California High-Speed Train Project

TECHNICAL MEMORANDUM

Communications Systems General Requirements

TM 3.4.1

Prepared by:	*Signed document on file* Blake Russo	17 Sep 10 Date
Checked by:	*Signed document on file* Rick Schmedes	27 Sep 10 Date
Approved by:	*Signed document on file* Ken Jong, PE, Engineering Manager	05 Oct 10 Date
Released by:	*Signed document on file* Cliff Eby, Program Director	08 Oct 10 Date

Revision	Date	Description
0	27 Sep 10	Initial Release

Note: Signatures apply for the latest technical memorandum revision as noted above.

Prepared by PB
for the California High-Speed Rail Authority

System Level Technical and Integration Reviews

The purpose of the review is to ensure:

- Technical consistency and appropriateness
- Check for integration issues and conflicts

System level reviews are required for all technical memoranda. Technical Leads for each subsystem are responsible for completing the reviews in a timely manner and identifying appropriate senior staff to perform the review. Exemption to the system level technical and integration review by any subsystem must be approved by the Engineering Manager.

System Level Technical Reviews by Subsystem:

Systems:	*Signed document on file* Richard Schmedes	27 September 10 Date
Infrastructure:	*Signed document on file* John Chirco	25 July 10 Date
Operations:	*Signed document on file* Joseph Metzler	17 September 10 Date
Maintenance:	*Signed document on file* Joseph Metzler	17 September 10 Date
Rolling Stock:	*Signed document on file* Frank Banko	22 July 10 Date

Note: Signatures apply for the technical memorandum revision corresponding to revision number in header and as noted on cover.

TABLE OF CONTENTS

ABSTRACT

To insure safe and reliable operations, the CHSTP requires the deployment of a robust, high-speed Optical Communications Network as well as a Wireless Communications System for train-to-wayside, portable and mobile field communications along the entire alignment.

The design will incorporate existing, proven, and accepted communication industry standards and equipment for its implementation.

This technical memorandum presents the major elements of the Communication Transmission System (CTS) for the California High-Speed Train (CHST) project (CHSTP). It will provide a high-level description of the communications elements and requirements, along with drawings, technical references and summary recommendations to insure the design of a secure and reliable communications systems to support the CHSTP.

1.0 INTRODUCTION

1.1 PURPOSE OF TECHNICAL MEMORANDUM

This technical memorandum presents the major elements of the Communication Transmission System (CTS) for the California High-Speed Train (CHST) Project (CHSTP). It provides a high-level description of the communications elements and requirements, along with drawings, technical references and summary recommendations to guide the design of a secure and reliable communications system.

Following review, specific guidance in this technical memorandum will be excerpted for inclusion in the CHSTP Design Manual. This document is also to provide an informative document to the Regional teams on the nature of the communications network.

1.2 STATEMENT OF TECHNICAL ISSUE

To assure passenger safety and operational reliability the CHSTP requires the deployment of a robust, high-speed Optical Communications Network as well as a Wireless Communications System for train-to-wayside, portable and mobile field communications along the entire alignment. The design will incorporate existing, proven, and accepted communication industry standards and equipment for its implementation.

These goals will be achieved by a dual fiber optic ring operating as the system backbone, by redundant dual-homed fiber optic drop cables, a tunnel distributed antenna system (DAS) and strategically placed wayside wireless communications nodes that provide overlapping radio coverage.

The Main and Regional Operations Control Centers (OCC, RCC) and Passenger Stations will provide major and redundant connection and switching points for the communications network.

The planned 10 Gbps fiber optic rings have been sized to accommodate all currently planned applications and subsystems plus allowing for a 100% capacity growth

Communications facilities and equipment need to be connected to ground for both equipment and personnel safety and to assure proper operation of the communications system. Technical Memorandum 3.3.4 describes the communications facilities grounding requirements. Other technical memoranda clarify the interfaces between Communications, Traction Power, Train Control and other CHST systems.

1.3 GENERAL INFORMATION

1.3.1 Definition of Terms and Acronyms

CAT	Category
CCTV	Closed-Circuit Television
CTS	Communications Transmission System
FOCN	Fiber Optic Cabling Network
FCC	Federal Communications Commission
Gbps	Giga-bits per second
GigE	Giga-bit Ethernet
IEEE	Institute of Electrical and Electronics Engineers
LAN	Local Area Network
Mbps	Mega-bits per second
MDS	Mobile Data System
MPLS	Multi-Protocol Label Switching

NFPA	National Fire Protection Association
OCC	Operations Control Center
QoS	Quality of Service
RF	Radio Frequency
RTU/PLC	Remote Terminal Unit / Programmable Logic Controller
SCADA	Supervisory Control and Data Acquisition
SLAN	Passenger Station LAN
TC	Train Control
TCCR	Train Control and Communications Room
TCP/IP	Transmission Control Protocol/Internet Protocol
TPF	Traction Power Facility
TPSS	Traction Power Substation
TRC	Tunnel Radio Communications
TVM	Ticket Vending Machine
VLAN	Virtual Private Local Area Network
VMS	Variable Message Sign
VPN	Virtual Private Network
VRCS	Voice Radio Communications System
WAN	Wide Area Network
WCS	Wireless Communications System
WLAN	Wireless Local Area Network

A complete listing of all abbreviations and acronyms used by the Project are contained in Technical memorandum TM 0.0.a; Design Terms, Abbreviations, and Acronyms.

1.3.2 Units

The California High-Speed Train Project (CHSTP) is based on U.S. Customary Units consistent with guidelines prepared by the California Department of Transportation (Caltrans) and defined by the National Institute of Standards and Technology (NIST). U.S. Customary Units are officially used in the U.S. and are also known in the U.S. as “English” or “Imperial” units. In order to avoid any confusion, all references to units of measure should be made in terms of U.S. Customary Units.

