Special Provision 725 (SP725)

Regarding

Intelligent Transportation Systems (ITS)

Last updated August 2024 by Stantec Consulting Services Inc.

Revision	Description	Author	Date	Quality Check	Date	Independent Review	Date
0.0	Initial Update	K. Thimmesch	8/18/22	M. Davis	8/18/22	D. Goudeau	8/19/22
1.0	Addressed 1st Round Comments	K. Thimmesch	10/21/22	M. Davis	10/26/22	K. Irvin	11/28/22
2.0	Periodic Update; Added Sections 6, 17, 18, and 19	K. Thimmesch	7/31/23	M. Davis	8/4/23	M. Holt	8/4/23
2.1	Periodic Update; Added Fiber Micro-Cable and Micro-Conduit, updated Systems Integration, and addressed comments from version 2.0	Z. Domingue	11/14/23	M. Davis	11/16/23	K. Irvin	12/8/23
2.2	Periodic Update, Added Portable Smart Work Zone System Section, and Addressed Comments from Version 2.1	L. Overn	5/5/24	M. Davis	5/31/24	K. Irvin	5/15/24
3.0	Periodic Update and Addressed Comments from Version 2.2	Z. Domingue	8/21/24	M. Davis	8/28/24	W. Munshaw	8/29/24

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1 INTRODUCTION

The contents of this SP725 supersede all project Plans and other TDOT Standard Specifications.

This document is organized in several parts, starting with Section 2, GENERAL REQUIREMENTS, then moving into device-specific requirements and ending with system-wide requirements that lead to Final Acceptance in Section 25. ABBREVIATIONS AND ACRONYMS are included in APPENDIX A and PREVENTIVE MAINTENANCE PROCEDURES are included in APPENDIX B. APPENDIX C includes the list of Spare Parts required to be Furnished and Stored by the Contractor under this contract. Please refer to the Table of Contents for a full listing of document Sections and Subsections.

TDOT reserves the right to amend this SP725 after project award; any compensable costs incurred by the contractor as a result of changes to this SP725 will warrant change order considerations.

Item numbers used in this SP725 are for reference only. The actual item numbers to be used are those shown in the estimated quantity sheet of the Plans.

If reviewing the editable, electronic version of this document, please note that additional appendices beyond APPENDIX C are intended for use when preparing new project specifications and should be deleted, along with this statement, prior to finalizing the document. If reviewing the PDF version of this document, please note that appendices beyond APPENDIX C are not intended to be included in this SP725 and they should be disregarded within the context of this project.

2 GENERAL REQUIREMENTS

1. All commands and references in, or in connection with, the text in this Special Provision (SP725) document are written to direct Contractor responsibility for action unless otherwise specified.
2. This section specifies the minimum general requirements for this contract. These Section 2 requirements apply to all aspects of the contract including but not limited to the materials, installation, measurement, and payment requirements for all contract items.
3. The Contractor is responsible for all work required in this Section 2. All costs associated with the work in this Section 2 shall be included in the contract price for the items included in the project and no separate payment shall be made by TDOT.

2.1 Scope of Work Requirements

For specific information about the project, see the Scope of Work on the Plans. The Contractor shall be fully responsible for complete construction and testing of the Project as shown in the contract documents. Contract documents include but are not limited to Plans, TDOT Standard Specifications, this SP725, any supplemental specifications, and circular letters. This contract includes work on segments of roadways where proposed ITS devices, electrical infrastructure, and system communications shall be installed as detailed in the contract documents.

The system includes but is not limited to the furnishing and installation of devices, poles, sign structures, cabinets, foundations, guardrail, conduit, hub buildings, fiber optic cable network, wireless communication network, electrical power service, other required vendor software/hardware, and TDOT ATMS software integration necessary to complete a fully functioning system as required by the contract documents.

All the equipment provided shall comply with the applicable industry approved standards for the subsystems and communications network. Contractor shall follow approved industry standards and utilize the National Transportation Communications for ITS Protocols (NTCIP) for the DMS, CCTV Camera, RDS, ESS, RSU, OVDS, WIM, HAR, and other devices.

Field adjustments may be needed for conduit, cabinet, and device locations shown throughout the project. These adjustments shall be coordinated with and approved by the Engineer.

2.1.1 ITS and Network Communications Devices

Quantitative and performance requirements for each type of equipment provided in this SP725 are mandatory minimum requirements. Functional equivalents proposed by the Contractor that fully meet or exceed this SP725 will be considered, provided the functional equivalent is compatible with the communications, hardware, and software included in the project, and provided that the functional equivalent meets all design and operational objectives of TDOT. Experimental devices that are not proven in existing field installations at the time they are proposed for this project shall not be considered. All equipment and component parts that are furnished shall be new, with original manufacturer's warranty and not used or refurbished, shall meet all requirements of this SP725, and shall be in an operable condition at the time of delivery. All parts shall be of high-quality workmanship and no part or attachment shall be applied contrary to the manufacturer's recommendations or standard practices. All materials and installation of all devices shall be in accordance with this SP725 and Plans and with the manufacturer's recommendations for the exact intended application. The entire quantity of any particular added item shall be the exact same manufacturer, model, revision, firmware, etc. In addition, each major component must be provided, successfully integrated into the existing TDOT ATMS system by the contractor and warranted by a single vendor/manufacturer.

Manufacturers of ITS and Network Communications active electronic equipment and other critical system components shall be required to establish minimal qualifications prior to approval of equipment submittals, by submitting for consideration the following years of experience supplying the general type of device indicated:

- Network Switches, RDS, ESS, OVDS, WIM, HAR, CCTV Camera, and DMS: 5 years
- RSU: 3 years

The experience statements shall include but not be limited to 3 owner references and documentation of operational equipment installations. The statement of experience shall identify the number of years of experience as well as the references listed above and shall be provided during the submittal program as outlined in Section 2.7 of this SP725.

2.1.2 Applicable Standards

All materials and installation procedures shall conform to the Plans, Special Provisions, the latest adopted edition of the TDOT Standard Specifications for Road and Bridge Construction, the latest adopted edition of the TDOT Standard Drawings, the latest adopted edition of the Manual on Uniform Traffic Control Devices (MUTCD), and the supplemental Specifications, as included in the Specifications package.

1. Electrical Standards

    a. All electrical materials and work shall conform to the standards of the National Electrical Manufacturers Association (NEMA), the Underwriters' Laboratories Inc. (UL), the Electrical Testing Laboratories (ETL), the National Electrical Testing Association (NETA), Institute of Electrical and Electronics Engineers (IEEE), and the Electronic Industries Association (EIA), wherever applicable. In addition to the requirements of the approved shop drawings to be prepared by the Contractor, and this Special Provision, all materials and workmanship shall conform to the requirements of the National Electrical Code (NEC), National Electrical Safety Code (NESC) and applicable codes of governing jurisdictions. Unless specified, all standards used for this project shall be the latest edition available.

2. Video Standards and Protocols

    a. One of the major system components to be furnished, installed, and tested under this project is IP addressable Closed-Circuit Television (CCTV) video equipment. Digitization of the video signals for transmission shall utilize the H.264 standard, MPEG4, Part 10 Standard as defined by the International Telecommunication Union (ITU), Motion Picture Experts Group (MPEG) and as required by the device specifications within this SP725.

3. NTCIP Standard Protocols

    a. The Dynamic Message Signs (DMS) shall be compatible with the latest approved version of the National Transportation Communications for ITS Protocol (NTCIP) as applicable. The Contractor shall provide documentation from an independent testing entity, which may be in the vendor’s possession, to identify NTCIP objects successfully incorporated and tested. The Contractor shall provide the Management Information Base (MIB) for all objects from the sign vendor during the submittal process. Additional NTCIP testing may also be required as part of the Factory Acceptance Test. Deviation from NTCIP compliance shall require advance written approval by the Engineer prior to installation of the non-compliant device. The Engineer may withhold this approval at their discretion.

b. CCTV control protocol for pan, tilt, and zoom in addition to other camera controls shall meet NTCIP and Open Network Video Interface Forum (ONVIF) requirements.

4. Ethernet and IP Standards and Protocols

a. The Ethernet communications system and all connected devices shall, as an entire interconnected system, completely implement and be compatible with IEEE 802.3 industry standards for Ethernet and NTCIP standards supporting Ethernet as applicable and required. Ethernet switching equipment is used to transport the digital IP-based video and control data from field devices to hub cabinets. Network equipment at the field master hub switches routes the video and data to the TDOT Regional TMC, other facilities and end users as needed.

2.1.3 Device Control Protocols

For all active electronic devices controllable through any type of communications interface, the Contractor shall be required to voluntarily, and without seeking additional fees, restrictions, licenses or compensation from TDOT, coordinate with each respective system representative for each piece of equipment supplied, to support direct communication with and control of devices by the TDOT ATMS software identified. If the Software Integration Pay Item is included in this project for interfacing of device types new to TDOT, the Software Integration Pay Item shall be utilized to pay for development and coordination required to support direct communication with and control of devices by the TDOT ATMS software.

A list of all pertinent device makes and models that are already supported by each system will be provided at the project pre-bid meeting. If a supported make and model is provided under this contract, no further coordination with the operating system vendors will be required. However, if a new make and/or model is provided, the Contractor shall be responsible for coordinating with the system vendors to ensure sufficient drivers are developed to support the new devices without additional compensation. Complete documentation of the interface protocol and/or MIB shall be provided during the submittal program as outlined in Section 2.7 of this SP725.

2.1.4 Contractor and Subcontractor Qualifications

The Contractor or Subcontractor selected to perform the ITS portion of the project certifies to be qualified as an expert in the trade, capable of understanding the intent of this SP725 and constructing the project in accordance with the prevailing standard practice of the trade. Firms qualifying as Contractor and or Subcontractors to perform ITS work must demonstrate at least 5 years of experience and at least 2 projects within the last 5 years in the type of work they plan to perform on this project:

1. Fiber-Optic Communications
2. Wireless Communications
3. CCTV camera surveillance
4. RDS
5. ESS

6. RSU
7. DMS
8. OVDS
9. WIM
10. HAR
11. Electrical Power Distribution
12. Hardware and Software used for Transportation Management Centers

2.1.5 Complete, Compatible Installations

This SP725 is for materials and equipment necessary to construct the proposed Project; however, every fitting, minor detail, or feature may not be described. Any component not explicitly stated in this SP725, but necessary for the ITS sites to function, shall be considered incidental and shall be furnished and installed by the Contractor at the sole discretion of the Engineer. The Contractor is responsible for providing all miscellaneous, associated, and incidental materials to provide fully operational and complete ITS Equipment Sites as specified in this SP725, on the Plans, and in the contract documents. The fully operational and complete ITS shall be readily compatible with the communications technologies utilized, and compatible with the hardware, software, and communications equipment installed at the TDOT Regional TMC, and such miscellaneous materials required to achieve fully operational and complete status shall be considered incidental to the project.

2.1.6 Complete Operational Systems

The Contractor shall furnish and install all necessary equipment for completely operational ITS Equipment Sites which are of high quality, high reliability, and operational stability. Compliance with minimum requirements for individual items identified in this SP725 does not, in and of itself, constitute compliance with the reliability and operational stability requirements necessary to provide for the integration of the sites into a complete, integrated system. It is the Contractor's responsibility to ensure that the components provided will work together to form a complete working system as specified in this SP725, on the Plans, and in the contract documents. It is the Contractor's responsibility to notify the Engineer in writing of any components outlined in the Specifications or Plans that would prohibit the Contractor from being able to install a completed working system. The completed system shall be fully integrated with TDOT ATMS software already in use and be able to be fully monitored and controlled from the TDOT Regional TMC.

2.1.7 Communications System/Equipment Software Compatibility

The Contractor is responsible for ensuring that all equipment and software versions provided for this project is compatible with the existing communications system, TDOT ATMS software, and all other equipment provided for this project, as installed, configured, and programmed by the Contractor and while complying with all system functionality and performance requirements. This compatibility includes but is not limited to all field devices and their respective controllers, all wired and wireless communications links, all control center hardware, and all software applications and control systems including but not limited to the CCTV, DMS, RDS, ESS, RSU, OVDS, WIM, HAR, network switches, video communications equipment, and the network management system. The Contractor shall ensure that the delay in equipment response times throughout the entire system is compatible with the existing software. Any modifications to the vendor software, firmware, and hardware to account for system latency and compliance with the total video response delay performance requirements shall be the responsibility of the Contractor.

2.1.8 Equipment and Materials

1. All equipment and materials furnished and installed on this project shall be new and unused.
2. All equipment and materials of a similar type and nature shall be of the same manufacturer, model, revision, firmware, etc.
3. All bolts, nuts, and fastening hardware less than 5/8” diameter shall be stainless steel. All bolts, nuts, and fastening hardware 5/8” in diameter and greater shall be hot-dipped galvanized. Refer to Subsection 908.04 of the Standard Specifications for High Strength Structural Bolts.
4. All components, materials, and incidentals shall be recommended by the manufacturer as suitable for the intended application, including any material exposed to the weather.
5. All equipment and associated materials shall be installed and configured in accordance with the manufacturer’s recommendations and standard practices.
6. All equipment and materials furnished and installed on this project shall comply with the current requirements of the Build America Buy America (BABA) Act.

2.1.9 Coordination with Various TDOT Highway and Bridge Construction Contractors

The Contractor shall coordinate their activities with any other Contractors, which may be in the same work area. There are areas within the project limits where roadway construction activities may be occurring during the same timeframe as this project. Conflicts will be handled at the discretion of the Engineer. The Contractor shall notify TDOT promptly in writing if there are any conflicts which may impact the Contractor’s schedule or construction activities. The mere presence of these roadway construction activities alone will not be a sufficient reason for schedule delays. The ITS Contractor is expected to coordinate with these other Contractors to the extent possible.

