RTU provided, including chassis space, addressing, and firmware/software shall prevent the future addition of, and operation with, up to 100% additional I/O points (over the amount provided in this Contract).

12. The RTU application software shall be written in an industry-standard high-level language.

13. RTUs shall be capable of communicating with a future supervisory computer system at the OCC/ROC at a minimum data rate of 10 Mbps.

14. Any RTU remote I/O connected via a communications network or link shall be non-proprietary.
15. RTUs shall automatically initiate comprehensive self-tests and begin normal operation upon power-on.
16. RTUs shall normally operate unattended.
17. RTUs shall automatically resume full operation upon restoration of communications after a loss of communication to the supervisory computer system at the OCC/ROC.
18. Failure of an RTU shall not impair the continued operation of other RTUs.
19. All RTUs shall operate in a fail-safe manner such that a failure in an RTU shall not cause unsafe operating conditions. Failure(s) in one or more RTUs shall not affect other Communications systems or systems associated with Signaling, AVL, Traffic, or Traction Power.
20. RTUs shall perform auto-restart upon restoration of power following loss of source power.
21. RTUs shall support local initialization and execution of diagnostics from either a local control panel or RTU test set. Initialization shall also be capable remotely from the supervisory computer system at the OCC/ROC.
22. Additionally, design and configuration of RTU equipment shall minimize the possibility of unintended device control actions due to EMI.
23. RTUs shall perform self-tests upon power-on, command from the OCC/ROC; local command through test set or local control panel, and upon any restoration to service. The RTU self-test shall include:
   a. RTU processor system operation, including ROM checksum, RAM check, timer checks, and system bus check;
   b. I/O system and I/O card checks;
   c. Data communications interface check.
24. Faults shall be indicated to at least the field replaceable unit level.
25. The following faults shall be indicated locally and shall be immediately reported by the RTU to the supervisory computer system at the OCC/ROC. Upon introduction of replacement cards or modules, the RTU shall report the reintroduction to service to the OCC/ROC.
   a. I/O card faults;
   b. I/O system faults;
   c. Any inability of the RTU to communicate with the supervisory computer system at the OCC/ROC via normal or redundant channels.
26. The RTU shall, within five seconds after restart, report a restart condition to supervisory computer system at the OCC/ROC, after power-on; after return to operation following local control panel or test set activity; and after restart following a power failure.

27. The RTU software program shall be stored on non-volatile media/device.

28. The RTU software program shall be located in a secure storage space.

29. The RTU software program shall provide the means and methods to access on-line services and it must be password protected.

30. The Contractor shall load and update the RTU software program through the completion of the Work, and the O&M Manual shall include detailed instructions on operating and maintaining the RTU software program thereafter.

31. Each RTU shall record an accurate sequence of events for all inputs and outputs, independent of time-stamping.

32. The RTUs shall operate in the following conditions:
   a. Temperature
      1) 0 to +70 degrees C (+32 to +140 degrees F).
   b. Humidity
      1) 0 to 95% non-condensing.

C. Input and Output Points

1. The RTUs provided under this Contract, to be installed in C&S, CIC, and Driver Comfort Station shall be provided with the number of input and output points as indicated in Table 284600-1 including spares as specified herein, and shall be capable of 100 percent expansion through the use of additional hardware modules.

2. All input points (i.e. discrete indications and analog points) associated with a RTU shall be interrogated by the RTU at least once every ten milliseconds.

3. Discrete Indication Points
   a. Contractor shall connect discrete indication points for status monitoring to isolated dry contacts. These shall be monitored at the remote location with the following provisions:
      1) Each discrete indication point shall have an associated LED indicator illuminated when the contact is closed.
2) All discrete indication points shall be protected against voltage surges and shall meet the IEEE Standard C37.90.1P.

3) Separated industrial barrier type interposing terminal blocks shall be provided for all interface connections between other, Contractor furnished equipment, and the discrete indication points. These terminal blocks shall accommodate up to 10 AWG (2.588 mm) wire.