2.0 DEFINITION OF TECHNICAL TOPIC

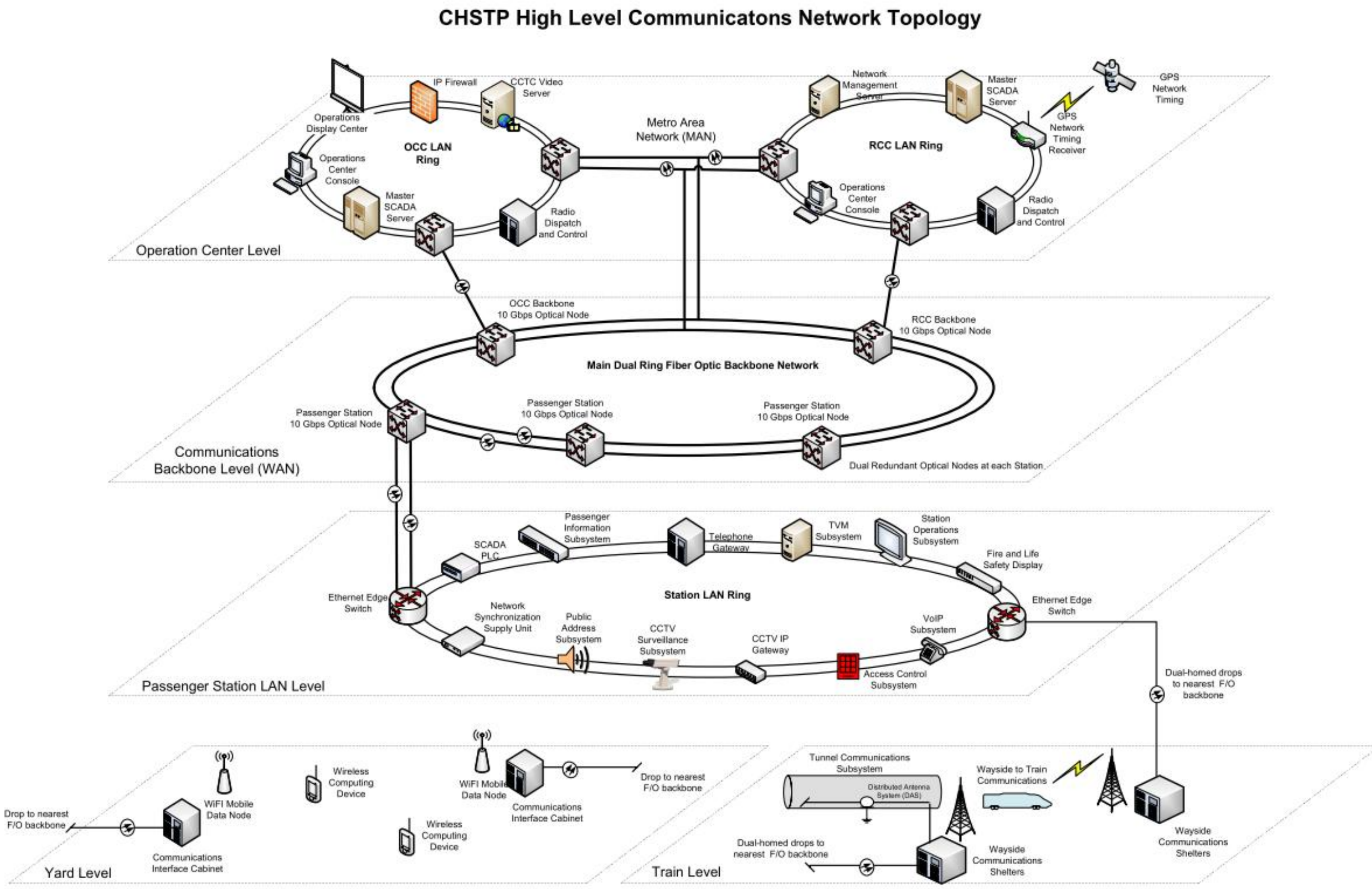
The technical topic of the memorandum is a high-level description of the Communications Transmission Network (CTS) used to provide communications services to the CHST system. The CTS provides connectivity and communications to all devices and subsystems needing central control. Its purpose is to insure the safe operation of high-speed trains on the CHST system by delivering data from any point on the network in a secure and reliable fashion.

The CST is defined as all the equipment and software required to switch, process, control, and deliver data traffic between field locations and a central control facility. The CTS includes the entire radio and optical digital data transmission system for the CHST transportation corridor. Digital data refers to voice, video, as well as any control, alarm and status messages plus Network Management System (NMS) data used to support CTS configuration and management.

The CTS does not include application-specific equipment, processing or data display except to enable the connection of such systems to a central control authority. The major components of the CTS are:

- Optical Network Node Switches
- Ethernet Edge and Aggregation Switches
- Fiber Optic Cabling Network (FOCN) including backbone and drop cables
- Wireless Communication System (WCS)
- Local Area Network (LAN) for OCC, RCC, passenger stations, traction power, train control, and maintenance and operations centers.
- Metro Area Network (MAN) for OCC/RCC interconnection
- Tunnel Radio Communication System (TRCS)

The following diagram presents the high-level overview of the CTS



2.1 GENERAL CHSTP COMMUNICATION SYSTEM REQUIREMENTS

The communications network will be capable of supporting any application protocols that are required by CHST operations. The communications network presumes that data is Ethernet-framed and IP-addressable according to IEEE standards to be set forth in future Communications Design Criteria and Specification documents.

Fault tolerance will be provided by pre-provisioned failover paths using MPLS or VLAN Access Control Lists to reroute traffic in the event of any cable break or electronic failure. Network data traffic will travel over a dual redundant fiber optic network which provides two 10 Gigabits paths of bandwidth.

Network operations, provisioning, monitoring and control will be from a centralized communications facility at the Operations Control Center (OCC) and/or from Regional OCCs.

