SECTION 7 - COMMUNICATIONS AND CENTRAL CONTROL

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7.1.0 GENERAL

The Communications and Central Control System (CCS) includes communications equipment, the remote I/O equipment, and the human interface equipment to help allow controllers to monitor wayside systems and facilities and supervise mainline rail operation. The CCS and Supervisory Control and Data Acquisition (SCADA) System shall be provided on the entire LRT system. The scope includes:

- A CCS with supervisory control to allow RTD Operations personnel to remotely monitor the signal system, traction electrification system, ticket vending machines, and station and wayside facilities, issue route requests to the signal system and issue commands to open and close breakers to the traction electrification system.
- Remote I/O equipment interconnecting RTD's OCC with signal cases and houses, communications equipment houses and cabinets, and traction power substations.
- Radio control equipment to be used at the control room.
- Microwave equipment to connect RTD facilities.
- Telephone PBXs and telephones for voice communication from the control room to other RTD personnel and to outside personnel.
- Emergency telephones installed in elevators, LRT tunnels, on platforms and other passenger waiting areas.
- A closed circuit television (CCTV) system to allow RTD personnel at the control room and in the Security Command Center to monitor activity at parking facilities, elevators and station platforms. Refer to Section 14 - System Safety and System Security.
- A public address/variable message sign system (PA/VMS) and interface equipment, accessible from the control room and at designated passenger stations to enable audible and visual text display of passenger information.
- A communications transmission system (CTS) consisting of hardware, and copper and fiber optic cable to carry RTD voice, data, and video communication information. The Design Engineer shall coordinate fiber optic specifications with RTD's SCADA Communications Engineer.
- Communication houses, cabinets, batteries, chargers, raceway, etc. to enable reliable operation of wayside communications equipment.

7.2.0 STANDARDS AND CODES

The communications and central control system shall be designed and implemented to the latest revision at the time of award of contract of the applicable codes and standards of the following organizations:

- American National Standards Institute (ANSI)
- Electronic Industries Association (EIA)

- Federal Communication Commission (FCC)
- Institute of Electrical and Electronics Engineers (IEEE)
- International Organization for Standardization (ISO)
- National Electrical Manufacturers Association (NEMA)
- National Fire Protection Association (NFPA)
- Building Industry Consulting Standards Institute (BICSI)
- Internet Engineering Task Force (IETF)

7.3.0 OPERATIONS CONTROL CENTER (OCC)

The OCC shall be designed to be a comfortable, quiet, and uncluttered working area that meets the requirements of the Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG).

7.3.1 Control Room Layout

The layout of the control room shall be such that the control room staff can work and interact with each other effectively and efficiently. To be most effective, the staff positions within the control room shall be within line-of-sight of one another to allow the use of visual signals to supplement their voices.

Access to the control room shall be located to minimize the disturbance to staff communications or their view of the overview display.

7.3.2 Consoles

Control room staff shall utilize consoles to supervise LRT system activities. Each console within the control room shall contain the communications, reporting, controls, and monitoring equipment necessary to carry out the assigned functions by the controllers. All controller consoles shall be identical.

All consoles shall have the following design requirements:

- Like equipment and procedures shall be used for like functions and like functions shall be in the same general physical location in each console.
- Frequently used equipment shall be located most conveniently. Most frequently used procedures shall require the fewest, least extended motions possible.
- The amount of equipment and variety of procedures at a console shall be minimized, consistent with requirements for modular and expandable design.
- Voice communication interfaces shall be integrated such that OCC staff need not switch between more than two devices to interact

with the several parties with whom they may need to maintain contact. Audio outputs shall have volume and tone controls.

- Console physical dimensions shall be consistent with ergonomic limits. Consoles shall be designed to accommodate the reach of a 5th percentile female and the size of a 95th percentile male.
- Console components shall be modular to allow replacement of a failed unit within 30 minutes, and replacement shall not require shutdown of the functioning portion of the console.
- Writing and documentation storage space shall be provided. The controller consoles shall have the following design requirements.

A keyboard and point-and-click device shall be able to be used for display item selection and function initiation. Single purpose function buttons and switches may be used for, but limited to, functions which are frequently used or require rapid activation.

Console display monitors shall be high resolution, low flicker. Color capabilities shall be consistent with information requirements. Console monitors shall be selected and placed to minimize emission exposure. Monitors shall have easily accessible intensity and color controls.

Console furniture and chairs shall be consistent with ANSI/HFS 100, "American National Standard for Human Factors Engineering of Visual Display Terminal Workstations".