2.1.10 Project Completion and Liquidated Damages

The project shall be completed in accordance with the requirements set forth in SP108B.

2.2 Design Summary

For specific information about the project, see the Scope of Work on the Plans.

2.2.1 Phasing

All work in this project will be completed in a single phase. However, proper sequencing of the work is still critical to ensure that the existing devices are taken off-line for as short a time as possible.

This project sequencing is intended to establish a general workflow for the Contractor’s various discrete crew types. For example, the Contractor’s underground crew should complete 75% or more of the work in a specific geographic location before moving into a new location. However, crews that have completed work in a given area can move to the next area prior to the completion of work performed by different crew types within the earlier area. For example, the Contractor may move the conduit crews to secondary locations after completing the initial location even though other crews such as cable crews and cabinet crews have not completed their efforts in the initial area. However, the actual physical cutover of the existing devices to the new network cannot occur until all efforts are complete.

The Contractor shall ensure continuous operation of the fiber optic communication lines and ITS devices affected by the work activities unless otherwise authorized by the Engineer. Prior to temporary disconnect of the fiber optic communication network or ITS network devices, Contractor shall notify the Engineer and coordinate with the TDOT Regional TMC at least 2 weeks in advance of a planned outage. Any outage must avoid peak roadway traffic periods. ITS network devices include but are not limited to CCTV cameras, Radar Detection Systems (RDS), and Dynamic Message Signs (DMS) within the project limits or those devices outside project limits that may be affected by communication failures caused by this project. Failure to restore communication and ITS devices beyond the specified time frame shall result in liquidated damages in accordance with rates established in Special Provision 108B until communication and/or ITS devices are restored.

Upon Conditional System Acceptance, TDOT will assume operations of those devices where practical. This use by TDOT does not constitute Final Acceptance or waive any other requirements in this Contract. Also, the Burn-In Period described in this SP725 does not begin until Conditional System Acceptance of all Phases has been achieved.

2.2.2 Electrical Power

The local electrical service provider within the limits of this contract is indicated on the Plans. For new devices, the provider shall provide power drops at proposed demarcation points, as appropriate. The Contractor shall include the initial install cost from the utility as well as the cost of coordinating with the utilities in the bid price for electrical connections. The Contractor is required to coordinate with the utility company for the installation of the service. The addresses recorded in the power company records are included on the Plans. The Contractor shall pay for all monthly service charges until after Conditional System Acceptance. Within the interstate right-of-way, any physical facilities, such as conduit runs, needed by the service provider shall be the responsibility of the Contractor to install as shown on the Plans. The electrical demarcation points within the existing device project limits will remain in place.

2.3 General System Requirements

2.3.1 CCTV and Control Data Latency

Control commands shall be generated from the off-the-shelf video control software provided by the Contractor and shall pass through the Ethernet network to the field equipment, such as CCTV cameras. Operation of the pan, tilt, zoom, presets, focus, iris, and any other available functions of the CCTV cameras shall be provided. Status data generated by the camera shall be transmitted to the camera control unit and to the TDOT Regional TMC. The total video response delay between the operator issuing a command to move a camera (through a mouse through the TDOT ATMS software), movement of that camera, and the resulting display on the operator’s monitor of that camera’s viewing image as it is moving, shall be minimized to avoid over steering and operator difficulty in positioning the camera. The maximum allowable total video response delay anywhere in the project shall not exceed an average of 1.0 second for any 10 cameras sequentially randomly sampled and shall not exceed 1.5 seconds for any single camera sampled.

2.3.2 DMS Control Latency

The total delay in sending a message to a DMS or receiving a polling response from a DMS shall not exceed 5 seconds from the time the operator commands the message at the TDOT Regional TMC until the message is displayed on the DMS.

2.3.3 Existing System

Details on the location of the existing devices are included on the Plans. If any additional information regarding the existing system is needed for bidding purposes, it is the Contractor's responsibility to request in writing the specific information desired in accordance with the question submittal deadlines in the pre-bid instructions. Questions shall be addressed to the Engineer.

2.4 Training

Prior to Conditional System Acceptance, the Contractor shall provide a 6-hour training session covering the operation and maintenance of all devices included in the project such as CCTV camera and camera lowering device, DMS, RDS, ESS, OVDS, HAR, WIM, and RSU as well as configuration and operation of all electronic equipment including network switches, wireless ethernet radios, video communications equipment, communications hubs and associated equipment, electrical power services, and fiber optic cable network. A second, redundant 6-hour training session shall be provided on a different day of the week for a total of 2, 6-hour training sessions.

The training shall be provided at the TDOT Regional TMC for at least 10 personnel with individual printed and electronic copies of all training materials and manuals provided to each participant. The training must include a complete demonstration of the configuration, operation, and capabilities of each component in the system. The training should also consist of a hands-on demonstration of all software configuration and functionality where applicable.

Each training session shall include a mixture of classroom style training in equipment operation, hands-on operator training, and question and answer sessions. The Contractor shall submit the trainers' qualifications to the Engineer for approval prior to scheduling the training. The qualifications of the trainers must meet, at a minimum, the recommended qualifications of the equipment manufacturer. If qualified personnel are not on the Contractor's staff, a representative of the manufacturer shall provide the training.

The Contractor shall submit to the Engineer for approval a detailed Training Plan including course agendas, detailed description of functions to be demonstrated, deviations in training location, and a schedule. The Contractor shall also provide all training material in electronic format to the Engineer.

2.5 Project Testing Plan Requirements

The Contractor shall submit for review and approval a Project Testing Plan as required below in addition to all other project testing and acceptance procedures required elsewhere in this SP725 and Plans. The Project Testing Plan shall include a series of tests on all project materials occurring at various stages in the project. The Project Testing Plan includes all testing in the Standard Specifications including all modifications and supplemental procedures contained in this SP725. All costs associated with the Project Testing Plan shall be included in the associated bid price for each item; no separate payment will be made for any testing.

Separate FAT, BTC, BTS, and SAT documents shall be provided for each ITS component as required for the project and specified in this SP725. See the Testing Subsections within this SP725 for specific testing requirements. A CSAT document shall be provided for the overall system.

2.5.1 General Requirements

The Contractor is responsible for planning, coordinating, conducting, and documenting all aspects of the Project Testing Plan and providing all required equipment for the tests. The Engineer is responsible only for attending and observing each test and reviewing and approving the Contractor's test results documentation. The Engineer reserves the right to attend and observe all tests.

Each test shall be an individual and separate event for each type of test and for each type of equipment as defined in this SP725. The Contractor shall follow the testing sequence as described in this SP725 and shall perform the required tests on all applicable devices and infrastructure.

Each test shall fully demonstrate that the material under test is clearly and definitively in full compliance with all project requirements.

Test procedures shall be submitted and approved for each test as part of the project submittal program requirements in Section 2.7. Test procedures shall include every action necessary to fully demonstrate that the material under test is clearly and definitively in full compliance with all project requirements. Test procedure actions shall cross-reference to this SP725 or Plans requirement that is the subject of the test action. Test procedure actions shall cross-reference the applicable sections of the final approved Project Submittal Compliance Form and the submittal materials for the subject of the test action. Test procedures shall contain test setup and block/wiring diagrams showing all materials being tested and all test and measurement equipment, with calibration documentation, and shall contain documentation regarding the equipment configurations and programming. Test procedures shall include check off blanks for each project requirement included in that test and shall include forms for the documentation of all measured test results. Test procedures shall include all qualifications required for the personnel conducting the tests.

No testing shall be scheduled until approval of all project submittals is granted by the Engineer for all materials covered under a given test and approval of the test procedures for the given test.

Unless otherwise required herein, the Contractor shall request in writing the Engineer's approval for each test occurrence a minimum of 60 calendar days prior to the requested test date. Test requests shall include the test to be performed and the material to be tested. The Engineer reserves the right to reschedule test requests if needed.

For any series of tests on different installations of a given material (e.g., different sections of cable), the Contractor shall request in writing the Engineer's approval for the first test occurrence of the series a minimum of 60 calendar days prior to the requested test date, regardless of the notification requirements for subsequent test occurrences.

The Contractor shall provide all appropriate personnel, ancillary equipment, and materials as required in the approved test procedures. Appropriate personnel may be a qualified employee of the Prime Contractor, their Subcontractors, or a vendor representative capable of conducting test procedures.

The Contractor shall document all test results, including all raw data necessary to validate the test results, in writing in accordance with the test procedure and submit to the Engineer within 7 calendar days of the test. Any given test session is considered incomplete until the Engineer has approved the documentation for that test session.

The Contractor shall repeat all tests if results are deemed by the Engineer to be unsatisfactory, following all test requirements as given here. In the written request for each test occurrence that is a repeat of a previous test, the Contractor shall summarize the diagnosis and correction of each aspect of the previous test that was deemed unsatisfactory. Any revisions to the test procedures for a repeated test occurrence shall meet all requirements for the original test procedures, including review and approval by the Engineer.

The satisfactory completion of any test shall not relieve the Contractor of their responsibility to provide a completely acceptable and operating system that meets all requirements of this project as specified in this SP725, on the Plans, and in the contract documents.

The tests for the Conditional System Acceptance may be completed in Phases as described in Section 2.2.1. However, the overall Conditional System Acceptance which starts the Burn-In Period shall not be granted until all elements in this contract have passed the Conditional System Acceptance Test. The phased acceptance testing is only to allow the Contractor to receive milestone payment for work completed.

2.5.2 Factory Acceptance Test (FAT)

FATs shall be conducted at the Manufacturer or Contractor's facility or at a facility acceptable to all parties. All equipment to be utilized for this project shall be subject to tests that demonstrate the suitability of the design and manufacturing procedures and compliance with the contract requirements unless an exception for a specific equipment item is granted by the Engineer. The tests shall be performed on production units identified to be delivered under this Contract. As a minimum, a FAT is required for each of the following project materials:

1. Dynamic Message Sign and Controller
2. Diesel Engine Standby Generator
3. Hub Building

The FAT procedure shall demonstrate all requirements defined in this Special Provision are met including but not limited to functional/system performance requirements, electrical requirements, data transmission/communication requirements, safety/password requirements, environmental requirements, and interface requirements with other components of the system including the DMS control software, the Ethernet switches, etc.

The FAT procedure for Hub Buildings shall be a visual inspection prior to leaving the factory. Photos and/or videos of the finished building shall be provided to TDOT to verify that there are no manufacturing issues prior to leaving the factory site.

The Engineer reserves the right to witness all FATs. At a minimum, the Engineer will attend the FAT for the first new DMS, Diesel Engine Standby Generator, and/or Hub Building (if the project contains these items). Attendance at the FAT can be in-person or through a virtual meeting with the manufacturer at the discretion of the Engineer. The FAT for the first 2 units of each item type shall be conducted during the same time period and shall be completed before additional units of that item type are produced.

The Engineer shall be notified a minimum of 60 calendar days in advance of such tests. Salary and travel expenses of the Engineer and their representatives will be the responsibility of TDOT. In case of equipment or other failures that make a retest necessary, travel expenses of the Engineer and their representatives shall be the responsibility of the Contractor. This shall include all costs associated with having 2 of the Engineer's representatives on site including but not limited to airfare, automobile rental, lodging, and per diem. These costs, excluding airfare, shall not exceed $500.00, per representative, per day. These costs shall be deducted from the payments due or charged to the withholding account of the Contractor when the project is terminated.

The vendor must complete the FAT on all remaining signs on their own and submit documentation to the Engineer that the FATs were completed. The Engineer reserves the right to randomly attend those FATs.

No equipment for which a FAT is required shall be shipped to the project site without successful completion of a FAT as approved by the Engineer and the Engineer’s approval to ship.

2.5.3 Bench Test Component (BTC)

The Contractor shall perform a complete BTC on all equipment and materials as specified in this Subsection below. The Contractor shall provide the testing location and facility, which shall be in Tennessee and within a 25-mile radius of the project limits or as directed by the Engineer. The test location must be approved by the Engineer as part of the BTC test procedure submittal. The full contract quantity of all materials shall be tested, unless a different quantity for the purposes of the BTC is given in this Subsection below. The quantity listed in the Subsection below is a “minimum” quantity and the Engineer reserves the right to require testing of additional quantities if the initial testing is not deemed adequate.

The BTC shall demonstrate that all equipment and materials are in full compliance with all project requirements and works “out of the box,” by visual inspection, setup and operation "on the bench", functional testing of the component including manufacturer’s recommended startup diagnostics, and testing prior to any field installation of that equipment or material. Test results documentation shall be provided for each equipment item and material in the full contract quantity; test results documentation shall include the manufacturer’s serial number and the project location ID for each item.

As part of the BTC, the Contractor shall install bar code labels on all equipment prior to installation as described in Section 24.7 of this SP725. The cost of the bar code installation shall be considered incidental and included in the cost of the item being labeled.

Contractor shall also configure all devices as if they’re operating in the field during the BTC phase. The devices must be configured in preparation for Bench Test System and subsequent integration into the TDOT ATMS software.