Communications switching and optical terminating equipment will be provided for all Passengers Stations, Traction Power Substations, Traction Power Switching Stations, Paralleling Stations, Interlocking, and Wireless Communication Facilities. This equipment will allow these subsystems to interconnect to the main fiber optic communications backbone and to communication with any point in the system to support all necessary CHST control, maintenance and emergency operations.

All communications equipment is required to be powered from a UPS system with eight hour battery backup. Equipment is required to automatically start-up following a power outage of any length without requiring manual re-initialization and must retain full status memory and process recall when operating on power from battery or inverter sources.

The communications system will provide and deliver synchronize time for all equipment and devices from the Master System Clock and network time server. If network time server is not available, a stand-alone Stratum 3 clock shall be provided for each sub-system to maintain system time until the network server is available.

2.2 LAWS AND CODES

Initial high-speed train (HST) design criteria will be issued in technical memoranda that provide guidance and procedures to advance the preliminary engineering. When completed, a Design Manual will present design standards and criteria specifically for the design, construction and operation of the CHSTP's high-speed railway.

Criteria for design elements not specific to HST operations will be governed by existing applicable standards, laws and codes. Applicable local building, planning and zoning codes and laws are to be reviewed for the stations, particularly those located within multiple municipal jurisdictions, state rights-of-way, and/or unincorporated jurisdictions.

In the case of differing values, the standard followed will be that which results in the satisfaction of all applicable requirements. In the case of conflicts, documentation for the conflicting standard is to be prepared and approval is to be secured as required by the affected agency for which an exception is required, whether it be an exception to the CHSTP standards or another agency standards.

2.2.1 Federal Requirements

Title 47 of the Code of Federal Regulations (CFR) regulates radio communications all applicable Parts.

Title 49 of the CFR governs rail transportation. It provides standards for compliance with the Americans with Disabilities Act and with safety of rail transportation.

2.2.2 State Requirements

The Communications System will be designed to be in compliance with requirements of the State of California, California Public Utilities Commission, and local codes and regulations.

3.0 ASSESSMENT / ANALYSIS

3.1 COMMUNICATIONS NETWORK ARCHITECTURE

The general data network concept includes different types of networks: A Wide Area Network (WAN), a Regional Metro Area Networks (MAN) and Local Area Networks (LAN).

The Wide Area Network also known as the backbone Fiber Optical Cable Network (FOCN) includes the entire alignment and has major optical Nodes at Passenger Stations, Regional and Main OCCs. Most of the CHST communications subsystems will use this network. It provides a dual 10 Gigabit Ethernet Ring and fast failover network recovery for all systems requiring interconnection back to central control facilities. These systems include, but are not limited to, the following: fire alarm reporting, traction power and facilities SCADA, train control supervisory messages, hazard-detection, access control and security messages, passenger information, CCTV surveillance data, telephones, fare vending, and general network maintenance information (NMS).

A Regional Metro Area Network will interconnect the OCC and the RCCs for purposes of providing a failsafe means to allow any central control facility to take over operations in the event of a failure of the others.

Local Area Networks will be located at passenger stations and at major Regional Control Centers (RCC) including the main OCC. The purpose of the LANs are to provide short range communication (e.g. in building or between nearby buildings) for each device needing a connection to the Core fiber optic backbone network. The LAN allows devices to share a common local high-speed network to improve system utilization, share bandwidth and reduce system wiring costs.

Every main computing center will have its own LAN and all peripheral devices, display terminals, consoles and communication gateways to the outside world will reside and be managed members of the LAN. For example, fire alarm or building control circuits would appear as IP addresses on the LAN corresponding to assigned locations in the building where the LAN is situated. These points can then be accessed by a central fire safety application server. The communication network would be responsible for delivery of the data while the application servers and alarm display equipment would be provided by others at their designated locations.

When local data needs to be sent to a regional or main control facility, the local station LAN will have the capability of passing that information onto the system-wide WAN via a 10 Gigabit Ethernet Station Node. Passenger information, CCTV images, fire alarm status, voice telephone services, etc. can be carried back to any control facility.

See TM 3.4.1 – B, “High Level CHSTP Logical Backbone Topology Concept”, TM 3.4.1 – C “High Level CHSTP Station LAN Logical Topology Concept”, TM 3.4.1 - D “Wayside Wireless Radio Communication Concept”, and TM 3.4.1 – E “CHST Dual Logical Fiber Optic Cable Network “.

3.2 COMMUNICATION NETWORK DESIGN CONSIDERATIONS

The main communications backbone will be segment into virtual private networks tailored to the communications needs of each service (e.g. SCADA, CCTV, Telephone, Passenger Information, etc.). Bandwidth for any service will be allocated independently from the demands of other services.

CTS core ring redundancy will be implemented using two (2) ninety six (96) fiber strand optical cables of the raceways on each side of the right-of-way. Spatial diversity will be required for all laterals and drop cables. Communications network capacity will be based on network traffic requirements to accommodate the 800 mile system plus 100% spare bandwidth.

3.2.1 Fiber Optic Cabling Network (FOCN)

The FOCN system provides physical layer transport of data, voice and video signals along the entire alignment using single mode fiber optic cable. It includes termination distribution panels for connections to end devices or network equipment as well as wayside and facility splice cases. The layout and location of the optical cable(s) will be designed to be compatible with the railway design, location of raceway, tunnels, and configuration of the track.

Directive Drawing TM 3.4.1 –B illustrates the CHSTP CTS System Topology concept.

3.2.2 Communications Transmission System (CTS)

The CTS will provide system survivability by pre-provisioned switched paths through the Wide Area Network (WAN) using open protocols such the Multi-Protocol Label-Switched (MPLS) protocol, the use of VLAN Access Control Lists, or any other equivalently performing open-standard industry accepted communication protocols.

Main optical nodes on the CTS will employ carrier grade 10 Gbps Ethernet switches at major facilities such the OCC/RCC and 1 Gigabit Ethernet aggregation or edge switches at other network access locations.