4) Local LED indicators shall be provided to display the state of all discrete indication points.

5) Wiring shall be provided for connection of discrete indication points as specified in Section 271500.

4. Control Points

a. All control operations shall be on a direct basis.

b. All control points shall be protected such to meet the IEEE Standard C37.90.1P.

c. Each control point shall have an associated LED indicator illuminated when the output contacts are closed.

d. Momentary output contacts shall be closed for a programmable time interval.

1) Timer shall be adjustable from 0.1 seconds to 30 minutes.

2) Timer duration shall be programmable in 50-millisecond or smaller increments.

e. The contact rating and type of control relays shall be as specified, required and approved by the Engineer.

D. Security and Reliability

1. Security and reliability shall be integrated into the RTU design concept such that proper consideration is given to communications, hardware, software, assembly and construction of the RTU itself.

2. Communication Path Security

a. The RTU’s encoding/decoding of information shall guard against false commands being executed and prevent false data from being transmitted to the OCC/ROC.

b. As a minimum the following security features shall be provided:

1) CRC-16 (Cyclical Redundancy Check-16 bit) error detection coding or equivalent crosshatch parity error
Section 284600 SCADA

detection encoding shall be used. All errors of up to 16 contiguous bits shall be detected.

2) At least 99 percent of all error-bursts greater than or equal to 16 bits shall be detected.

3) RTU’s shall be able to re-encode and retransmit (to the OCC/ROC) part of or all information control messages, according to the handshake methods in the communications protocol as documented in the SCADA IDD as specified herein.

3. Internal Operation and Construction Security

a. As a minimum, the following features shall be provided:

1) High stability clocks for internal timing. The time base of all RTUs shall be periodically synchronized according to the handshake methods in the communications protocol as documented in the SCADA IDD as specified herein. This is to ensure sequence of event accuracy and a time base for calculate and control programs.

2) The following conditions shall not produce false control operations by the OCC/ROC. In addition, these conditions shall not produce false or continuous transmission of data to the OCC/ROC. These conditions are:
   a) Power up of the RTU;
   b) Switching from a primary power source to a backup source;
   c) Communication circuit failure;
   d) Any component failure in the RTU;
   e) A I/O module left out of the RTU.

3) The RTU design shall be modular for ease of maintenance and expansion. Failure of any module or I/O card containing a group of input or output points shall not disable the entire RTU.

4) High reliability off-the-shelf components shall be used for RTUs
   a) The RTU availability shall be at least 99.98 percent.
   b) The RTU reliability shall have a mean time between failures (MTBF) of at least 10,000 hours.

5) Failure of any module or I/O module containing a group of I/O points shall be communicated to the
OCC/ROC for subsequent display and recording into the database.

6) Contractor shall provide details of all data security features for the review/approval of the Engineer as part of the SCADA IDD submittal specified herein.

E. Hardware Requirements

1. General

   a. RTUs shall be from the same manufacturer and shall be of the same product family.

   b. RTUs shall be the same model and revision level, with common modules interchangeable between RTUs.

   c. All RTU equipment shall be current-model equipment at the time of installation.

   d. RTU equipment shall provide a safe means for maintenance personnel to disable power to input/output circuits. The power enabled/disabled state shall be indicated locally.

   e. Each RTU shall be equipped to fully support additional inputs and outputs (i.e., in addition to those listed in this Specification). Provision for this extra capacity shall include: RTU processor and memory equipment; I/O configurations including I/O cable and I/O cards; software addressing; communications connectors and protocols; and power.

   f. RTU equipment shall provide for safe I/O card replacement. Self testing shall include verification that the I/O configuration of the replaced card matches the previous I/O configuration.

   g. I/O signal cable connection to the RTU I/O system shall be implemented using connectors or an approved equal method to facilitate removal of I/O signals for RTU maintenance and replacement.