As a minimum, a BTC is required for each of the following project materials:

1. Fiber Optic Drop Panel
2. Fiber Optic Cable (3 fibers from each buffer tube)
3. Wireless Ethernet Radio
4. Equipment Cabinet (Type A)
5. Equipment Cabinet (Type B)
6. Equipment Cabinet (Type C)
7. Equipment Cabinet (ITS Communications Hub)
8. Closed Circuit Television Equipment

9. Dynamic Message Sign and Sign Controller
10. Radar Detection System
11. Environmental Sensor System
12. Road Side Unit
13. Overheight Vehicle Detection System
14. Highway Advisory Radio
15. Weight in Motion
16. Permanent Speed Feedback Sign
17. Network Switch (Type A)
18. Network Switch (Type B)
19. Portable Smart Work Zone System
20. Off-the-Shelf and Vendor Software
21. TMC System Compatibility

2.5.4 Bench Test System (BTS)

The Contractor shall perform a complete BTS on all equipment and materials as specified below. The Contractor shall provide the testing location and facility, which shall be in Tennessee and within a 25-mile radius of the project limits or as directed by the Engineer. The test location must be approved by the Engineer as part of the BTS test procedure submittal. The Contractor shall not request any BTS until the BTCs have been satisfactorily completed for all equipment and materials to be included in the BTS.

The BTS shall demonstrate that all equipment and materials are in full compliance with all project requirements and that a fully set up and configured sample of the project is completely integrated and interoperable in accordance with the project requirements. The BTS shall include all manufacturer's recommended startup diagnostics, configuration, and testing procedures. Equipment items and materials included in the BTS shall be setup in temporary configurations (e.g., cameras, DMS and antenna on mounting stands). At least 1 camera shall be located a minimum of 20 feet above ground and shall have a clear one-mile viewing area in at least 1 direction. Equipment located in cabinets or equipment racks shall be mounted as if in its final installation. Test results documentation shall include the manufacturer's serial number and the project location ID for each item. All temporary permits, wiring and cabling, equipment mounting, electrical service, and permitting necessary for the BTS shall be the responsibility of the Contractor. The Contractor shall arrange, at no additional expense to the State, the attendance of qualified technical representatives of all of the equipment manufacturers to attend the BTS.

No field installation of any equipment and materials included in the BTCs shall occur until after the BTS has been satisfactorily completed, and the Engineer has approved test results.

2.5.5 Stand Alone Site Tests (SAT)

The Contractor shall perform a complete SAT on all equipment and materials associated with the field device site including but not limited to electrical service, conduit, pull boxes, fiber optic infrastructure, cable, poles, camera lowering devices, RDS cable, etc. A SAT shall be conducted at every field device site including communications hubs and all fiber optic infrastructure.

The SAT shall demonstrate that all equipment and materials are in full compliance with all project requirements and fully functional as installed and in final configuration. The SAT shall demonstrate full compliance with all operational and performance requirements of the project including but not limited to measurement accuracy for RDS and ESS. All SATs also include a visual inspection of the cabinet and all construction elements at the site to ensure they are compliant with the Plans, TDOT Standard Specifications and this SP725.

The Contractor shall request in writing the Engineer's approval for each test occurrence a minimum of 60 calendar days prior to the requested test date. No more than 2 SATs shall be scheduled simultaneously at any given time unless otherwise approved by the Engineer. The Contractor shall arrange, at no additional expense to the State, the attendance of a qualified technical representative of the equipment manufacturers to attend each test until a minimum of 2 sites of that particular type are approved.

2.5.6 Conditional System Acceptance Test (CSAT)

The Contractor shall perform a complete Conditional System Acceptance Test on all equipment, materials, and systems in the project. A Conditional System Acceptance Test can be requested and performed on a phased approach as described in Section 2.2.1 as the phases are completed. The Contractor shall not request the Conditional System Acceptance Test until the SATs have been satisfactorily completed, all as-built documentation has been submitted and approved, and all other project work has been completed to the satisfaction of the Engineer. Prior to a Conditional System Acceptance Test, the Contractor shall provide advance notice of and written test results documentation that the Contractor has performed a Dry-Run of the Conditional System Acceptance Test, and the Engineer reserves the right to require attendance of a Dry-Run Test session. A Dry-Run Test shall consist of the test requirements for the Conditional System Acceptance Test.

The Contractor shall test all project systems simultaneously from the TDOT Regional TMC in a manner equivalent to the normal day-to-day operation of the systems installed as part of this project. The Conditional System Acceptance Test shall demonstrate that all equipment and materials in the network are in full compliance with all project requirements and vendor recommendations and that they are fully functional as installed and in final configuration, communicating with and being controlled through the TDOT ATMS software at the TDOT Regional TMC.

The Engineer reserves the right to require, at no additional expense to the State, the attendance of a qualified technical representative of the equipment and/or software manufacturers to attend any given Conditional System Acceptance Test.

Upon completion and full approval of the Conditional System Acceptance Test for all equipment in all phases, Conditional System Acceptance will be given, and the Burn-In Period will begin.

2.5.7 Burn-In Period

1. Burn-In Period

    a. Following the Engineer's written notice of successful completion of the Conditional System Acceptance Test, the entire newly installed system must operate successfully for a 90-calendar-day Burn-In Period. The Contractor shall be responsible for the full maintenance of the newly installed equipment as required in Section 24.3 of this SP725 during the Burn-In Period. However, no separate payment will be made beyond the contract unit bid price for the Burn-In Period. Successful completion of the Burn-In Period will occur at the end of 90 complete calendar days of operation without a system failure attributable to hardware, software, or communications components. Each system failure during the Burn-In Period will require an additional 30 calendar days of successful operation prior to being eligible for Final Acceptance. (i.e., if there are 2 system failures during the initial 90-calendar-day period, the Burn-In Period may be increased to 150 calendar days at the discretion of the Engineer.) Successful completion of the Final System Acceptance is required to complete the Burn-In Period. Unsuccessful completion of the Final System Acceptance shall cause an automatic extension of the Burn-In Period beyond the contract duration for a duration to be determined by the Engineer.

2. Burn-In General Requirements

   a. Determination of a system failure shall be at the sole discretion of the Engineer.

   b. System failure is defined as a condition under which the system is unable to function as a whole or in significant part to provide the services as designed. While a single component failure will not constitute a system failure, chronic failure of that component or component type may be sufficient to be considered a system failure.

   c. Components are defined as contract items or major material elements in a contract item. For electrical and electronic contract items, components are defined as the complete assembly of materials that makes up the contract item.

   d. Chronic failure of a component or component type is defined as 3 or more failures (lasting more than 15 minutes) for components with a contract quantity of 50 units or less. For components or component types that have a contract quantity greater than 50 units, chronic failure will be defined as having a failure of that component type more times than a number equal to 5% of the total contract quantity of that unit.

   e. Multiple (more than 1) communication outages or failures (lasting more than 15 minutes) will be considered a system failure in any case. Communication failure due to a minor component may not be a system failure. A single path/link failure (e.g., CCTV or DMS link) is not considered a system failure.

   f. Specifically exempted as system failures are failures caused by an accident, acts of God, or other external forces that are beyond the control of the Contractor. However, failure of the Contractor to respond to the repair request for that failure within 24 hours may be considered a system failure.

   g. The existing devices and equipment are not part of the Burn-In Period; therefore, any hardware failures of the existing equipment will not affect the Burn-In Period.

   h. TDOT will advise the Contractor in writing when it considers that a system failure has occurred, or chronic failure exists.

   i. If multiple system and/or chronic failures continue to occur throughout the Burn-In Period due to a single component type, the Contractor may be required to replace all units of that component type with a different model or manufacturer.

   j. The Contractor shall document all failures and subsequent diagnosis and repair. The repair documentation shall include as a minimum:

      i. Description of the problem

      ii. Troubleshooting and diagnosis steps

iii. Repairs made

iv. List of all equipment and materials changed including serial numbers

v. Update of the equipment inventory where needed

k. The Contractor shall provide the repair documentation to the Engineer within 2 calendar days of completing the repair; failure to provide acceptable documentation as required shall be reason to not approve the repair as complete. The Engineer will provide acceptance or rejection of the repair and documentation within 7 calendar days.

l. The Engineer reserves the right to require, at no additional expense to the State, the presence of a qualified technical representative of the equipment and/or software manufacturers as related to the diagnosis and/or repair of any system failure.

m. During the Burn-In Period the Contractor shall perform incidental work such as touching up, cleaning of exposed surfaces, leveling and repair of sites, sodding/grassing, and other maintenance work as may be deemed necessary by the Engineer to ensure the effectiveness and neat appearance of the work sites.

n. During the Burn-In Period the Engineer shall maintain a "Burn-In Period punch list" that contains required Contractor actions but that the Engineer does not define as a system failure. Each Burn-In Period punch list action item shall be completed by the Contractor to the Engineer's satisfaction within 7 calendar days of Contractor notification of the action item.

o. During the Burn-In Period the Contractor shall maintain the system as specified in Section 24.3 of this SP725. No separate payment will be made beyond the contract unit prices for the Burn-In Period pay item.

p. The overall Burn-In Period will be considered complete upon the successful completion of all of the following items: Burn-In time periods, the Engineer's acceptance of all repairs and repair documentation, completion of all Burn-In Period punch list actions and a successful Final Systems Acceptance Testing and Inspection as described below.

2.5.8 Final System Acceptance Testing and Inspection

The Contractor shall perform a Final System Acceptance Test and Inspection on all equipment and materials in the project. Upon successful completion of the Burn-In Period, the entire project shall be eligible for Final System Acceptance Testing and Inspection. The Final System Acceptance Testing and Inspection will be conducted provided the Burn-In Period has demonstrated the entire system is operating successfully. The Final Systems Acceptance Testing and Inspection shall include:

1. Demonstration that all equipment and materials in the network are in full compliance with all project requirements and fully functional as installed and in final configuration, communicating with and being controlled through the control center at the TDOT Regional TMC. This will be performed in accordance with the submitted and approved CSAT procedures.
2. Verification that all Burn-In punch list items have been completed.
3. Verification that all final cleanup requirements have been completed.
4. Approval of final as-built documentation.

Prior to conducting the Final Systems Acceptance Testing and Inspection, the Burn-In Period shall demonstrate that all requirements defined in this SP725 have been met including but not limited to functional/system performance requirements, electrical requirements, data transmission/communication requirements, safety/password requirements, environmental requirements, and interface requirements with other components of the system.

The Contractor shall request in writing the Engineer's approval to start the Final Systems Acceptance Testing and Inspection a minimum of 60 calendar days prior to the requested start date. The Engineer reserves the right to reschedule the start date if needed. The start date for the Final Systems Acceptance Testing and Inspection cannot be prior to the successful completion of the overall Burn-In Period.

An unsuccessful or incomplete Final Systems Acceptance Testing and Inspection shall require a new Final Systems Acceptance Testing and Inspection after the Contractor has made the necessary corrections. Up to 14 calendar days' notice shall be given to the Engineer prior to the Contractor conducting a subsequent Final Systems Acceptance Testing and Inspection.

The Engineer reserves the right to require, at no additional expense to the State, the attendance of a qualified technical representative of the equipment and/or software manufacturers to attend a portion of a Final Systems Acceptance Testing and Inspection.

The Contractor shall be responsible for the full maintenance of all project equipment and materials as described in Section 24 of this SP725 during the entire time period from the beginning of the Burn-In Period until Final System Acceptance is granted, which will complete the Burn-In Period.

2.5.9 Final System Acceptance

Upon successful completion of the Final Systems Acceptance Testing and Inspection, the Engineer will grant a signed letter of Final System Acceptance. Upon Final System Acceptance, the Contractor is relieved of any further maintenance responsibilities and has TDOT's concurrence that all construction activities are complete and accepted. Final System Acceptance does not relieve the Contractor of project documentation completion as it relates to administrative final records.

2.6 Warranties

Each component of the Project shall be warranted against manufacturing defects and workmanship for a period of at least 1 year from the date of Final System Acceptance. These warranties shall cover complete replacement at no charge for the equipment. The Contractor shall be responsible for all labor, shipping, insurance, and other charges until Final System Acceptance. Equipment covered by the manufacturers' warranties shall have the registration of that component placed in TDOT's name prior to Final Systems Acceptance Testing and Inspection. Even though the warranties will be in TDOT's name, the Contractor is still responsible for executing the warranties during Annual Maintenance. The Contractor is responsible for ensuring that the vendors or manufacturers supplying the components and providing the equipment warranties recognize TDOT as the original purchaser and owner/end user of the components from new. See the Warranty Subsections within this SP725 for specific warranty terms for the components in this project.

2.7 Project Submittal Program Requirements

The Contractor shall develop and conduct a submittal management program that shall meet the following minimum requirements, supplemented by any additional requirements regarding submittals that may appear in subsequent sections of this SP725 or any other contract documents. All materials used on this project will require a submittal and approval prior to purchase and use regardless of whether they are called out specifically in this SP725.

With each submittal package, the Contractor shall complete a Project Submittal Compliance Form, which shall be provided by TDOT within 14 calendar days of the Pre-Construction Meeting. The compliance form will list each SP725 Subsection and will require the Contractor to verify and check that it meets the requirements of this SP725. At contract Notice to Proceed (NTP), the Engineer shall provide blank copies of the contract item specific compliance form. Submittal packages without these completed forms will be considered unallowable and returned to the Contractor without review or consideration.

The Project Submittal Compliance Form shall include but not be limited to the following data:

1. Contract pay item number
2. Submittal package identification
3. Submittal description with make/model/part number information
4. Reference to SP725 requirement
5. Compliance or non-compliance statement for each SP725 requirement
6. Cross-reference to attached documentation for each SP725 requirement
7. Authorized Contractor signature

The Contractor shall at minimum provide the following submittals for review and approval by the Engineer. All submittals must be submitted electronically. The table below is meant as a guide and is not all-inclusive. Items not listed below may also be required during the submittal stage.