Individual communications systems at passenger stations, train control houses, traction power facilities, wireless communication shelters and maintenance and operations facilities will interface to the main fiber backbone through a Local Area Network. Using this design, data traffic not required by the central control facility will be segmented and localized by the LAN to avoid congestion on the main data network.

In order prevent frequent breaks in the main fiber optic backbone rings, locations such as MOW facilities, train control housings, traction power facilities, communications shelters and other auxiliary wayside facilities needing communications services will be connect by a fiber optic drop cable back to the nearest fiber optic node switch.

Directive Drawing TM 3.4.1 –C illustrates a Wide Area and Local Area Network concepts.

3.2.3 Wireless Communications System (WCS)

The Wireless Communications System will support ATC, voice, and field communications for CHSTP maintenance, operation security personal. The system will be implemented by using Wireless Communications System Shelters at wayside intervals along the alignment to support overlapping coverage along the entire alignment.

The design of the ATC functional aspects of the WCS will be highly dependent on the type of ATC technology chosen.

The WCS include field personnel equipped mobile and portable radio transceivers and well as maintenance facility wireless data devices to support the downloading of stored video and other rolling stock maintenance data.

As currently conceived, the field radio subsystem of the WCS will have a minimum of Eight (8) RF channels each with multiple talk groups, with four RF Channels for Operations and Maintenance, two RF Channels for Train Control and Diagnostics and two RF Channels for Passenger Information, Emergency Telephone, and Fare Vending.

Directive Drawing TM 3.4.1-D represents the Wayside Wireless Radio Communications System concept.

3.2.4 Tunnel Radio Communications System

The purpose of the Tunnel Radio Communications (TRC) is to insure secure and reliable radio communications inside of all tunnel segments in the CHSTP alignment. The TRC will extend the coverage of the wireless wayside radio communications system into the tunnels to provide seamless two-way radio coverage for ATC, train communication, operations and maintenance portable radios and for public safety responders in the event of emergencies.

This system will function by receiving and repeating over-the-air radio communications amplifying and distributing them via a radiating coax distributed antenna system (DAS). The TRC will distribute radio signals in both single and twin bore tunnels.

Directive Drawing TM 3.4.1-M represents a conceptual schematic of the CHST Tunnel Communications Network Layout.

4.0 SUMMARY AND RECOMMENDATIONS

The communications systems will be designed to be compatible with and support all functions/features of other systems which require communications. Some key summary points are as follows.

4.1 PASSENGER STATION OPTICAL NODES

The Passenger Station Nodes contain the core 10 Gigabit Ethernet optical switches which are responsible for regenerating and routing large amounts of data throughout the backbone network. Only key locations in the CTS will contain these Node switches as these are relatively expensive devices that require carefully controlled environments for reliable operations. All FOCN backbone network access will be through either a direct connection to these switches or by LANs and fiber optic drop cables that terminate at these Station Nodes. Access to this equipment should be strictly controlled.

4.2 FIBER OPTIC DROP CABLE

Fiber optic drop cable will be used to provide data transport between traction power facilities, train control houses, Yard Wi-Fi nodes and wayside radio shelters back to the nearest Station Node. For purposes of network reliability, it is envisioned that there will be two drop cables from each facility to alternate Station Nodes along the alignment. These cables will terminate in a local fiber optic distribution unit within the facilities requiring connection and would take up a minimum of rack space. An Ethernet Edge switch, with dual redundant ports, will serve to interface the local equipment to the main FOCN switched network for transmission back to the RCCs and OCC.

4.3 SCADA COMMUNICATIONS

For the SCADA communications network to provide universal connectively from any SCADA RTUs and/or field I/O monitoring devices along the CHST corridor to centralized SCADA servers and display facilities the SCADA systems (provided by others) must be IP addressable and Ethernet ready communications I/O ports.

The scope of the SCADA communications system is limited to the transmission of SCADA status and control messages, and also ATS signals if required. While it will be the responsibility of the SCADA communications network to meet the connectivity, security, latency, reliability metrics provided by the various disciplines requiring this service, the SCADA communications system is a data delivery service only. How the data is processed, displayed, stored and acted upon will be the responsibility of the particular engineering discipline and is currently considered outside the scope of the communications design effort.

4.4 NETWORK TIMING AND SYNCHRONIZATION

Network timing and synchronization is necessary for consistent time stamping alarm and status messages especially in the event of system emergencies. The Network Timing System will be provided by the communications system designers and utilize the CTS to transmit standard NTP network protocols.

The Maintenance Management Information System (MMIS) will use the CTS to transmit relevant data concerning the operational status of equipment along the alignment to coordinate and update its database.

4.5 AUTOMATIC TRAIN CONTROL SYSTEM

The train control supervisory control system will monitor and control the train control system via the CTS/ FOCN/Wireless Radio Communications System to provide connectivity and communications for the train control system. Functional requirements include Communications between train control rooms and the OCC/RCC via switched or dedicated fibers of the FOCN. Supervisory control communications will be required for each interlocking. If dedicated fiber optic paths are required the FOCN will provide two dark fibers pairs for each interlocking with connectivity and supervisory control equipment provided by others.

5.0 SOURCE INFORMATION AND REFERENCES

Federal Communications Commission [FCC]

- CFR 47 CFR, Part 90 – Private Land Mobile Radio
- CFR 47 CFR, Part 15 – Class A

Americans with Disabilities Act

- 49 CFR Part 37, Transport Services for Individuals with Disabilities

National Fire Protection Association

- NFPA 70
- NFPA 101.