   h. The Contractor shall provide solid state isolation between the power source and the RTU equipment, and shall protect against damage to equipment.

   i. All RTU chassis and modules shall be grounded. A ground cable shall be provided to connect to the ground system of each location.

   j. RTU equipment shall be designed to operate in electromagnetic conditions of the C&S and CIC.

   k. RTU equipment shall be designed, configured and installed to optimize the safety of maintenance personnel.
l. All RTUs shall be provided with non-volatile and rewritable program and data memory, or battery-backed RAM with a battery low visual indication and software status bit. If the non-volatile program and data memory can execute in place, then no battery-backed RAM shall be necessary.

m. Power:
   1) C&S, CIC, and Driver Comfort Station: RTUs shall operate on 120 VAC.

2. Terminal Blocks
   a. All external wiring interfacing with the RTU cabinet shall terminate on the easily accessible interposing terminal blocks mounted in the RTU cabinet. This wiring shall include, but not be limited to, power supply wiring, test points, and I/O wires.
   b. All terminals, to which high voltages are to be connected, shall be provided with protective covers.
   c. All terminal blocks shall be labeled and have corresponding identification on unit schematic prints.
   d. Terminal blocks shall be design to accept ring-type wire termination or have a clamping screw for wire compression.

3. Wiring
   a. All wiring shall be stranded and of suitable gauge and insulation to meet the intended use. Refer to Section 271500 for requirements regarding wiring for status inputs, analog inputs, and control points for SCADA.
   b. Input and output wiring shall be kept physically separate where possible. High voltage (AC or DC), AC, and DC wiring shall be kept physically separate where possible.
   c. All wiring shall be clearly identified with destination at each end using white plastic slip-on markers with black lettering. The marker diameter shall be consistent with the wire diameter to ensure a snug fit, but yet be able to be rotated for identification.
   d. All wiring shall be secured into harnesses. All wiring including harnesses shall be routed in such a manner as not to obstruct the installation or removal of RTU components, and shall be secured to the rack or cabinet where appropriate for neatness and to reduce strain on components.
   e. All terminations to terminal strips within the RTU cabinet shall be made with crimp-on insulated ring type terminals or termination shall be to clamping screw on terminal blocks.
4. Input/Output Isolation and Protection
   a. All inputs and outputs including power supply and circuit ports shall be capable of withstanding the Standard C37.90.1P.

5. Components
   a. To the greatest extent possible, all components used in the SCADA system shall be high quality solid-state silicon type devices suitable for the application and sufficiently rated for long life.
   b. Proper mounting shall be employed for all components on printed circuit boards to prevent damage from shipping and vibration encountered in the rail “right-of-way” environments.
   c. RTU equipment shall be rack-mounted on EIA (Electronic Industries Association) standard mounting rails and installed in equipment cabinets as specified in Section 271100.

6. Construction/Packaging/Labeling
   a. In addition to general quality workmanship the following shall be implemented:
      1) All plug-in printed circuit cards shall be keyed to prevent damage to the RTU or devices connected to the RTU through improper connection.
      2) Gold plated contacts shall be used on all printed circuit board and other multi-pin connectors.
      3) All printed circuit boards shall be made of glass-epoxy material.
      4) Each printed circuit board and all subassemblies shall be serial numbered to uniquely identify them for warranty.
      5) All nameplates for panels, components, relays, fuse blocks, switches and terminal blocks (except terminal block numbering strips) shall be plastic, utilize white printing on a black background. All nameplates shall meet the approval of the Engineer.
      6) Contractor using standard methods shall suitably and clearly label all terminal blocks, rows, and/or columns.
      7) All plug-in devices/cards shall employ a positive locking design to prevent loosening from vibration.
      8) All internal components shall be labeled and referenced to the internal schematic diagram.