Item	Catalog Cutsheets and Technical Specifications	Test Procedure	Installation Procedures	Maintenance Manuals	Operational Manuals	Manufacturer’ s Statement of Experience	Final Documentation	Interface Protocols
CCTV Equipment	X	X	X	X	X	X	X	X
Camera Lowering Device with Tool	X	X	X	X	X	X	X	
Dynamic Message Signs	X	X	X	X	X	X	X	X
Travel Time Message Sign	X	X	X	X	X	X	X	X
Radar Detection System	X	X	X	X	X	X	X	X
Environmental Sensor Station	X	X	X	X	X	X	X	X
Road Side Unit	X	X	X	X	X	X	X	X
Overheight Vehicle Detection	X	X	X	X	X	X	X	X
Highway Advisory Radio	X	X	X	X	X	X	X	X
Weigh in Motion System	X	X	X	X	X	X	X	X
Speed Feedback Sign	X	X	X	X	X	X	X	
Cabinets	X	X	X	X	X		X	

Item	Catalog Cutsheets and Technical Specifications	Test Procedure	Installation Procedures	Maintenance Manuals	Operational Manuals	Manufacturer’ s Statement of Experience	Final Documentation	Interface Protocols
Network Switches (all types)	X	X	X	X	X	X	X	X
Portable Smart Work Zone System	X	X	X	X	X	X	X	X
All Software	X	X	X	X	X		X	
TMC Hardware	X	X	X	X	X		X	
System Console	X					X	X	
Demarcation Point Riser Assembly	X							
Ground Mounted Demarcation	X							
Systems Design Report							X	
Traffic Maintenance Plans	X							
Training Plan							X	
Conduit and Pull Boxes	X							
Fiber Optic Infrastructure	X	X	X	X	X	X	X	
Wireless Comm. Infrastructure	X	X	X	X	X	X	X	
Diesel Engine Generator	X	X		X	X		X	X
Electrical Power Equipment	X							

2.7.1 Fifteen (15) Day Submittals

Within 15 calendar days of Notice to Proceed, the Contractor shall submit a written description of their proposed submittal program, including a comprehensive list of all intended submittals and schedule of the submittals for the remainder of the project. The Contractor shall develop an appropriate schedule based on the schedule of work, with the exception of the items identified below that have specific due dates. At a minimum, the submittals listed in the table above shall be included in the submittal program. Note that the 15-day submittal is only a schedule of the submittal program. The 15-day submittal does not include any actual equipment submittals.

The Contractor shall submit to the Engineer for approval an electronic copy of the program including a complete list and initial schedule of all of those materials, components, and structures to be incorporated in the work for which submittals are required. This list shall form the basis for a log of submittals that will be used by the Contractor and Engineer to manage the submittal process. The list shall be submitted as an Excel spreadsheet. In addition, the 15-day submittal shall also contain a letter from the Contractor certifying that all required interface protocols will be submitted from all vendors as requested.

2.7.2 Forty-Five (45) Day Submittals

Within 45 calendar days of Notice to Proceed, the Contractor shall submit the following:

1. **Catalog Cut Sheets and Technical Specifications**: Within 45 Days of Notice to Proceed, the Contractor shall submit to the Engineer for approval equipment catalog cut sheets and technical specifications for all items listed in the above table and any related items. The catalog cut sheets and technical specifications shall include all necessary information to clearly demonstrate that the proposed equipment meets the requirements of this SP725 and the Plans. In addition, the equipment cut sheets shall include manufacturer's name, model number, and any other descriptive data as necessary to clearly evaluate the item. Interface Protocols for all devices and equipment should also be submitted. All materials included within a specific Section of this SP725 shall be submitted at the same time as a submittal package. The equipment cut sheet submittal shall also include BABA compliance documentation for each device and material that is provided on the project.

   Specific submittal requirements contained herein shall be supplemented by any requirements shown in the various Special Provisions such as the Traffic Maintenance Plans and Project Schedules as described in Section 108.03 of the TDOT Standard Specifications shall not be ordered or released for fabrication without the approval of submittals by the Engineer.

   The review and approval of submittals by the Engineer is based on the information provided in the submittal and the conformance with the design concept of the project. Submittal reviews do not relieve the Contractor of the responsibility for making the overall system conform to the requirements of the contract. Approvals at the submittal stage are always conditional upon demonstration that the equipment is fully compliant with the contract including compatibility with all other equipment in the system.

2. **Installation Procedures**: Within 45 Days after Notice to Proceed the Contractor shall submit to the Engineer the Installation Procedures for approval by the Engineer. The installation submittal shall include step-by-step installation directions as developed by the equipment manufacturer. The Contractor shall be required to follow these installation procedures during construction.

2.7.3 Ninety (90) Day Submittals

Within 90 Calendar Days of Notice to Proceed the Contractor shall submit the following:

1. **Shop Drawings and Design Calculations:** Within 90 calendar days of Notice to Proceed the Contractor shall submit to the Engineer shop drawings and design calculations for all structural elements and attachments including but not limited to all sign structures, support poles, structure attachments and foundations. Shop drawings and design calculations shall be sealed and signed by a Professional Engineer licensed with the State of Tennessee.

2.7.4 Other Submittal Timeframes

1. **Test Procedures**: Unless noted otherwise, a minimum of 60 calendar days prior to each desired test date, the Contractor shall submit to the Engineer all test procedures for approval by the Engineer. The test procedure submittal shall include all the test forms for each of the required tests as required in this SP725. The actual test cannot be scheduled until the test procedures are approved.

2. **Operational Manuals**: A minimum of 60 calendar days prior to Bench Test Component, the Contractor shall submit to the Engineer Operational Manuals for approval by the Engineer. The Operational Manual submittal shall include step by step directions for the operators to execute all the functions as required in this Special Provision. The Operational Manuals shall be functionally organized and identify available (built-in) options to operational characteristics. The Engineer reserves the right to request Operational Manuals during the cut sheet submittal stage if the

Engineer deems it necessary to adequately check the operational characteristics of the equipment. Operational Manuals shall be provided in a word-searchable electronic copy.

3. **Maintenance Manuals**: A minimum of 60 calendar days prior to bench testing, the Contractor shall submit to Engineer Maintenance Manuals for approval by the Engineer. The Maintenance Manual submittal shall include all the necessary steps to maintain the equipment in good working condition, and as indicated by the manufacturer to maintain the warranty. The Engineer reserves the right to request Maintenance Manuals during the cut sheet submittal stage if the Engineer deems it necessary to adequately check the required features of the equipment. Maintenance Manuals shall be provided in a word-searchable electronic copy.

4. **Final Documentation**: Prior to the start of the Burn-In Period, the Contractor shall submit a word-searchable electronic copy of final documentation for review and approval by the Engineer. Burn-In Period will not start until final documentation is approved by the Engineer. In addition to any specific final documentation requirements outlined in the individual sections of this SP725, final documentation shall include a single binder containing all of the equipment warranties and other manufacturer produced documentation. In addition, final documentation shall include an inventory list of all the furnished and installed equipment. This list shall include equipment description, manufacturer's part number, model number, serial number, warranty start and end date, and equipment location in decimal degrees of latitude and longitude. The final documentation shall also include a troubleshooting matrix which can be utilized by the system operators to determine the most appropriate action for various problems that may occur in the system.

2.7.5 Review Process

1. The Engineer will review and return submittals to the Contractor within 21 calendar days of receipt.

2. If additional information is requested or if a re-submittal is required, the Contractor is required to re-submit within 21 calendar days of receipt of the Engineer's comments.

3. The Engineer will review and return the re-submittals to the Contractor within 21 calendar days of receipt.

4. Any additional re-submittals must also meet this 21-calendar-day timeline.

5. The Contractor shall maintain a file of approved submittals, shop drawings, and operating data for reference purposes and shall provide an electronic copy of that file to the Engineer upon completion of construction.

2.8 System Documentation

The Contractor shall maintain a formal procedure to document the configuration of the As-Built system as described in Section 25 of this SP725. That program will include maintenance of record drawings and other documentation of the actual location and arrangement of all hardware installed on the project. In addition, the program will include maintenance of records of the system integration procedures. Provisions will be made to accommodate changes to the system both during and after construction.

2.9 Payment Terms For 725 Item Numbers

Stockpile, also known as "Stored Materials", Payment will be made for all 725 Item Numbers per TDOT Standard Specifications. For 725 items that describe payment terms based on completing certain testing or installation requirements, those payment terms will apply only to the unit price amount that is more than the stored materials payment. For example, if an item says that 50% of the contract unit price will be paid upon approval of Bench Test Component results, this payment will only be applicable if the stored materials payment was not already more than 50% of contract unit price. If the percentage associated with a testing requirement exceeds the amount previously paid for stored materials, the additional amount will be paid to the Contractor at the time of that particular test completion. See the Payment Subsections in this SP725 for specific payment terms.

3 CONDUIT

3.1 Description

This section specifies the minimum requirements for conduit furnished and installed on this project as shown on the Plans or as directed by the Engineer.

3.2 Materials

Contractor shall provide all materials according to the requirements in the following sections.

All equipment shall be constructed using new and commercially available components in accordance with manufacturers' recommendations. Prior to installation, the Contractor shall submit and receive approval from the Engineer on a complete set of shop drawings of all the equipment and components listed within this Special Provision and included as part of the installation.

3.2.1 General Requirements

1. All Continuous Flexible Conduit products and structure mounted multi-cell conduit shall meet the requirements specified herein.
2. All Continuous Flexible Conduit products and structure mounted multi-cell conduit shall have been manufactured and labeled no earlier than in the sixth calendar month preceding the TDOT letting date of the Contract.

3.2.2 Continuous Flexible Conduit (Conduit Duct Bank)

Continuous Flexible Conduit shall meet specifications for ASTM F2160 and ASTM D3350 (Cell Classification 334480C or E) Slow crack growth minimum requirement is F10>96 h per ASTM D1693, condition B, IGEPAL® CA-630 MegaPure™ Detergent,10% Solution.

1. Conduit shall be extruded from colored material for uniform full-thickness coloring.
2. All Continuous Flexible Conduit shall be labeled with durable identification giving the name of the manufacturer, ASTM F-2160, conduit size (inner diameter trade size and wall thickness/rating), manufacturer/date codes, the legend "TDOT ITS", and sequential foot marking. Labeling shall occur a maximum of every 2'.
3. Conduit to be used in bends and sweeps shall have a minimum burn through time of 30 minutes when tested in accordance with Generic Requirement GR-356-CORE.
4. The conduit manufacturer shall have a documented Quality Control/Assurance System.
5. All buried conduit used on this project shall conform to the color scheme and use described below:
    a. Conduit Bank Type 1
        - Green Drop Fiber and/or RDS Cable

b. Conduit Bank Type 2
    - Green Drop Fiber and/or RDS Cable
    - White RDS Cable, Second Drop Fiber or Spare
c. Conduit Bank Type 3
    - Green Drop Fiber and/or RDS Cable
    - Blue RDS Cable or Second Drop Fiber
    - White Second RDS Cable or Spare
d. Conduit Bank Type 4
    - Orange Trunk Fiber Cable
    - Blue RDS Cable or Drop Fiber
    - White Spare or Second RDS Cable
    - Brown Spare
e. Conduit Bank Micro-Conduit
    - Orange Trunk Fiber Cable
    - Blue Spare or Second Trunk Fiber Cable
    - Green Spare or Drop Fiber
    - Brown Spare
f. 2” and 3” Electrical Conduit
    - Gray Electrical wire
g. DMS Conduit Bank
    - Gray Electrical wire
    - Green Drop Fiber
    - Blue RDS Cable
    - Brown Spare

6. 1¼” conduit shall conform to ASTM F2160 and meet the following requirements:
    a. SDR 9 for all Bored conduits
    b. SDR 11 for all other conduits
7. 2” conduit shall conform to ASTM F2160 and meet the following requirements:
    a. SDR 9 for all Bored conduits
    b. SDR 11 for all other conduits
8. Micro-conduit shall be sized per manufacture recommendations for the proposed micro-fiber installation to facilitate blowing the fiber through the conduit. A minimum fill ratio of 50% and

maximum fill ratio of 80% shall be achieved in accordance with the requirements in Section 5.2.4. Micro-conduit shall have a minimum 2mm wall thickness and shall include an over sheath.

9. If micro-conduit is to be installed within the paved shoulder, the micro-conduit shall be heat-rated or utilize backfill material and construction methods to ensure that the micro-conduit is not affected by the maximum temperature produced by the grouting material used to restore the pavement.

10. Coupling

    a. Contractor shall make every effort to minimize coupling. Couplings are permitted only with the Engineer's prior approval.

    b. Approved couplings shall be airtight and watertight. All couplings shall be installed in accordance with the conduit and the coupling manufacturer's recommendations. Only couplings of the type specified below and approved by the conduit manufacturer are permitted.

    c. Couplings shall be accomplished only by hydraulic press-on, electro-fusion, or push-to-connect press-on coupling methods.

        i. Hydraulic press-on couplings of seamless tool-grade tubular aluminum with sealing ring barbs and center stop may be used. Use hydraulic compression duct coupling tools and follow all manufacturer's installation procedures, fully inserting both conduit sections to the coupling center stop.

        ii. Prefabricated electro-fusion couplings that are field installed using the coupling manufacturer's recommended automatic self-monitoring fusing machine and installation procedures may be used.

        iii. Push-to-connect press-on couplings that are field installed using the coupling manufacturer's recommended methods may be used. Press-on couplings shall lock onto conduits and contractor shall ensure to insert conduit to stop point.

3.2.3 Multi-Cell "Bullet Resistant" Fiberglass Conduit System (Structure Conduit Bank)

1. The multi-cell conduit system shall consist of a minimum round 4" inner diameter outer duct containing four, round 1-1/4" innerducts. System may be assembled in the field by Contractor. All conduits shall be rated for their use, with the outer duct meeting requirements for use outdoors where subject to UV and physical damage as further described below.

    a. The innerducts shall be held together in a square (four conduit system) configuration by a system of spacers or equivalent mechanism.

    b. The coupling system shall be resistant to water infiltration, air loss during cable installation and shall be capable of locking the system tightly together to avoid free twisting of the innerducts.