Controller consoles shall be assignable to a geographic portion of the LRT system.

7.3.3 Environmental Considerations

The following site requirements shall apply at the OCC:

- The OCC shall meet all applicable fire safety requirements, including NFPA 130. A fire alarm and suppression system shall be provided for the control room and equipment room.
- Raised flooring with removable tiles may be provided for the control room and equipment room. The metallic floor framing shall be grounded.
- Wide door access shall be provided at the control room and equipment room to accommodate the movement and placement of equipment.
- The control room and equipment room shall each be fully enclosed to create a secure environment and to minimize noise. The equipment room shall also be a secure area.

- The lighting within the control room shall be generally uniform, and at a level of at least 50 foot-candles. Consoles shall have additional, locally controlled, adjustable spot lighting to 100 foot-candles.
- Reflected glare on display screens, overview display and console work surfaces shall be minimized.
- Noise within the control room shall be minimized. There shall be acoustic treatment of the control room, including floors and walls, to absorb noise. Background noise, including background noise from Communications System equipment, shall not exceed 55 dba.
- The control room and Equipment Room shall be provided with air conditioning. There shall be independent temperature controls for the control room and Equipment Room. The temperature in each area shall be adjustable to be within the comfort zone for humans for interior spaces. The air distribution shall minimize temperature gradient and drafts. The temperature shall be maintained in the range of 24°C to 28°C.
- Approximately two air exchanges per hour shall be provided for. The air distribution shall minimize temperature gradient and drafts.
- Electrostatic control shall be provided for in the Control Room and Equipment Room. Antistatic flooring and carpeting shall be used.

7.4.0 SCADA

7.4.1 Safety Constraints on SCADA

The relationship between the Communications System and the Signal System shall be such that no action or failure of the CCS/SCADA (nor any other Communications System element) can cause or allow an unsafe train operating condition. Should the CCS/SCADA become completely inoperative, for any reason, the LRT System shall be able to continue to operate safely.

7.4.2 System Operation

CCS/SCADA shall normally function without operator intervention except for routine service.

CCS/SCADA shall have the capability for performing orderly system start-up and shut-down as commanded by a system operator.

Remote CCS/SCADA equipment shall operate in an unattended mode. The central CSS/SCADA equipment shall continue operation in the event of a failure of remote SCADA equipment, and upon return to service of failed equipment, automatically resume normal monitoring and management of that equipment.

7.4.3 System Requirements

7.4.3.1 Response Times

The elapsed time from the first possible detection by remote I/O equipment of an alarm or device change of state until display at the control room shall not exceed 2.5 seconds.

When a user enters a command for any individual device control, the remote I/O equipment shall generate the associated output signal, in the field, in no more than 2.5 seconds.

When a user requests a display, the completed display shall appear on the screen in not more than two (2) seconds.

7.4.3.2 Accuracy of Information

Display of train position shall be accurate to within a track circuit for signaled territory.

7.4.3.3 Availability

CCS/SCADA is intended to operate 24 hours a day, seven days a week. The CCS/SCADA central system availability shall be at least 99.8% for all operating functions.

Any console shall be capable of fully backing-up a failed console of the same type. Back-up shall take the form of assuming the full geographic and functional responsibilities of the failed console.

The CCS/SCADA shall be constructed such that it can be put in place and continue to operate while:

- Already-operating lines are retrofitted for the new Communications System
- New lines are equipped, tested and brought into service.

7.4.4 Displays

Displays at the control room shall be graphic and text displays. Graphic displays shall be provided at both the overview display and at the console displays. The overview display and console graphics displays shall provide a semi-geographic representation of the LRT System and its major subsystems. Information displayed shall be kept up-to-date.

At the control room, user interface equipment characteristics, equipment location, and display contents shall be consistent with MIL-STD-1472 "Human Engineering Design Criteria for Military Systems, Equipment, and Facilities" or

an equivalent human factors standard or guide such as the FAA's Human Factors Design Guide.

For all graphic displays the following guidelines shall be followed:

- Distinct colors and display attributes (e.g., flashing) shall be used to draw attention to alarm or abnormal conditions.
- There shall be consistent use of colors, geographic orientation, labels, display attributes, and object symbols.
- Label and message contents shall be in language consistent with RTD train operations terminology.