F. RTU Enclosures
1. RTUs in C&S and CIC
   a. Contractor shall mount all RTU hardware components in the Communications Equipment Cabinets as specified in Section 271100.
   b. Contractor shall refer to Section 271100 for a description of specifications for Communications Equipment Cabinets.

2. RTUs in Driver Comfort Station
   a. Contractor shall provide and install wall mount cabinet in the Driver Comfort Station.
   b. Contractor shall mount all RTU hardware components in the wall mount cabinet. See Section 271100 for requirements for the wall mount cabinet.
   c. Contractor shall mount industrial Ethernet switch, media converters, and associated power supplies in the wall mount cabinet.

2.02 SCADA TEST EQUIPMENT

A. The Contractor shall provide a minimum of two portable SCADA test sets.
   1. The SCADA test set shall consist of an industrial, rugged, laptop computer, with associated RTU software and communication data cables.
   2. Each SCADA test set shall be resistant to vibration and shock consistent with being transported in the trunks of cars.
   3. Each SCADA test set shall weigh no more than 9.07 kg (20 pounds) and shall include one or more handles for convenient carrying.

B. The SCADA test sets shall meet the following minimum requirements:
   1. Operate with each RTU.
   2. Display the real-time status of operator-selected control, indication, and analog points.
   3. Provide the ability for an operator to manually set the state of selected simulated RTU indication and analog points sent to the supervisory computer system at the OCC/ROC.
   4. Command the RTU to initiate operator-selected control points.
   5. Initiate local RTU diagnostics and indicate faults.

2.03 PROVISIONING
A. Communications RTUs
   1. The Contractor shall provide and install a minimum of one RTU in each C&S and CIC as shown in the Contract Drawings.

2.04 TYPICAL STATION SCADA I/O POINT SCHEDULE

A. An example schedule of typical SCADA I/O points, i.e. discrete indication points (IND), analog points (ANA), and control points (CMD), for a station in the P2GRT, is shown in Table 284600-1 below. The “Sub-System” column depicts which sub-system associated with a station is the source of the I/O point. Sub-systems shall include the following:

   1. C&S ALARM:
      a. Communication Alarm – Alarm indications from communications equipment, I/O points shall be connected to and processed by the RTU in the C&S.

   2. STA ALARM:
      a. Station Alarm – Alarm indications from station equipment, I/O points shall be connected to and processed by the RTU in the CIC cabinet, or Driver Comfort Station.

B. The Contractor shall note that Table 284600-1 is an example of typical SCADA I/O points for a station, and is intended to convey design concepts only. It is not to be utilized for manufacturing of equipment or construction of the SCADA System. This table is to be used as a starting point for the Contractor's design of the SCADA System. All manufacturing and construction shall be accomplished using the Contractor's SCADA Point Chart, Shop Drawings, System Design, Installation Plan, Wiring Plan, and other submittals as described herein, only after they have been approved by the Engineer.
Table 284600-1 : Example Schedule of Typical SCADA I/O points

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>Type</th>
<th>Sub-System</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>C&amp;S INTRUSION ALARM</td>
<td>IND</td>
<td>C&amp;S ALARM</td>
</tr>
<tr>
<td>2.</td>
<td>C&amp;S HIGH TEMPERATURE ALARM</td>
<td>IND</td>
<td>C&amp;S ALARM</td>
</tr>
<tr>
<td>3.</td>
<td>C&amp;S SMOKE DETECTOR ALARM</td>
<td>IND</td>
<td>C&amp;S ALARM</td>
</tr>
<tr>
<td>4.</td>
<td>C&amp;S UPS ON LINE</td>
<td>IND</td>
<td>C&amp;S ALARM</td>
</tr>
<tr>
<td>5.</td>
<td>C&amp;S UPS LOAD ON BYPASS</td>
<td>IND</td>
<td>C&amp;S ALARM</td>
</tr>
<tr>
<td>6.</td>
<td>C&amp;S UPS ON BATTERY</td>
<td>IND</td>
<td>C&amp;S ALARM</td>
</tr>
<tr>
<td>7.</td>
<td>C&amp;S UPS BATTERY LOW</td>
<td>IND</td>
<td>C&amp;S ALARM</td>
</tr>
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<td>SPARES (MINIMUM 50%)</td>
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PART 3 : EXECUTION

3.01 PREPARATION

A. The Contractor shall be responsible for field verification of dimensions and coordination of conduit entry and all other mounting conditions with the entity manufacturing the equipment.