2. All conduit system manufacturers shall have a documented Quality Control/Assurance System.

3. Outer duct shall conform to the following requirements:

    a. All outer ducts shall be a minimum of 4" inner diameter trade size and shall have a nominal 20' lay length. Types to be used shall be designated on the Plans.

b. The spigot end of the duct shall have a circumferential insertion depth mark to ensure that proper insertion depth is achieved.

c. Bullet resistant fiberglass conduit shall have a minimum wall thickness of 0.250”. The conduit shall prevent the penetration of a .45 caliber slug fired from 20’ away. The conduit shall conform to the following requirements when tested in accordance with this SP725. All accessories and fittings, including outer duct couplings, expansion joints, anchor and stop rings, etc., shall meet all the same “bullet resistant” requirements as the conduit. All conduit and fittings shall be gray.

d. Outer duct shall be labeled with durable identification giving the name of the manufacturer, manufacturer/date codes and the legend “TDOT ITS.” Labeling shall occur a maximum of every 2’.

e. Outer duct shall comply with and be tested according to the following Physical and Mechanical Properties and Test Methods

i.	Ultimate Tensile Strength – 11,000PSI Minimum	ASTM D-2105
ii.	Dielectric Strength - >=500V/Mil.	ASTM D-149
iii.	Water Absorption – 1% Maximum	ASTM D-570
iv.	Specific Gravity – 1.9 – 2.0	ASTM D-792
v.	Glass Content – 68 + - 2%	API Spec 15 LR
vi.	Barcol Hardness – 58-52	ASTM D-2583

f. Where Structure Conduit Bank Type 1 and 2” Structure Conduit w/bank is shown on the Plans, the conduit shall be 2” fiberglass conduit and shall meet the same applicable characteristics as the outer duct described above.

4. Innerduct shall conform to the following requirements:

a. Innerduct shall be manufactured from polyvinyl chloride (PVC) or high-density polyethylene (HDPE). Innerduct shall be factory treated with an atomized silicone or manufactured in a manner to reduce friction during pulling of fiber optic cable. Innerduct to be used in bends and sweeps shall have a minimum burn through time of 30 minutes when tested in accordance with Generic Requirement GR-356-CORE, Issue 2, June 2009. The dimensions of innerduct shall meet the requirements of the manufacturer’s catalog cuts approved by TDOT.

b. HDPE innerduct shall have a permanent dry lubricant extruded within the inner wall and shall incorporate longitudinal ribs within the inner wall.

c. Micro duct in accordance with the material requirements within this SP may be used as the innerduct. If micro duct is used, it shall be secured within outer duct to prevent movement.

d. HDPE innerduct shall have the following color and size:

i. Color of innerducts – four-way (orange, blue, brown, white)

ii. Nominal Inner Size – 1 ¼”

5. Coupling Bodies shall conform to the following requirements:

a. The coupling body shall be designed with 4 bores (conduit entries) and shall ensure that when the conduit is joined, the outer walls of the innerducts and the inner walls of the outer duct shall be sealed, providing an airtight seal from within the innerduct system and a watertight seal from the outside of the outer duct. The coupling body shall be tested for water tightness and air tightness. The coupling body shall conform to the following requirements:

    i. Water tightness – 6 PSI Minimum

    ii. Air tightness - no leakage at 100 PSI

6. Bends and Sweeps shall conform to the following requirements:

    a. Each multi-cell system shall offer a complete line of factory-made fixed bends and sweeps. No flexible bends or field-made bends will be permitted in multi-cell systems. Bullet resistant fiberglass bends and sweeps shall have compatible bell and spigot ends. In no case shall bends and sweeps exceed a 90-degree direction change.

    b. Fixed bends for bullet resistant fiberglass multicell conduit shall be available in radii no less than 3' and provide the following bending radii:

        i. 4' radius: 11 ¼ degrees

        ii. 6' radius: 22 ½ degrees

        iii. 9' radius: 45 and 90 degrees

3.2.4 Rigid Galvanized Steel (RGS) Conduit

All rigid galvanized steel conduit shall meet TDOT Standard Specifications.

3.2.5 PVC Schedule 40 Conduit

All PVC Schedule 40 conduit shall meet TDOT Standard Specifications.

3.2.6 Marking Tape

The Marking Tape shall meet the following requirements:

1. The color of the tape shall be orange with the legend "TDOT ITS FIBER OPTIC CABLE" printed at intervals no greater than 6'.

2. The tape shall be a dielectric, polyolefin film tape, 0.004". thick, and 3". wide. The tape shall be constructed using material and ink colors which will not change when exposed to the acids and other destructive substances commonly found in the most common soil types in Tennessee.

3. Marking Tape shall comply with and be tested according to the following Physical and Mechanical Properties and Test Methods:

a. Standard Weight – 0.02 lb./ft²	ASTM D-2103
b. Thickness-Overall – 0.004"	ASTM D-2103
c. 3" Tensile Break-MD – 35 lbf	ASTM D-882
d. 3" Tensile Strength-MD – 2900 PSI	ASTM D-882
e. 3" Tensile Break-TD – 38 lbf	ASTM D-882

f.	3” Tensile Strength-TD – 3160 PSI	ASTM D-882
g.	Elongation-MD – 530%	ASTM D-882
h.	Elongation-TD – 660%	ASTM D-882
i.	PPT Resistance-MD – 12 lbf	ASTM D-2582
j.	PPT Resistance-TD – 14 lbf	ASTM D-2582
k.	Tear Strength – 3” x 8” – MD – 24 lbf	ASTM D-2261
l.	Tear Strength – 3” x 8” – TD – 32 lbf	ASTM D-2261

m. The following acronyms are referenced in the section above:

   i. **PPT** – Puncture Propagation Tear

   ii. **MD / TD –** Machine Direction / Transverse Direction

3.2.7 Conduit Detection Wire

The conduit detection wire shall meet the following requirements:

Conduit detection wire shall be #10 AWG stranded copper orange-insulated THHN-THWN conductor. #20 AWG stranded copper orange insulated THHN-THWN conductor shall be allowed for micro-conduit installations.

3.2.8 Cable Markers

The Cable Markers shall meet the following requirements:

1. Shall be a six-foot post with an 18” Cable Marker as shown on the Plans.
2. Shall be a cylindrical polymeric marker mounted on a 3.5” outside diameter post and may be used for the identification of buried utility services. These markers may be used in road rights-of-way and installations requiring 360-degree visibility, good outdoor durability, and impact resistance.
3. The marker shall be comprised of polymer materials, which are resistant to impact (high MTBF), ultraviolet light, ozone, or hydrocarbon damage. The post and marker shall remain impact resistant in temperatures of -28°C to 60°C.
4. Shall incorporate a cylindrical tube construction.
5. The marker shall be capable of permanent installation on a 3.5” O.D. tube and may utilize an anchor barb below ground level to prevent rotation and marker removal.
6. The marker shall have an outside diameter of 3.5” – 4.0”. The wall thickness shall be 0.12” – 0.15” and the overall length shall be 18.00”.
7. The marker shall be orange in color and be pigmented throughout its entire cross section.
8. The graphics shall consist of a solvent-based ink that is abrasive and UV resistant and include the text, “TDOT ITS Fiber Optic Cable” “Call XXX-XXX-XXXX Before Digging in this Area.” (Phone number will be provided upon approval of cable marker cut sheets)
9. The marker shall have a minimum tensile strength of 2700 pounds per square inch, as measured by ASTM D-638 (specimen type I with separation rate of 2 inches per minute.) Tensile strength

shall not deviate more than 10% from the standard room temperature result when tested at both 60°C and -6°C after a minimum of 2 hours conditioning at the respective temperature.

10. A "Distance to Conduit" sticker or label shall also be provided. This label shall meet the following minimum requirements:
    a. Lettering shall be a minimum of 1" in height.
    b. Labels shall be manufactured from pre-coated adhesive backed reflective sheeting material meeting the minimum requirements of AASHTO M268 Type 1.
    c. The Label shall have the words "Distance to Conduit XX Feet" pre-printed on the label. The distance numerals shall be added in the field and shall be manufactured from the same type of reflective sheeting. (See Plans for layout of label).

3.2.9 Pull Tape

The Pull Tape for cable installation shall meet the following requirements:

1. 1250 lb. tensile strength
2. Flat, not round, construction
3. Printed sequential foot markings
4. Pre-lubricated for reduced pulling tension at start of cable pull
5. Low susceptibility to absorption of moisture

3.2.10 Duct Plugs

Duct plugs shall meet the following requirements:

1. Duct plugs intended for underground telecommunications infrastructure shall be installed on underground conduits.
2. Duct plugs shall be sized to fit the conduits and cables with which they are used.
3. Duct plugs shall provide watertight and airtight gasketed seals by use of mechanical expansion of the duct plug body and gasket. No sealants or caulks shall be used to install duct plugs.
4. All metallic components of duct plugs shall be stainless steel.
5. Blank duct plugs shall be used to seal spare conduits and shall have inner rings to which pull tape can be tied.
6. Cable duct plugs shall be used to seal conduits that contain 1 or more cables. The plug shall be sized to fit the conduit and cable(s) with which it is used and shall be a split plug with a bushing assembly for sealing around the cable(s) by mechanical compression.

3.2.11 Grouting Compound

Grouting compound shall meet or exceed the following requirements.

1. Grouting compound shall be a 3-component epoxy resin design for installation for grouting of micro-conduit in road bituminous, asphalt, or concrete surfaces.

2. Grouting compound shall have rapid shrink free curing, site ready use packaging, high tensile strength, chemical resistance, and rapid strength agents.

3. Grouting compound shall allow installation without heating equipment with pavement temperature and air temperature between 20°C and 50°C. Heating equipment may be utilized for lower temperatures but must adhere to manufacturers requirements.

3.3 Installation Requirements

Contractor shall abide by the installation requirements in the following sections.

3.3.1 General Requirements

1. Use blank duct plugs to seal the ends of all conduits within twenty-four hours of conduit placement. This includes intermediate/incomplete sections of conduit placed twenty-four hours prior to conduit splicing or termination in pull boxes and empty conduits installed in pull boxes twenty-four hours prior to cable installation.

2. Conduit shall be installed in a straight-line horizontal path between pull boxes except where shown otherwise on the Plans.

3.3.2 Continuous Flexible Conduit (Conduit Duct Bank)

1. Install Conduit Duct Banks by configuring individual continuous flexible conduits into a continuous duct bank from termination point to termination point as shown in the Standard Details and other contract documents. The following general requirements apply to all conduit installations:

    a. Continuous flexible conduit installation in earth, rock, or shoulder shall be trenched, horizontal directional bored or drilled, or plowed at the Contractor’s discretion, unless otherwise noted on the Plans, at a minimum depth of 24” from the top of the conduit.

    b. Contractor shall make every effort to minimize coupling. Couplings are permitted only with the Engineer’s prior approval and will typically be approved where conduit types change or at locations where conduit reels end. Other locations will be on a case-by-case basis. Couplings are not permitted on micro-conduit systems. Micro-conduit systems shall be continuous from pull box to pull box.

    c. There shall not be more than 360 degrees of total bend between pull points in accordance with NEC 358.26.

2. All horizontal directional bored or drilled conduit shall meet the following requirements:

    a. Bore Logs will be required for each bore location.

    b. The Contractor shall submit a proposed bore log format to the Engineer for review and obtain approval prior to performing any boring activity.

    c. Contractor to document GPS location for entry and exit points as well as every 20 feet for every bore and include this information in the As-Built deliverables. See Section 25.2.7 for more information on Conduit As-Buit Documentation Requirements.

3. All trenched conduit shall meet the following requirements:

    a. Conduit shall be placed in the straightest orientation possible, reducing bends, twists, rises, and waves. Conduits shall be held in place during backfilling when necessary to keep straight and at the proper depth. Where field conditions require the trench to change direction and bends are necessary, the bends shall be formed in the trench and should be smooth and even and shall not have less than a 4-foot radius (as measured to the inside surface of the conduit).

   b. Contractor to document GPS location for pull box entry and exit points as well as every 20 feet of trenched conduit between pull boxes and include this information in the As-Built deliverables. See Section 25.2.7 for more information on Conduit As-Buit Documentation Requirements.

4. All micro-conduit installed within the paved shoulder shall meet the following requirements:

   a. Installation of micro-conduit systems in pavement shall be in accordance with the manufacturer's specifications and recommendation to avoid damage to conduit during installation, during backfilling, or during operation once traffic has returned to the paved surface.

   b. The top edge of the micro-conduit systems shall be installed at a minimum depth of 6 inches into the pavement by saw cutting and sealing with grouting compound. All sharp edges within the saw cut shall be removed and corners shall be rounded. Saw cuts shall be blown out with compressed air or vacuumed to remove loose materials. Slot must be dry, clean, and free from dust, oil, or grease prior to micro-conduit installation.

   c. Once the micro-conduit is installed in the slot, grouting compound shall be prepared, placed, and finished in accordance with manufacture's requirements. Backfill shall meet TDOT Standard Specifications for a paved shoulder.

   d. All areas in the paved shoulder shall be completely restored daily according to the time frames set under the approved Traffic Control Plan.

   e. Unless otherwise approved by the Engineer, the conduit shall only be placed within the paved shoulder in the areas identified on the Plans.

   f. Contractor to document GPS location for pull box entry and exit points as well as every 20 feet of micro-conduit between pull boxes and include this information in the As-Built deliverables. See Section 25.2.7 for more information on Conduit As-Buit Documentation Requirements.