7.4.5 Software

Software design and implementation of CCS shall:

- Follow guidelines for software design and documentation as defined in IEEE Std. 729
- Conduct a software quality assurance program for software development consistent with practices as defined in IEEE Std. 730
- The LRT software system shall be easily definable and modifiable so that:
- The overview display and console display contents can change as track, stations, and devices are added;
- Console display devices can be changed.

Application software shall be written in an industry-standard high level language. It shall be built on a commercially prevalent or industry-standard operating system and be portable to higher capacity computer system configurations running that standard operating system. Networking system software shall satisfy the Open System Interconnect (OSI) requirements and/or utilize industry-standard physical level and link level communication protocols.

All CCS software shall be completely tested before it is used for train operations.

7.4.6 Central Equipment

The CCS central equipment shall be compatible with the existing system and shall:

- Utilize commercially available computer equipment and peripheral devices. Custom equipment shall be limited to special functions and interfaces.
- Normally operate unattended.

- Have sufficient redundant equipment to permit automatic switch-over so that no single failure will interrupt operation for more than 30 seconds.
- Automatically detect equipment failures and provide corresponding failure indications.
- Where feasible, provide for on-line replacement of failed components, console devices, computers, peripheral devices and data communications interface equipment while it continues to operate
- Be sized to handle the defined LRT system size under peak period operating conditions and have provisions for future expansion
- Be capable of communicating and providing control and indication of all of the existing RTD remote I/O, VMS, PA, signal and traction electrification equipment.
- Be physically located and configured in such a way so as to provide for easy maintenance access.
- Be provided with an UPS, with a minimum capacity of 4 hours, and a redundant source of AC power.

7.4.7 Remote I/O Equipment

The Remote I/O Equipment (e.g. PLCs or RTUs), which is the field portion of SCADA, shall:

- Be solid-state, microprocessor based with logic elements and auxiliary components configured on easily replaceable plug-in modules.
- Be of common design for all remote sites to provide interchangeability of modules.
- Be capable of continued operations with the loss of communication to the OCC as a result of either communication equipment failures or central equipment failures.
- Operate normally unattended. Remote I/O equipment logic and configuration data shall reside in non-volatile memory.
- Perform self-tests upon power up and on command from local test equipment and from OCC. Self-tests shall also be performed by input/output subsystems and input/output cards.
- Provide for maintenance of input/output circuits (including disabling power to output circuits) and safe replacement of input/output cards without the removal of any wiring.
- Operate within a power supply range of 90 to 130 volts ac and a frequency between 57 to 63 Hz.
- Be capable of continued operation in the electromagnetic environment where they will be located, such as TES substations, signal cases, and communications houses.

- Support local initialization and troubleshooting with either a local control panel or portable test equipment. Also support remote initialization and troubleshooting via the data communications network.
- Be modular in design to provide expansion of performance and capacity by adding subsystem modules. This shall include the ability to add a minimum of 20% more input/output subsystem modules, be supplied with hardware and software tools and documentation for reconfiguration and expansion.
- Temperature specification of -40ºC to +65ºC
- See the below sections for SCADA requirement interfaces to other LRT elements:
  - Traction Electrification System – Section 9
  - Signals – Section 8
  - Elevators - Section 5
  - Train-to-Wayside Communication – Sections 8 and 13
  - Fare Collection Equipment – Section 12

7.4.8 Simulator

A CCS simulator shall be provided. The simulator shall allow training of CCS users.

The simulator shall model the physical plant so as to present accurate representations of train movement, interlocking response, and traction power system response for the above purposes. The simulator shall model all discrete state indications, which are normally presented to the CCS. The simulator shall be deterministic. The simulator shall be capable of simulating normal and abnormal equipment operation. The simulator shall also provide the capability to playback (e.g. re-display) real wayside events as originally depicted on the controllers' displays and the overview display.

The simulator shall provide both an Instructor user interface and a trainee user interface. The Instructor shall be able to alter the simulated behavior of trains as well as all wayside devises. The trainee's user interface to the simulator shall be the same displays as those used in normal operations at the controller consoles. The simulator shall use the standard commands and displays, which normally support active operations, supplemented by simulator-specific commands.

The simulator shall model the entire physical plant including the traction power system. The simulator shall be capable of modeling train control and traction power simultaneously together.

7.5.0 COMMUNICATIONS

7.5.1 Radio System

Modifications to RTD's existing UHF radio system shall be made to enable communication between:

- LRT trains and Controllers
- LRT trains and Rail Supervisors
- LRT Rail Supervisors and Controllers
- LRT non-revenue vehicles and Controllers
- LRT MOW personnel and Controllers
- LRT trains and maintenance personnel
- LRT Controllers and other LRT personnel along the ROW

All LRT LRV's and transportation and MOW non-revenue vehicles are equipped with mobile radio transceivers, with a minimum of 25 watts of radio frequency output power. A sufficient number of hand-held portable radios are furnished to allow LRT train operators and RTD employees along the LRT right-of-way to carry a portable transceiver.