B. The entity manufacturing the equipment shall provide onsite technical supervision and assistance during installation and interconnection of the system equipment installed by the Contractor. Said supervision is to insure the safety of the proper installation and operation of the system equipment, prior to the installed system beginning the 30-day operational test.

C. After the system equipment has been delivered, an onsite inspection will be made by the Engineer. If any equipment has been damaged or for any reason does not comply with the requirements of this Section, the Contractor will be notified in writing, and shall be required to replace the equipment at his own cost and expense, even though the equipment has been previously inspected, tested and approved for shipment. After such satisfactory replacement, the system shall be installed by the Contractor.

3.02 INSTALLATION

A. The Contractor shall install all SCADA equipment in accordance with the manufacturers’ instructions at each location as shown in the Contract Drawings, and as specified herein.

B. Contractor shall install all RTU connections, including power, communications, I/O, and in each C&S, CIC, and Driver Comfort Station.

1. Contractor shall refer to Section 271500 for requirements regarding terminal blocks, protector blocks, conduits, raceways, cable trays, wire, and cables required for installation of the SCADA equipment defined in this Section.

C. Contractor shall install all data cabling and all necessary Ethernet fiber optic device servers or media converters between RTU communications ports to the Ethernet Access switch associated with the CTS as described in Section 272100.

1. Contractor shall refer to Section 271500 for requirements regarding copper and fiber optic horizontal data cabling.

2. Contractor shall refer to Section 271600 for requirements regarding Ethernet fiber optic media converters and/or device servers.
3. Contractor shall provide and install fiber optic horizontal data cabling, between the C&S and CIC as specified in Section

D. Contractor shall provide and install all mounting hardware associated with the SCADA equipment specified herein.
   1. A grounding cable shall be attached mechanically to the cabinet where SCADA RTU equipment is mounted such that it can be easily removed if necessary.

E. Installation of all SCADA equipment shall be consistent from site to site to provide uniformity in installations.

F. The Contractor is required to ensure that the installation of new equipment does not adversely affect the operation of any existing systems.

3.03 TESTING

A. Factory Tests
   1. Contractor shall perform all factory tests as required in Section 279000.

B. Following completion of the installation of all SCADA equipment at each site, Contractor shall inspect all equipment and wiring to verify that all mechanical connections are made and properly secured, and all hardware is installed in its proper location and is properly terminated
   1. This inspection shall include conductor and shield continuity and isolation verification of all installation wiring.
   2. Data sheets containing evidence of such inspection, certified as correct by Contractor, shall be delivered to the Engineer for approval.
   3. Contractor shall receive approval of such inspection certification before applying power to the SCADA equipment covered by such certification.

3.04 HARDWARE DOCUMENTATION

A. SCADA Manuals
   1. The Contractor shall provide SCADA Operation, Maintenance (O&M) and Programming Manuals as specified in Article 1.04 herein.

B. SCADA Manuals At Each Location
1. The Contractor shall provide SCADA station manuals for each C&S and CIC.

2. The SCADA manuals at each RTU location shall include as a minimum the following items:
   a. Installation and startup instructions;
   b. Instructions for expansion of RTU I/O modules;
   c. Theory of operation;
   d. Maintenance and troubleshooting guidelines;
   e. Functional block diagrams;
   f. Complete list of I/O points associated with the RTU location.

END OF SECTION