Institute of Electrical and Electronics Engineers

- 802.1b: "LAN/MAN Management"
- 802.1d: IEEE MAC Bridging Standard
- 802.1q: VLAN Tagging Standard
- 802.1u: Amended version of 802.1q
- 802.3i: 10Base-T. 10Mbps Ethernet over CAT-5 twisted pair.
- 802.3j: 10Base-F. 10 Mbps Ethernet over fiber.
- 802.3u: Fast Ethernet. 100Base-TX for UTP Cat5e PHY layer and 100Base-FX fiber optic cable.
- 802.3ab: 1000Base-T (Gigabit Ethernet over twisted pair CAT-5 cabling)
- 802.3ae: 10 Gig Ethernet
- 802.3af: Power Over Ethernet
- 802.3z: 1000BASE-X Gigabit Ethernet.
- 802.11i: Encryption for Networks that use 802.11a, 802.11b and 802.11g wireless standards.
- 802.16: WiMax Standard
- 802.2

Electronic Industries Association and Telecommunications Industry Association (EIA/TIA).

- EIA 472, Generic Specifications for Fiber-optic cable.
- EIA RS-310, Racks, Panels, and Associated Equipment.
- EIA/TIA-598, Optical Fiber Cable Color Coding.
- EIA/TIA-310-D - Racks, Panels, and Associated Equipment.
- EIA/TIA-4750000B - Generic Specifications for Fiber Optic Connectors.
- TIA/EIA 568-B – Commercial Building Telecommunications Cabling Standard.

6.0 DESIGN MANUAL CRITERIA

6.1 COMMUNICATIONS NETWORK ARCHITECTURE

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Directive Drawing TM 3.4.1-A illustrates the Communications Architecture Concept for the CHSTP.

6.2 COMMUNICATION NETWORK DESIGN

The main communications backbone will be segment into virtual private networks tailored to the communications needs of each service (e.g. SCADA, CCTV, Telephone, Passenger Information, etc.). Bandwidth for any service will be allocated independently from the demands of other services.

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The design of the ATC functional aspects of the WCS will be highly dependent on the type of ATC technology chosen.

Directive Drawing TM 3.4.1-D represents the Wayside Wireless Radio Communications System concept.

6.2.4 Tunnel Communications System

(1) Radio Subsystem

The purpose of the Tunnel Radio Communications System (TRCS) is to insure secure and reliable radio communications inside of all tunnel segments in the CHSTP alignment. The TRCS will extend the coverage of the wireless wayside radio communications system into the tunnels to provide seamless two-way radio coverage for ATC, train communication, operations and maintenance portable radios and for public safety responders in the event of emergencies.

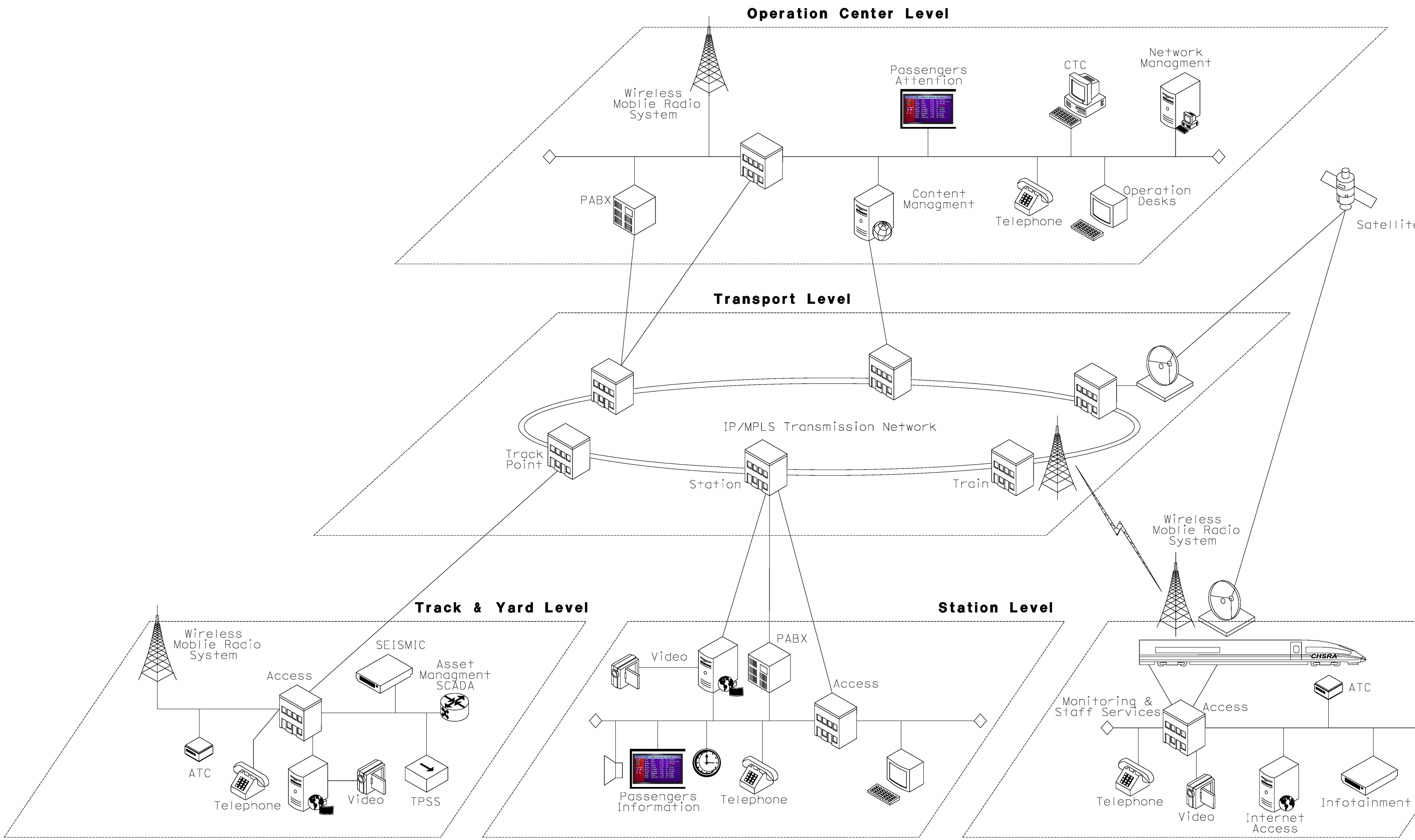
This system will function by receiving and repeating over-the-air radio communications amplifying and distributing them via a radiating coax distributed antenna system (DAS). The TRCS will distribute radio signals in both single and twin bore tunnels. Directive Drawing TM 3.4.1-M represents a conceptual schematic of the CHST Tunnel Communications Radio Layout.