Radio coverage along the LRT alignment including covered sections shall enable a two-watt portable radio to be heard with 20-dB quieting at the OCC along 98% of the alignment, 99% of the time. No "dead sections," with less than 20-dB quieting, longer than 100 feet shall be allowed.

7.5.2 Microwave System

Where required for communications to RTD facilities not on the ROW, RTD LRT maintenance and operations facilities and the OCC shall be interconnected via LRT's existing microwave system. The number of microwave channels supplied shall be consistent with RTD's operating requirements for that location. The microwave system may carry RTD's radio audio. All new microwave equipment shall be of the same manufacturer and model number as RTD's existing equipment and shall be installed to support the 'ring' configuration whenever possible.

7.5.3 PBX/Telephone System

Each RTD maintenance and operations facility shall be equipped with its own Private Automatic Branch Exchange (PBX) and networked into RTD's existing telephone system. PBX, telephones, and interface equipment will provide communications between Operations personnel and RTD personnel and personnel outside of RTD property. The PBX/Telephone system shall be compatible with RTD's existing telephone system at other RTD facilities.

The emergency telephone system on station platforms shall be designed to permit passengers at stations to communicate with 911 dispatch. In addition, the emergency telephones shall allow monitoring of the audio between the station emergency telephone and 911 by rail operations. The phones will be activated by push button and contain Braille lettering to be ADA compliant.

Tunnel 'bluelight' phones and elevator phones in station elevators will be received by Rail Controllers only.

All phone conversations at the controller workstations shall be recorded.

See Section 14 – System Safety and System Security for additional telephone requirements in elevators, tunnels, parking facilities, pedestrian bridges and pedestrian tunnels.

7.5.4 CCTV System

The CCTV system shall comply with the requirements of Section 14 of the Design Criteria – System Safety.

In addition the CCTV system shall be coordinated with Section 5 – Station Design Criteria and 11 – Operations Facility to ensure that the CCTV system design is optimized based on the requirements of these elements. Refer to Section 14 System Safety and Security.

7.5.5 PA/VMS System

Where requested, RTD station platforms and public areas will be equipped with PA/VMS equipment. PA/VMS equipment will consist of amplifier-driven loudspeakers and variable message signs installed and operated in compliance with ADAAG requirements. Local input to both audible and visual portions of the PA/VMS system will be provided at designated stations

Text message entry will be by way of easily and understandable graphical user interface with Windows-type entry screens and prompts. Audible and text messages will be coordinated so that playback to the public occurs at the same time. It shall also be possible to transmit audio and text messages independent of each other.

Controllers at the control room shall be provided with the ability to distribute both pre-recorded and ad-hoc messages to passenger stations. This ability will include provisions to send messages to an individual station, a group of stations, or all stations.

7.5.6 Communication Transmission System

A high bandwidth, fault tolerant, wide area communications transmission system (CTS) shall be installed along the LRT ROW to inter-connect the various field CCTV, data and voice signals to/from the field from/to the

OCC. The CTS includes fiber optic cable plant, optical and electronic transmission equipment, grooming and provisioning equipment, and other equipment necessary to provide communications channels at native signal level between sites. The portion of the CTS that interconnect communications system nodes, central control, and major RTD operating and administration facilities shall be configured so that it will continue to operate normally on loss of a single fiber or any single equipment module. The reliability of this system shall be 99.99% with failover and resumption of normal communication traffic to a redundant path on loss of the operating path in less than 1 second.

The CTS shall be compatible with the existing system.

See section 12 for the communication transmission system interface to the fare collection network.

7.5.7 Network Management System

Network management for the CTS shall be on the same platform as the CCS management. SNMP compatible MIBs shall be provided on all electronic devices on the CTS and configured on the network management system for alarm and monitoring. The NMS shall be compatible to the existing tiered level approach utilized.