5. All continuous flexible conduit routes installed perpendicular to the roadway underneath asphalt or concrete roadways or other travel ways shall meet the following requirements:

   a. Conduit shall be horizontal directional bored or drilled at a minimum depth of 5' from the top of the conduit under roadways. No open trenching will be allowed in asphalt or concrete unless specified on Plan sheets.

   b. Separate encasement is not required for borings unless needed for proper installation due to poor soil conditions as directed by the Engineer.

6. All conduit underneath railroad tracks shall meet the following requirements:

   a. Conduit shall be horizontal directional bored or drilled at a minimum of 10' below the railroad bed.

   b. It is the Contractor's responsibility to determine any additional requirements from the railroad owner and shall meet those requirements in addition to those included on the Plans and this SP725.

   c. Any required steel casings or other materials needed to meet the railroad authority requirements shall be included in the cost of the conduit.

7. All conduit to be installed under streams, drainage canals, wetlands, or other waterways shall be horizontal directional bored or drilled. No open trenching through an area deemed to be a current or wet weather stream will be allowed. All conduit bored under streams shall be a minimum depth of 5' below the streambed.

8. If a drainage or utility conflict arises, the Contractor shall submit a plan for resolving the conflict to the Engineer for review and approval.

9. Separate encasement for borings is not required unless necessary for proper installation due to poor soil conditions as directed by the Engineer or the inability to meet the required installation depth.

10. Continuous flexible conduit may be required to be installed in rock. As called out on the Plans and where encountered by the Contractor, trenching and boring conduit in rock may require additional tools and machinery to install. If trenching in rock is performed, the following is required:

    a. A minimum depth of 24" of cover from the top of the conduit must be maintained.

    b. A minimum of 3" of sand must sit below the conduit in the bottom of the trench.

    c. A minimum 3" sand cover over the conduit must be maintained directly on top of the conduit layered with 9" back fill of soil free of rocks or other foreign matter layered on top of the sand. The remainder of the trench may be backfilled with existing material removed from the trench provided that no material is larger than #2 stone.

3.3.3 Multi-Cell "Bullet Resistant" Fiberglass Conduit System (Structure Conduit Bank)

1. Contractor shall attach conduit to bridge decks by either clamps or hanger systems as indicated on the Plans.

2. If conduit is to be hung by a bridge hanger system attached to the bridge decking, Contractor shall design the system and obtain approval from TDOT Division of Structures prior to ordering the components of the system. Hangers shall be spaced no more than 10' apart.

3. For all bridge installed conduit, it is the Contractor's responsibility to obtain the bridge design drawings from TDOT Structures Division to show the exact location and design of the attachment.

4. Contractor shall obtain from the manufacturer or supplier of the multi-cell system complete and comprehensive written installation manuals for the complete system and provide to the Engineer. At the start of the multi-cell installation, Contractor shall engage the manufacturer or supplier to provide technical assistance, as needed. At any time during the construction process, Contractor shall ensure that the manufacturer or supplier provides technical assistance to the Contractor and/or TDOT as needed to install a functional and warrantied system.

5. Contractor shall install expansion and deflection joints, anchors, stop rings, etc. according to the multi-cell conduit system and support hanger manufacturers' recommendations. Fiberglass couplings shall be epoxied unless otherwise recommended by the manufacturer. Contractor shall ensure that during the construction process and at the request of the Engineer, the multi-cell

conduit system or support hanger manufacturer is available to provide on-site technical assistance at no additional cost to TDOT.

6. All holes in concrete for conduit passes shall be core drilled.
7. All conduit passing through abutment walls shall be sealed around, using a sealant approved by the TDOT Division of Structures.
8. Damage to paved end fills shall be repaired to the satisfaction of the Engineer at the expense of the Contractor.

3.3.4 Rigid Galvanized Steel (RGS) Conduit

1. All exposed conduit runs shall be 2” rigid galvanized steel unless otherwise required on the Plans.
2. Contractor shall properly terminate all conduit runs on structures and poles into the respective device or install a weather head so as to seal the conduit from moisture, insects, rodents and other foreign material. The cost of the galvanized steel conduit, weather heads and all associated fittings shall be included in the cost of other items.
3. Contractor shall install bushings in conduit at all exposed conduit terminations for protection of the conductors.
4. All RGS conduit shall be grounded per NEC.

3.3.5 PVC Schedule 40 Conduit

1. Shall meet the specifications of Section 3.3.2.

3.3.6 Marking Tape

1. As shown on the Plans Typical Details, Contractor shall install marking tape above all underground conduit installed by trenching or plowing.
2. Marking tape shall be installed in continuous manufactured lengths. No splicing or overlap shall be permitted.
3. Marking tape is not required when conduit is bored.

3.3.7 Conduit Detection Wire

1. Contractor shall install 1 conduit detection wire with all conduits directly below or at the same level as the conduit. Conduit detection wire is required with all conduits installed by any underground installation method, including trenching, directional boring, or plowing.
2. Only 1 conduit detection wire is required per installed conduit segment regardless of the number of conduits installed in that segment.
3. Contractor shall install conduit detection wire outside of the conduit, except when boring conduit, then the detection wire shall be placed in a spare conduit. Alternatively, conduit with an integrated detection wire may be utilized.
4. The conduit detection wire shall be continuous and unspliced between pull boxes and shall enter the pull boxes at the same location as the conduit with which it is installed, entering under the lower edge of the pull box.
5. Coil and secure 4’ of conduit detection wire in each pull box or vault.

3.3.8 Cable Markers

1. Contractor shall install cable markers at the following locations:
    a. At the back side of the right-of-way (or tree line) laterally even with each pull box, or adjacent pull boxes, on conduit runs parallel to the roadway. If distance between pull boxes is greater than 650', 1 additional cable marker shall be placed at the midpoint between the adjacent pull boxes, at the back of the right-of-way (or tree line). Additional cable markers shall be placed such that no distance between cable markers shall be greater than 650'.
    b. Directly beside any pull box that is on the interior of an interchange.
    c. At each end of any bore under a roadway, directly beside the pull boxes.
    d. Any additional locations directed by the Engineer.
2. All cable marker locations shall be approved by the Engineer prior to installation. The proposed schedule for installing the cable markers shall also be approved by the Engineer prior to installation.
3. After the cable markers are installed, Contractor shall apply the distance to conduit labels.

3.3.9 Pull Tape

1. Contractor shall install pull tape into each empty conduit and empty cell within a multi-cell conduit. Pull tape shall not be installed in Micro-Conduit as the intent is for Micro-Cable to be blown in place.
2. Contractor shall install the pull tape after conduit testing has been completed.
3. Contractor shall install and secure 5' of slacked pull tape in each empty conduit or cell at each pull box.
4. Contractor shall secure the pull tape by tying it to the blank duct plug for the conduit in which it is installed.

3.3.10 Duct Plugs

1. Contractor shall install blank duct plugs in each empty conduit that enters a pull box, ground-mounted cabinet, pole foundation, hub, or building entrance.
2. Contractor shall install duct plugs within twenty-four hours of the associated duct installation.
3. Contractor shall install cable duct plugs in each conduit containing fiber optic or RDS communications cable that enters a pull box, ground-mounted cabinet, hub, or building entrance.
4. Contractor shall not install cable duct plugs on conduits containing power service conductors.
5. Contractor shall install cable duct plugs within twenty-four hours of installing cables in the associated duct.

3.3.11 Spare Conduits in Foundations

1. A minimum of 1-2" spare conduit shall be installed in all pole foundations and a minimum of 2-2" conduits shall be installed in the base of all ground mounted cabinets.
2. Spare conduits shall be sealed with blank duct plugs.

3.4 *Testing Requirements*

3.4.1 General Requirements

1. The Contractor shall conduct a project testing program for all materials specified in this section and as required in Section 2.5 of this SP725.
2. All test results shall confirm physical and performance compliance with this SP725.
3. The Contractor shall submit all test results documentation to the Engineer within 7 calendar days of completion of the tests. The Engineer will review test documentation in accordance with the Submittal Review Process in Section 2.7.
4. Payment for all testing is included in the cost of the Conduit.

3.4.2 Factory Acceptance Test

FAT is not required for Conduit.

3.4.3 Bench Test Component (BTC)

BTC is not required for Conduit.

3.4.4 Bench Test System (BTS)

BTS is not required for Conduit.

3.4.5 Stand Alone Site Test

SAT shall be performed using the procedures and mandrel size recommended by the conduit manufacturer. Testing shall be performed in the presence of the Engineer. The SAT shall include the following tests and inspections:

1. Verify all components have been installed per manufacturer requirements.
2. Verify all items have been attached properly (as per manufacturer recommendations and the Plans) to each other and any applicable structures.
3. Verify the Conduit has no internal or external damage.
4. Contractor shall test every conduit for airtightness after installation and before cable or pull tape is installed. Contractor shall perform testing on all conduit types in this SP725 including but not limited to each cell of multi-cell conduits, each conduit in duct banks, and each individual conduit.
5. Contractor shall perform a continuity or tone test after installation of conduit detection wire to confirm that a continuous run of wire was installed between pull boxes.

3.5 *Warranty*

All materials specified in this section (individually and as a system) shall carry a minimum one-year manufacturer’s warranty from the date of Final Acceptance against any imperfections in workmanship or materials. Warranties shall cover complete replacement at no charge for the equipment. Warranties shall be transferred to TDOT upon Final Acceptance of the project as per the requirements in Section 2.6 of this specification.

3.6 Method of Measurement

1. All conduit material shall be measured following the guidelines in the following sections.
2. All conduit types shall be measured in linear feet per type to the nearest foot. All conduit types will be measured along the conduit by the following:
    a. From center of pull box to center of pull box.
    b. No additional measurement will be made for vertical conduit inside the pull box or structure.
    c. No additional measurement will be made for conduit between a pull box and the nearby pole or structure, within 5'or less.
3. Unless otherwise specified on the Plans, all costs for materials, trenching, installing, backfilling trench, plowing, directional boring, restoration, repaving of shoulders, marking tape, pull tape, duct plugs, fittings, conduit detection wire, testing, bore logs, and other accessories and hardware necessary for installation of the conduit system shall be included in the overall cost of the conduit or conduit duct bank.
4. Separate encasement for borings is not required unless necessary for proper installation due to poor soil conditions or the inability to meet the required installation depth. If encasement is needed in those situations the cost of the encasement shall be included in the cost of the conduit.

3.6.1 Conduit (2IN, 3IN, and 4IN)

Conduit will be measured by the linear foot for each type of conduit indicated after installation and shall include the items identified in Section 3.2.2, as well as the type and number of conduits indicated below.

1. 2" Conduit: 1 – 2" Continuous Flexible Conduit or PVC Schedule 40 Conduit installed in soil or areas with intermittent (non-solid) rock. This pay item applies to areas where trenching or plowing is physically possible using typical trenching equipment.
2. 3" Conduit: 1 – 3" Continuous Flexible Conduit or PVC Schedule 40 Conduit installed in soil or areas with intermittent (non-solid) rock. This pay item applies to areas where trenching or plowing is physically possible using typical trenching equipment.
3. 4" Conduit: 1 – 4" Continuous Flexible Conduit or PVC Schedule 40 Conduit installed in soil or areas with intermittent (non-solid) rock. This pay item applies to areas where trenching or plowing is physically possible using typical trenching equipment.

3.6.2 Conduit Bored (2IN, 3IN, and 4IN)

Bored Conduit will be measured by the linear foot for each type of conduit indicated after installation and shall include the items identified in Section 3.2.2, as well as the type and number of conduits indicated below.

1. 2" Conduit (Bored): 1 – 2" Continuous Flexible Conduit installed via jacking or boring the conduit in soil or areas with intermittent (non-solid) rock.
2. 3" Conduit (Bored): 1 – 3" Continuous Flexible Conduit installed via jacking or boring the conduit in soil or areas with intermittent (non-solid) rock.
3. 4" Conduit (Bored): 1 – 4" Continuous Flexible Conduit installed via jacking or boring the conduit in soil or areas with intermittent (non-solid) rock.

3.6.3 Conduit In Rock (2IN, 3IN, and 4IN)

Conduit In Rock will be measured by the linear foot for each type of conduit indicated after installation and shall include the items identified in Section 3.2.2, as well as the type and number of conduits indicated below.

1. 2" Conduit (In Rock): 1 – 2" Continuous Flexible Conduit installed in solid rock or solid shot rock fill by means of trenching as called out in the Plans or determined in the field by the Engineer. The locations for this pay item are identified on the Plans. Final determination of the applicability of this item will be at the discretion of the Engineer.
2. 3" Conduit (In Rock): 1 – 3" Continuous Flexible Conduit installed in solid rock or solid shot rock fill by means of trenching as called out in the Plans or determined in the field by the Engineer. The locations for this pay item are identified on the Plans. Final determination of the applicability of this item will be at the discretion of the Engineer.
3. 4" Conduit (In Rock): 1 – 4" Continuous Flexible Conduit installed in solid rock or solid shot rock fill by means of trenching as called out in the Plans or determined in the field by the Engineer. The locations for this pay item are identified on the Plans. Final determination of the applicability of this item will be at the discretion of the Engineer.

3.6.4 Conduit Bored In Rock (2IN, 3IN, and 4IN)

Conduit In Rock will be measured by the linear foot for each type of conduit indicated after installation and shall include the items identified in Section 3.2.2, as well as the type and number of conduits indicated below.