(2) Emergency Telecommunications Subsystem

In addition to radio subsystems, tunnel emergency communications shall be provided by an Emergency Telephone System (E-TEL) located at designated sites within the tunnel. This access shall be via a voice-over-IP (VoIP) gateway through a fiber optic drop cable connecting back to the Communications Interface Cabinet (CIC) at the tunnel portals.

APPENDIX - TM 3.4.1 DIRECTIVE DRAWINGS

TM 3.4.1 - A	Integrated Rail Communication Architecture Concept
TM 3.4.1 - B	High Level CHSTP Logical Backbone Topology Concept
TM 3.4.1 - C	High Level CHSTP Station LAN Logical Topology Concept
TM 3.4.1 - D	Wayside Wireless Radio Communications System Concept
TM 3.4.1 - E	Conceptual CHST Dual Logical Fiber Optic Cable Network Backbone Rings Layout
TM 3.4.1 - M	Conceptual CHST Tunnel Communications Network Layout



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DESIGNED BY H. BOWIE
DRAWN BY G. SPENCE
CHECKED BY H. BOWIE
IN CHARGE R. SCHMEDES
DATE 06-25-10

CALIFORNIA HIGH-SPEED RAIL AUTHORITY
FLYCALIFORNIA
Without ever leaving the ground.

CALIFORNIA HIGH-SPEED TRAIN PROJECT

INTEGRATED RAIL COMMUNICATION ARCHITECTURE CONCEPT

CONTRACT NO.
DRAWING NO. TM 3.4.1-A
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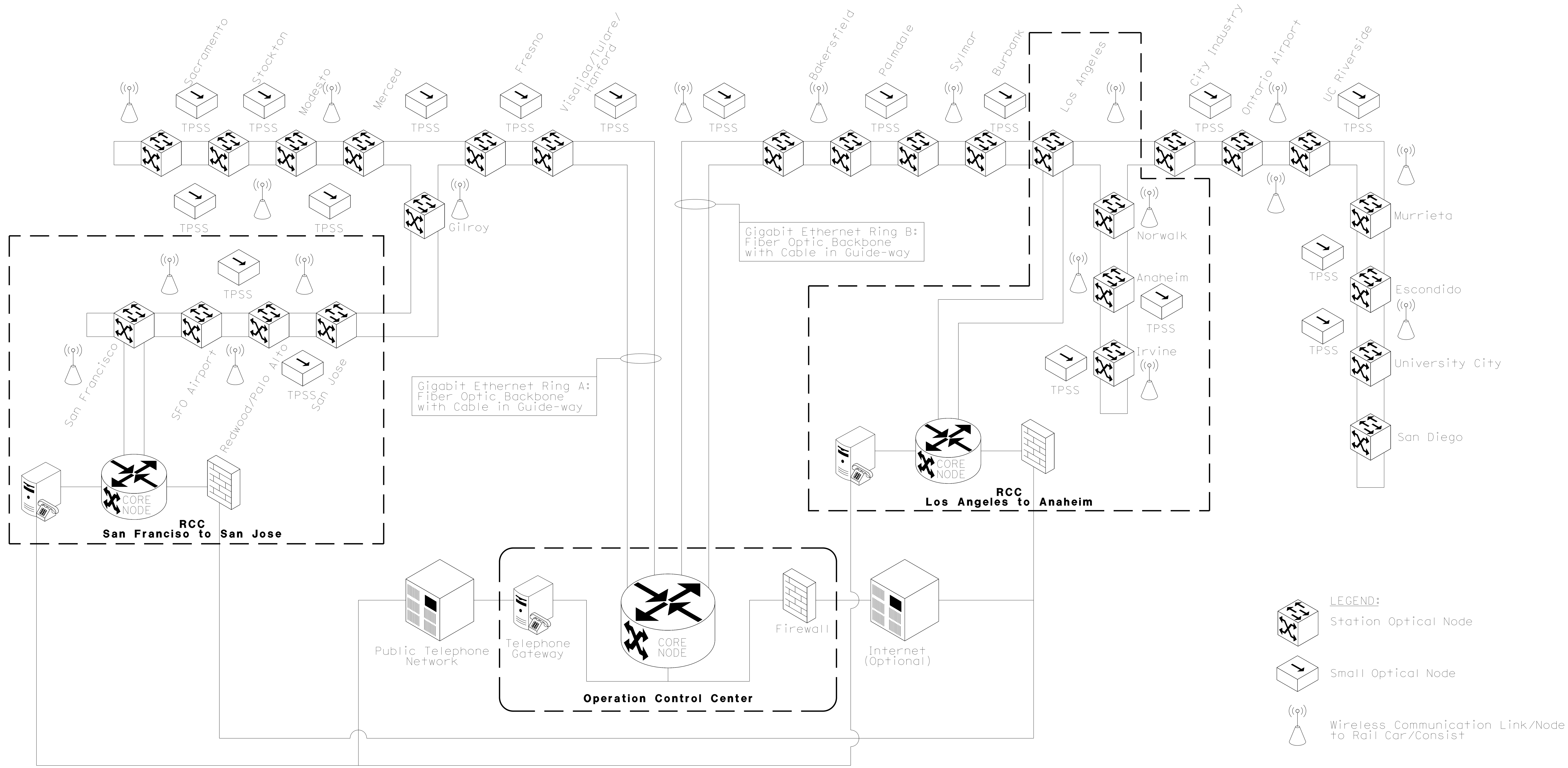

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IN CHARGE R. SCHMEDES
DATE 06-25-10

CALIFORNIA HIGH-SPEED RAIL AUTHORITY
FLYCALIFORNIA
Without ever leaving the ground.