7.5.8 Communication Houses and Enclosures

Material and equipment shall be designed to ensure satisfactory operation and operational life in the environmental conditions which will prevail where the material or equipment is installed. Communications and CCS equipment that is not housed in an environmentally controlled enclosure shall be rated to operate in the environmental conditions described in Section 1 – General Information. In addition the equipment shall be designed to operate and not have degraded operational life in the below conditions:

- ½ inch ice loading
- 85 mph wind withstand load
- Seismic zone 1 rating

Field communications equipment will be located in dedicated communications equipment houses or cabinets. All houses and cabinets shall be equipped with appropriately sized air-conditioning and heating equipment to maintain temperatures within the operating range of all equipment.

Outdoor security lighting shall be provided above communications houses. The security lighting will be controlled by a photo-electric cell and shall not overflow into surrounding residential communities.

Communication house and cabinet foundations shall be designed to withstand all live and dead loads of the house and cabinet and equipment. Foundations will be designed in accordance with all applicable standards as well as local Building Codes. An appropriate factor of safety according to the standards shall be applied at each site. Each foundation slab will be provided with openings to connect the equipment to the local power supply system and to outside circuits.

Communication houses will be of double roof and wall construction to accommodate insulation material to reduce heat transfer.

7.5.9 Communication Power System

All critical devices in the CCS, remote I/O equipment, CTS, radio equipment, and microwave equipment shall be powered from an uninterruptible power supply. A device is considered critical if removing power to it will degrade the performance of the system it is a part of. The UPS shall be sized to carry the full load of the above equipment at a communication house, case or RTD facility for at least 4 hours. The UPS charger shall be sized to carry the above load while recharging a completely discharged battery set. The UPS charger shall be able to recharge the batteries under these conditions in less than 12 hours.

7.5.10 Location of Communication Enclosures and Equipment

All communications devices, including platform mounted equipment, houses, cabinets, antennas and raceway shall clear the LRV dynamic clearance envelope by a minimum of 6 inches. This requirement includes clearance for enclosure doors in any open, intermediate, or closed position. Communication houses and cabinets shall be located so as not to obstruct the LRV operators', motorists' or pedestrians' view of trains.

Communication house placement and access shall accommodate the addition of heavy equipment via a roll cart or dolly.

7.6.0 INTERFACE REQUIREMENTS

7.6.1 Central Control Facility

The communications system and human interface equipment within the OCC, including consoles, radios, telephones and computers, shall be connected to essential power. Other equipment to be connected to essential power includes all OCC emergency systems and at least 40% of OCC and Equipment Room lighting.

A grounding system shall be installed in the OCC. This grounding system shall include a ground bus connected to the building entrance power distribution grounding and shall interface to connection points in the Equipment Room and the Control Room.

7.6.2 SCADA Remote I/O Equipment

Remote I/O equipment shall support digital inputs and outputs via relay contact closures (or optically isolated solid state equivalents such a silicon controlled rectifiers). All digital inputs to SCADA shall be of the same type. All digital outputs by SCADA shall be of the same type. The following SCADA input and output requirements shall be met:

- Digital inputs to SCADA shall be from normally open and normally-closed contacts. The operating voltage DC power supply shall nominally be in the SCADA domain. Contact ratings shall be as required for the circuit.
- Input and output signals shall be electrically isolated from SCADA equipment.
- SCADA shall generate outputs via relays. Transient suppression circuits shall be provided by the SCADA contractor. Contact ratings shall be as required for the circuit. SCADA interface relays and relay contacts shall have an MTBF at rated loads of 5,000,000 cycles or more.
- SCADA outputs shall be momentary contact closures with a time duration that is stable and adjustable.
- The remote SCADA equipment shall prevent unintended action such as energizing output circuits upon power-up and power restore.

SCADA shall be designed and implemented so that wiring and cabling between remote I/O equipment and field devices are uniform in type, routing, and connection locations. The following interface requirements shall be met:

- I/O signals to/from SCADA at each signal facility shall terminate at one centralized location.
- I/O signals to/from SCADA at each TES site shall terminate at one centralized location.
- SCADA terminations shall include test points and rapid disconnect
- All wires and cable shall be labeled using a logically consistent labeling convention

Remote I/O equipment shall be equipped for protection from electromagnetic interference levels consistent with their locations. Bus bars shall be provided for grounding in all input/output termination cabinets.

Data communications between SCADA remote I/O equipment and the OCC shall utilize industry non-proprietary protocols, which support error detection and message retransmission.

Conduits

Adequate conduit shall be provided to a communication house or case to accommodate the initial cabling requirements and still have the equivalent of one 4 inch conduit spare.

For communication conduit requirements in the mainline ductbank, stations, parking facility, or to a TVM see section 9.7.0 – Conduit and Ductbanks.