1. 2" Conduit (In Rock): 1 – 2" Continuous Flexible Conduit installed in solid rock or solid shot rock fill by means of boring as called out in the Plans or determined in the field by the Engineer. The locations for this pay item are identified on the Plans. Final determination of the applicability of this item will be at the discretion of the Engineer.
2. 3" Conduit (In Rock): 1 – 3" Continuous Flexible Conduit installed in solid rock or solid shot rock fill by means of boring as called out in the Plans or determined in the field by the Engineer. The locations for this pay item are identified on the Plans. Final determination of the applicability of this item will be at the discretion of the Engineer.
3. 4" Conduit (In Rock): 1 – 4" Continuous Flexible Conduit installed in solid rock or solid shot rock fill by means of boring as called out in the Plans or determined in the field by the Engineer. The locations for this pay item are identified on the Plans. Final determination of the applicability of this item will be at the discretion of the Engineer.

3.6.5 Conduit Bank (All Types)

Conduit Bank will be measured by the linear foot for each type of conduit bank indicated after installation and shall include the items identified in Section 3.2.2, as well as the type and number of conduits indicated below.

1. Conduit Bank (Type 1): 1 – 1 ¼" Continuous Flexible Conduit installed in soil or areas with intermittent (non-solid) rock. This pay item applies to areas where trenching is physically possible using typical trenching equipment.
2. Conduit Bank (Type 2): 2 – 1 ¼" Continuous Flexible Conduits installed in soil or areas with intermittent (non-solid) rock. This pay item applies to areas where trenching is physically possible using typical trenching equipment.

3. Conduit Bank (Type 3): 3 – 1 ¼” Continuous Flexible Conduits installed in soil or areas with intermittent (non-solid) rock. This pay item applies to areas where trenching is physically possible using typical trenching equipment.
4. Conduit Bank (Type 4): 4 – 1 ¼” Continuous Flexible Conduits installed in soil or areas with intermittent (non-solid) rock. This pay item applies to areas where trenching is physically possible using typical trenching equipment.
5. Conduit Bank (Micro-conduit): Micro-conduit Continuous Flexible Conduits installed in soil or areas with intermittent (non-solid) rock. This pay item applies to areas where trenching is physically possible using typical trenching equipment.

3.6.6 Conduit Bank Bored (All Types)

Conduit Bank Bored will be measured by the linear foot for each type of conduit bank indicated after installation and shall include the items identified in Section 3.2.2, as well as the type and number of conduits indicated below.

1. Conduit Bank (Type 1–Bored): 1 – 1 ¼” Continuous Flexible Conduits installed via jacking or boring the conduit bank.
2. Conduit Bank (Type 2–Bored): 2 – 1 ¼” Continuous Flexible Conduits installed via jacking or boring the conduit bank.
3. Conduit Bank (Type 3–Bored): 3 – 1 ¼” Continuous Flexible Conduits installed via jacking or boring the conduit bank.
4. Conduit Bank (Type 4–Bored): 4 – 1 ¼” Continuous Flexible Conduits installed via jacking or boring the conduit bank.
5. Conduit Bank (Micro-conduit–Bored): Micro-conduit Continuous Flexible Conduits installed via jacking or boring the conduit bank.

3.6.7 Conduit Bank In Rock (All Types)

Conduit Bank In Rock will be measured by the linear foot for each type of conduit bank indicated after installation and shall include the items identified in Section 3.2.2, as well as the type and number of conduits indicated below.

1. Conduit Bank (Type 1–In Rock) 1 – 1 ¼” Continuous Flexible Conduits installed in solid rock or solid shot rock fill. The locations for this pay item are identified on the Plans. Final determination of the applicability of this item will be at the discretion of the Engineer.
2. Conduit Bank (Type 2–In Rock) 2 – 1 ¼” Continuous Flexible Conduits installed in solid rock or solid shot rock fill. The locations for this pay item are identified on the Plans. Final determination of the applicability of this item will be at the discretion of the Engineer.
3. Conduit Bank (Type 3–In Rock) 3 – 1 ¼” Continuous Flexible Conduits installed in solid rock or solid shot rock fill. The locations for this pay item are identified on the Plans. Final determination of the applicability of this item will be at the discretion of the Engineer.
4. Conduit Bank (Type 4–In Rock) 4 – 1 ¼” Continuous Flexible Conduits installed in solid rock or solid shot rock fill. The locations for this pay item are identified on the Plans. Final determination of the applicability of this item will be at the discretion of the Engineer.

5. Conduit Bank (Micro-conduit–In Rock) Micro-conduit Continuous Flexible Conduits installed in solid rock or solid shot rock fill. The locations for this pay item are identified on the Plans. Final determination of the applicability of this item will be at the discretion of the Engineer.

3.6.8 Conduit Bank Bored In Rock (All Types)

Conduit Bank Bored In Rock will be measured by the linear foot for each type of conduit bank indicated after installation and shall include the items identified in Section 3.2.2, as well as the type and number of conduits indicated below.

1. Conduit Bank (Type 1–Bored In Rock) 1 – 1 ¼" Continuous Flexible Conduits installed via boring the conduit bank in solid rock or solid shot rock fill. The locations for this pay item are identified on the Plans. Final determination of the applicability of this item will be at the discretion of the Engineer.
2. Conduit Bank (Type 2–Bored In Rock) 2 – 1 ¼" Continuous Flexible Conduits installed via boring the conduit bank in solid rock or solid shot rock fill. The locations for this pay item are identified on the Plans. Final determination of the applicability of this item will be at the discretion of the Engineer.
3. Conduit Bank (Type 3–Bored In Rock) 3 – 1 ¼" Continuous Flexible Conduits installed via boring the conduit bank in solid rock or solid shot rock fill. The locations for this pay item are identified on the Plans. Final determination of the applicability of this item will be at the discretion of the Engineer.
4. Conduit Bank (Type 4–Bored In Rock) 4 – 1 ¼" Continuous Flexible Conduits installed via boring the conduit bank in solid rock or solid shot rock fill. The locations for this pay item are identified on the Plans. Final determination of the applicability of this item will be at the discretion of the Engineer.
5. Conduit Bank (Micro-conduit–Bored In Rock) Micro-conduit Continuous Flexible Conduits installed via boring the conduit bank in solid rock or solid shot rock fill. The locations for this pay item are identified on the Plans. Final determination of the applicability of this item will be at the discretion of the Engineer.

3.6.9 Micro-Conduit Bank In Pavement

Micro-Conduit Bank In Pavement will be measured by the linear foot for the micro-conduit bank and shall include the items identified in Section 3.2.2. This item will also include the cost to sawcut the pavement and restore the pavement with grouting compound as identified in Section 3.2.11.

3.6.10 DMS Conduit Bank

DMS Conduit Bank will be measured by the linear foot for each type of conduit bank indicated after installation and shall include the items identified in Section 3.2.2, as well as the type and number of conduits indicated below.

1. DMS Conduit Bank: 4 – 2" Continuous Flexible Conduits installed in the same trench.

3.6.11 Structure Conduit Bank (All types)

Unless otherwise specified on the Plans, all costs for materials, cutting asphalt or concrete, trenching, installing, backfilling trench, restoring asphalt or concrete, drilling existing concrete shoulder, replacement of existing transverse joint material, directional boring, bridge hanger materials and assemblies, testing of conduit, pull tape, duct plugs, and bridge attachment design shall be included in the overall cost of structure conduit or structure conduit bank.

Conduit will be measured by the linear foot for each type of conduit bank indicated after installation.

1. Structure Conduit Bank Type 1: 1-4” Fiberglass Conduit outer duct with 1-1 ¼” innerducts
2. Structure Conduit Bank Type 2: 1-4” Fiberglass Conduit outer duct with 2-1 ¼” innerducts
3. Structure Conduit Bank Type 3: 1-4” Fiberglass Conduit outer duct with 3-1 ¼” innerducts
4. Structure Conduit Bank Type 4: 1-4” Fiberglass Conduit outer duct with 4-1 ¼” innerducts
5. 4” Structure Conduit: 1-4” Fiberglass Conduit
6. 4” Structure Conduit with Bank: 1-4” Fiberglass Conduit installed in the same Hanger assembly as the related Conduit Bank type as specified on the Plans.

3.6.12 Conduit with Bank (2IN, 3IN, and 4IN)

Conduit with Bank will be measured by the linear foot for each conduit indicated after installation and shall include the items identified in Section 3.2.2.

1. 2” Conduit with Bank: 1 – 2” Continuous Flexible Conduit installed in the same trench as the related Conduit Bank Type as specified in the Plan Sheet.
2. 3” Conduit with Bank: 1 – 3” Continuous Flexible Conduit installed in the same trench as the related Conduit Bank Type as specified in the Plan Sheet.
3. 4” Conduit with Bank: 1 – 4” Continuous Flexible Conduit installed in the same trench as the related Conduit Bank Type as specified in the Plan Sheet.

3.6.13 Conduit with Bank Bored (2IN, 3IN, and 4IN)

Conduit and Conduit with Bank will be measured by the linear foot for each type of conduit bank indicated after installation and shall include the items identified in Section 3.2.2, as well as the type and number of conduits indicated below.

1. 2” Conduit with Bank (Bored): 1 – 2” Continuous Flexible Conduit installed in the same bore as the related Conduit Bank Type as specified on the Plans.
2. 3” Conduit with Bank (Bored): 1 – 3” Continuous Flexible Conduit installed in the same bore as the related Conduit Bank Type as specified on the Plans.
3. 4” Conduit with Bank (Bored): 1 – 4” Continuous Flexible Conduit installed in the same bore as the related Conduit Bank Type as specified on the Plans.

3.6.14 Structural ITS

Unless otherwise specified on the Plans, all costs for materials, cutting asphalt or concrete, trenching, installing, backfilling trench, restoring asphalt or concrete, drilling existing concrete shoulder, replacement of existing transverse joint material, directional boring, underground conduit, conduit transitions from barrier wall or retaining wall to underground, conduit within barrier wall or retaining wall, conduit hanger materials within barrier wall or retaining wall reinforcement, pull boxes in accordance with Section 4 of this SP, pull box attachment brackets, testing of conduit, pull tape, and duct plugs shall be included in the overall cost of Structural ITS. This item is to be measured on a lump sum basis based on the specified linear feet of conduit and specified number of pull boxes specified on the Plans.

3.6.15 ITS Cable Marker

Cable Markers will be measured per each and paid for at the contract price per each. The bid price shall include furnishing and installing the complete cable marker, and distance sticker/label. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

3.6.16 Rigid Galvanized Steel (RGS) Conduit

Rigid Galvanized Steel Conduit, and all related materials including but not limited to weather heads, bushings, couplings, mounting straps, bonding to ground, etc., that is installed on sign structures, poles, or between the pull boxes and equipment cabinets is included in the cost of other items and will not be measured separately.

3.6.17 PVC Schedule 40 Conduit

PVC Conduit is included in the cost of other items and will not be measured separately.

3.6.18 Marking Tape

Marking Tape is included in the cost of the conduit and will not be measured separately.

3.6.19 Conduit Detection Wire

Conduit Detection Wire is included in the cost of the conduit and will not be measured separately.

3.6.20 Pull Tape

Pull Tape is included in the cost of the conduit and will not be measured separately.

3.6.21 Duct Plugs

Duct Plugs are included in the cost of the conduit and will not be measured separately.

3.7 Payment

The contract unit price shall be full compensation for all work specified in this section.

Payment will be made under:

Item No.	Description	Unit
725-01	STRUCTURAL ITS	LS
725-01.01	STRUCTURAL ITS (BRIDGE NO.)	LS
725-01.02	STRUCTURAL ITS (BRIDGE NO.)	LS
725-01.03	STRUCTURAL ITS (BRIDGE NO.)	LS
725-01.04	STRUCTURAL ITS (BRIDGE NO.)	LS
725-01.20	STRUCTURAL ITS (RET. WALL NO.)	LS

Item No.	Description	Unit
725-01.21	STRUCTURAL ITS (RET. WALL NO.)	LS
725-01.22	STRUCTURAL ITS (RET. WALL NO.)	LS
725-01.23	STRUCTURAL ITS (RET. WALL NO.)	LS
725-10.86	2 IN CONDUIT IN ROCK	LF
725-21.20	DMS CONDUIT BANK STRUCTURE	LF
725-22.21	CONDUIT BANK (TYPE 1)	LF
725-22.22	CONDUIT BANK (TYPE 2)	LF
725-22.23	CONDUIT BANK (TYPE 3)	LF
725-22.24	CONDUIT BANK (TYPE 4)	LF
725-22.26	CONDUIT BANK (MICRO-CONDUIT)	LF
725-22.31	CONDUIT BANK BORED (TYPE 1)	LF
725-22.32	CONDUIT BANK BORED (TYPE 2)	LF
725-22.33	CONDUIT BANK BORED (TYPE 3)	LF
725-22.34	CONDUIT BANK BORED (TYPE 4)	LF
725-22.36	CONDUIT BANK BORED (MICRO-CONDUIT)	LF
725-22.41	CONDUIT BANK IN ROCK (TYPE 1)	LF
725-22.42	CONDUIT BANK IN ROCK (TYPE 2)	LF
725-22.43	CONDUIT BANK IN ROCK (TYPE 3)	LF
725-22.44	CONDUIT BANK IN ROCK (TYPE 4)	LF
725-22.47	CONDUIT BANK IN ROCK (MICRO-CONDUIT)	LF
725-22.50	DMS CONDUIT BANK	LF
725-22.51	DMS CONDUIT BANK IN ROCK	LF
725-22.61	STRUCTURE CONDUIT BANK (TYPE 1)	LF
725-22.62	STRUCTURE CONDUIT BANK (TYPE 2)	LF
725-22.63	STRUCTURE CONDUIT BANK (TYPE 3)	LF
725-22.64	STRUCTURE CONDUIT BANK (TYPE 4)	LF