CALIFORNIA HIGH-SPEED TRAIN PROJECT

HIGH LEVEL CHSTP
LOGICAL BACKBONE TOPOLOGY CONCEPT

CONTRACT NO.
DRAWING NO. TM 3.4.1-B
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CALIFORNIA HIGH-SPEED RAIL AUTHORITY
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Without ever leaving the ground.

CALIFORNIA HIGH-SPEED TRAIN PROJECT

HIGH LEVEL CHSTP STATION
LAN LOGICAL TOPOLOGY CONCEPT

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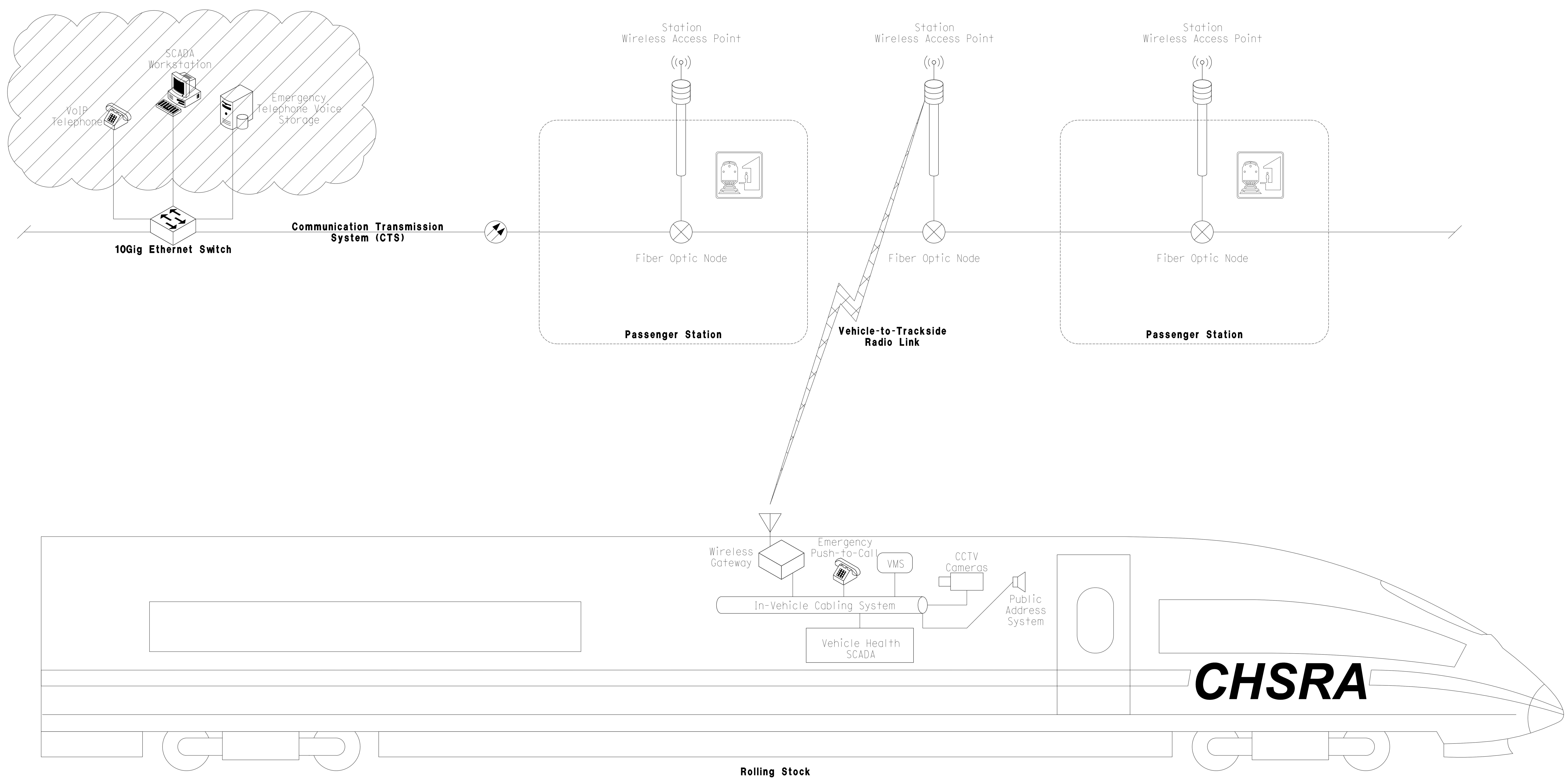

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IN CHARGE R. SCHMEDES
DATE 06-25-10

CALIFORNIA HIGH-SPEED RAIL AUTHORITY
FLYCALIFORNIA
Without ever leaving the ground.

CALIFORNIA HIGH-SPEED TRAIN PROJECT

WAYSIDE WIRELESS RADIO
COMMUNICATIONS SYSTEM CONCEPT

CONTRACT NO.
DRAWING NO. TM 3.4.1-D
SCALE NOT TO SCALE
SHEET NO.

T:\13259c-CHSTP\CAD\02 Dgn\TM 3.4.1\TM 3.4.1-E.dgn

7/7/2010

spenceg

REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY H. BOWIE
DRAWN BY G. SPENCE
CHECKED BY H. BOWIE
IN CHARGE R. SCHMEDES
DATE 06-25-10

CALIFORNIA HIGH-SPEED RAIL AUTHORITY
FLYCALIFORNIA
Without ever leaving the ground.

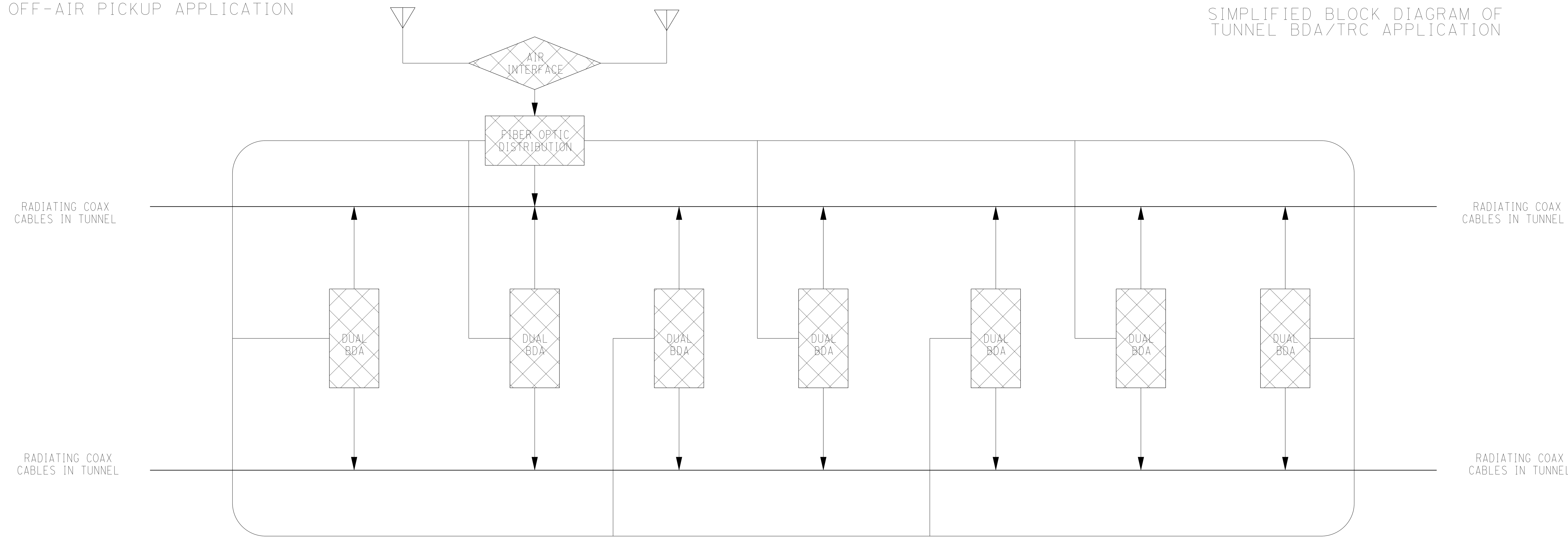
CALIFORNIA HIGH-SPEED TRAIN PROJECT

CONCEPTUAL CHST DUAL LOGICAL FIBER OPTIC CABLE NETWORK BACKBONE RINGS LAYOUT

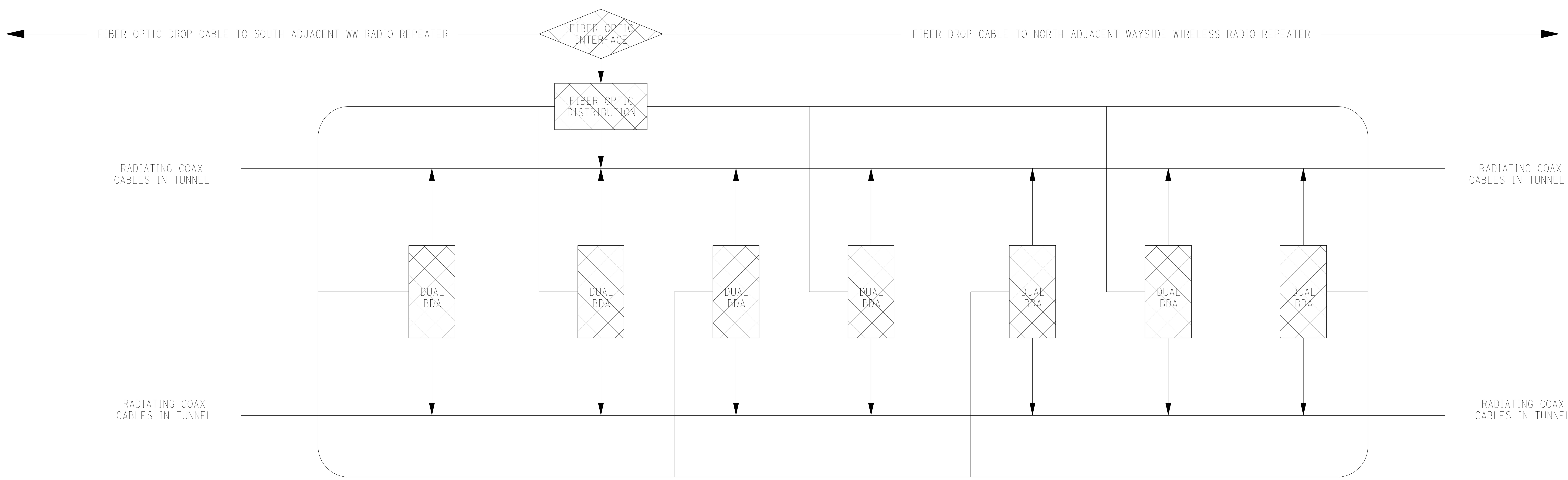
CONTRACT NO.
DRAWING NO. TM 3.4.1-E
SCALE NOT TO SCALE
SHEET NO.

OFF-AIR PICKUP APPLICATION

SIMPLIFIED BLOCK DIAGRAM OF TUNNEL BDA/TRC APPLICATION



FIBER OPTIC DROP CABLE FROM WAYSIDE WIRELESS RADIO REPEATERS



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7/7/2010

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REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY H. BOWIE
DRAWN BY G. SPENCE
CHECKED BY H. BOWIE
IN CHARGE R. SCHMEDES
DATE 06-25-10

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CALIFORNIA HIGH-SPEED TRAIN PROJECT

CONCEPTUAL CHST
TUNNEL COMMUNICATIONS NETWORK LAYOUT

CONTRACT NO.
DRAWING NO. TM 3.4.1-M
SCALE NOT TO SCALE
SHEET NO.