Item No.	Description	Unit
725-22.71	2 IN CONDUIT	LF
725-22.72	2 IN CONDUIT BORED	LF
725-22.74	2 IN CONDUIT W/BANK	LF
725-22.75	2 IN CONDUIT BORED W/ BANK	LF
725-22.78	3 IN CONDUIT	LF
725-22.79	3 IN CONDUIT BORED	LF
725-22.80	3 IN CONDUIT W/ BANK	LF
725-22.81	3 IN CONDUIT BORED W/ BANK	LF
725-22.82	3 IN CONDUIT IN ROCK	LF
725-22.83	4 IN CONDUIT	LF
725-22.84	4 IN CONDUIT W/BANK	LF
725-22.85	4 IN CONDUIT BORED W/ BANK	LF
725-22.86	4 IN CONDUIT BORED	LF
725-22.87	4IN CONDUIT IN ROCK	LF
725-22.88	4IN CONDUIT STRUCTURE	LF
725-22.89	4IN CONDUIT STRUCTURE W/BANK	LF
725-22.90	CONDUIT BANK BORED IN ROCK (TYPE 1)	LF
725-22.91	CONDUIT BANK BORED IN ROCK (TYPE 2)	LF
725-22.92	CONDUIT BANK BORED IN ROCK (TYPE 3)	LF
725-22.93	CONDUIT BANK BORED IN ROCK (TYPE 4)	LF
725-22.95	CONDUIT BANK BORED IN ROCK (MICRO-CONDUIT)	LF
725-22.96	2 IN CONDUIT BORED IN ROCK	LF
725-22.97	3 IN CONDUIT BORED IN ROCK	LF
725-22.98	4IN CONDUIT BORED IN ROCK	LF
725-22.99	MICRO-CONDUIT BANK IN PAVEMENT	LF
725-23.01	ITS CABLE MARKER	EA

All Conduit will be paid per linear foot, as applicable, as follows:

1. Stored Materials will be paid per TDOT Standard Specifications.
2. Final Payment will be made after complete installation and satisfactory completion of Stand Alone Site Test of all items for which it is specified.

Cable Markers will be paid per each, as applicable, as follows:

1. Stored Materials will be paid per TDOT Standard Specifications.
2. Final Payment will be made after complete installation and satisfactory completion of Stand Alone Site Test of the Conduits.

Structural ITS will be paid at the lump sum price as follows:

1. Stored Materials will be paid per TDOT Standard Specifications.
2. Final Payment will be made after complete installation and satisfactory completion of Stand Alone Site Test of all items for which it is specified.

4 PULL BOXES

4.1 Description

This section specifies the minimum requirements for furnishing and installing pull boxes and covers as indicated on the Plans.

The Contractor shall install standard pull boxes at the locations shown on the Plans. The Plans will indicate pull box locations relative to the cabinet and other installation details, final location of pull boxes shall be determined in the field.

4.2 Materials

Contractor shall provide all materials according to the requirements in the following sections.

All equipment shall be new and constructed using the highest quality, commercially available components and techniques to assure high reliability and minimum maintenance. Prior to installation, the Contractor shall submit and receive approval from the Engineer on a complete set of shop drawings of all the equipment and components listed within this Special Provision and included as part of the installation.

4.2.1 Pull Box (Type C)

Type C pull boxes shall meet the following requirements:

1. Minimum dimensions: 25"W x 16"L x 18"D exterior, 24"W x 13"L x 16"D interior.
2. Pull Box cover shall be precast composite polymer concrete product and shall be secured with stainless steel tamper resistant (e.g. pentahead) bolts. The Contractor shall furnish a total of 5 adapter/tools for removal of each type of tamper resistant bolt as part of this project.
3. Pull Boxes and covers shall be single-stack, open-bottom assemblies configured as shown in the standard drawings.
4. Shall meet or exceed current ANSI/SCTE 77 Tier 22 loading requirements.
5. Pull Box shall meet current NEC standards for handhole enclosures.
6. Pull Box cover shall be labeled (TDOT ITS ELECTRICAL).
7. Type C pull boxes shall only be used for electrical power conduit/wiring.

4.2.2 Pull Box (Type D)

Type D Pull Boxes shall meet the following requirements:

1. Minimum dimensions: 24"W x 36"L x 36"D exterior.
2. Pull Box cover shall be precast composite polymer concrete product and shall be secured with stainless steel tamper resistant(e.g. pentahead) bolts. The Contractor shall furnish a total of 5 adapter/tools for removal of each type of tamper resistant bolt as part of this project.
3. Pull Boxes and covers shall be single-stack open-bottom assemblies configured as shown on the Plans.
4. Shall meet or exceed current ANSI/SCTE 77 Tier 22 loading requirements.

5. Pull Box shall meet current NEC standards for handhole enclosures.
6. Pull Box cover shall be labeled (TDOT ITS COMMUNICATIONS).
7. Each Pull Box shall come equipped with 4 Cable Racks and 12 Rack Hooks. The Cable Racks shall be a minimum of 24"and Rack Hooks shall be a minimum of 7" in length. The cable Racks and Rack Hooks shall be Hot-Dipped Galvanized Steel.
8. Type D pull boxes shall only be used for communications conduit/cabling.

4.2.3 Pull Box (Type E)

Type E Pull Boxes shall meet the following requirements:

1. Minimum dimensions: 30" W x 48" L x 36" D exterior.
2. Pull Box cover shall be precast composite polymer product and shall be secured with stainless steel tamper resistant (e.g. pentahead) bolts. The Contractor shall furnish a total of 5 adapter/tools for removal of each type of tamper resistant bolt as part of this project.
3. Pull Boxes and covers shall be single-stack open-bottom assemblies configured as shown on the Plans.
4. Shall meet or exceed current ANSI/SCTE 77 Tier 22 loading requirements.
5. Pull Box shall meet current NEC standards for handhole enclosures.
6. Pull Box cover shall be labeled (TDOT ITS COMMUNICATIONS).
7. Each Pull Box shall come equipped with 4 Cable Racks and 12 Rack Hooks. The Cable Racks shall be a minimum of 24" and Rack Hooks shall be a minimum of 7"in length. The cable Racks and Rack Hooks shall be Hot-Dipped Galvanized Steel.
8. Type E pull boxes shall only be used for communications conduit/cabling.

4.2.4 Pull Box (Structure Mounted)

Structure Mounted Pull Boxes shall meet the following requirements:

1. Minimum dimensions: 36" L x 12" D x 24" H exterior.
2. All components of pull box shall be 316 stainless steel except conduit adapter, O-rings and gasket.
3. Pull Box shall be NEMA 4X rated, 16-gauge, 316 stainless steel with gasketed, hinged door and tamper-resistant bolts.
4. Pull Boxes and cover assembly shall be configured as shown on the Plans.
5. Pull Box shall meet current NEC standards for handhole enclosures.
6. Pull Box cover shall be labeled (TDOT ITS COMMUNICATIONS). Labels shall be manufactured from pre-coated adhesive backed reflective sheeting material meeting the minimum requirements of AASHTO M268 Type 1.

4.2.5 Terminator Ring

The Terminator Ring shall meet the following requirements:

1. Shall accommodate the number of ducts penetrating the side of the Pull Box or Manhole.
2. The Terminator shall mount securely to the side of the box or cast into the side of the Manhole. The Terminator shall be a minimum of 1” thick and allow adequate spacing of the ducts.
3. The Terminator shall be manufactured from a composite material that will not deteriorate in any type of weather conditions.

4.3 Installation Requirements

Contractor shall abide by the installation requirements in the following sections. This section shall be as per guidelines of the TDOT Standard Specifications. Pull Boxes and covers shall be installed per the design details.

1. All items paid under this spec shall be installed per the manufacturer’s recommendations.
2. A ground rod shall be installed in each Pull box. Bond all equipment ground conductors to the ground rod.

4.3.1 Pull Box (Type C)

1. Ducts shall enter the bottom of the Pull Box and shall extend into the box no more than 4”and no less than 2”.

4.3.2 Pull Box (Type D)

1. Cable Racks and Rack Hooks shall be installed per the manufacturer’s recommendations.
2. Ducts shall enter the side of the Pull Box using a Terminator and shall extend into the box no more than 4” and no less than 2”.

4.3.3 Pull Box (Type E)

1. Cable Racks and Rack Hooks shall be installed per the manufacturer’s recommendations.
2. Ducts shall enter the side of the Pull Box using a Terminator and shall extend into the box no more than 4”and no less than 2”.

4.3.4 Pull Box (Structure Mounted)

1. Pull Box Support Hangers shall be installed per the manufacturer’s recommendations.
2. Pull Box shall include a conduit box adapter with O-ring on both sides (inside and out) for connection to conduit system where required on the Plans. Ducts shall extend into the box no more than 4” and no less than 2”.

4.4 Testing Requirements

4.4.1 General Requirements

1. The Contractor shall conduct a project testing program for all materials specified in this section and as required in Section 2.5 of this SP725.
2. All test results shall confirm physical and performance compliance with this SP725.

3. The Contractor shall submit all test results documentation to the Engineer within 7 calendar days of completion of the tests. The Engineer will review test documentation in accordance with the Submittal Review Process in Section 2.7.
4. Payment for all testing is included in the cost of the Pull Box.

4.4.2 Factory Acceptance Test

FAT is not required for Pull Boxes.

4.4.3 Bench Test Component

BTC is not required for Pull Boxes.

4.4.4 Bench Test System

BTS is not required for Pull Boxes.

4.4.5 Stand Alone Site Test

SAT shall be performed in the presence of the Engineer. The SAT shall include the following tests and inspections:

1. Verify all components have been installed per manufacturer requirements.
2. Verify all items have been attached properly (as per manufacturer recommendations and the Plans) to each other and to any applicable structures.
3. Verify the Pull Boxes have no internal or external damage.
4. Verify that security bolts are in place and properly fastened to covers.

4.5 Warranty

All materials specified in this section shall carry a minimum one-year manufacturer’s warranty from the date of Final Acceptance against any imperfections in workmanship or materials. Warranties shall cover complete replacement at no charge for the equipment. Warranties shall be transferred to TDOT upon Final Acceptance of the project as per the requirements in Section 2.6 of this specification.

4.6 Method of Measurement

4.6.1 Pull Box (Type C)

Pull Box will be measured in units of each and paid for at the contract price per each after the complete installation. The bid price shall include furnishing and installing the pull box and cover including excavation, gravel, restoration, tamper-resistant bolt removal adapter/tool, and miscellaneous materials necessary for a complete and accepted installation. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

4.6.2 Pull Box (Type D)

Pull Box will be measured in units of each and paid for at the contract price per each after the complete installation. The bid price shall include furnishing and installing the pull box and cover including excavation, gravel, restoration, cable rack rails and hooks, terminator rings, tamper-resistant bolt removal adapter/tool, and miscellaneous materials necessary for a complete and accepted installation. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

4.6.3 Pull Box (Type E)

Pull Box will be measured in units of each and paid for at the contract price per each after the complete installation. The bid price shall include furnishing and installing the pull box and cover including excavation, gravel, restoration, cable rack rails and hooks, terminator rings, tamper-resistant bolt removal adapter/tool, and miscellaneous materials necessary for a complete and accepted installation. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

4.6.4 Pull Box (Structure Mounted)

Pull Box will be measured in units of each and paid for at the contract price per each after the complete installation. The bid price shall include furnishing and installing the pull box and cover including support hangers, conduit box adapters with O-ring, tamper-resistant bolt removal adapter/tool, and miscellaneous materials necessary for a complete and accepted installation. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

4.7 Payment

The contract unit price shall be full compensation for all work specified in this section. Payment will be made under:

Item No.	Description	Unit
725-20.43	PULL BOX (TYPE C)	EA
725-20.44	PULL BOX (TYPE D)	EA
725-20.45	PULL BOX (TYPE E)	EA
725-20.46	PULL BOX (STRUCTURE MOUNTED)	EA

Pull Boxes will be paid per each as follows:

1. Stored materials will be paid per TDOT Standard Specifications.
2. Final Payment will be made after complete installation and satisfactory completion of Stand Alone Site Test of all items for which it is specified.

5 FIBER OPTIC INFRASTRUCTURE

5.1 Description

This section specifies the minimum requirements for fiber optic infrastructure furnished and installed on this project. This work includes cable, splicing, termination, connectors, closures, panels, installation, and testing.

The fiber optic infrastructure will serve as the backbone for the communications systems (wireline) and will be used to transport data and video signals to/from field device locations using an Ethernet protocol.

5.2 Materials

Contractor shall provide all materials according to the requirements in the following sections.

All equipment shall be new and constructed using the highest quality, commercially available components and techniques to assure high reliability and minimum maintenance. Prior to installation, the Contractor shall submit and receive approval from the Engineer on a complete set of shop drawings of all the equipment and components listed within this Special Provision and included as part of the installation.

5.2.1 General

1. Furnish fiber optic infrastructure materials that meet applicable industry standards for links less than 100 km including but not limited to:
    a. Manufacturer of optical fiber, fiber optic cable, fiber optic drop cable, integrated fiber optic termination unit, optical termination and connectorization materials and all ancillary and incidental materials shall comply with RUS Bulletin 1753F-601a where applicable and be currently ISO 9001 certified.
    b. Provide and install optical fiber, fiber optic cable, fiber optic drop cable, integrated fiber optic termination unit, optical termination and connectorization materials in accordance with contract drawings, specifications, IEEE C2 (NESC(R)), NFPA 70 (NEC), ICEA S-83-596, UL 1666, EIA/TIA-568-B.3, EIA/TIA-598-D, EIA/TIA-758-B, ITU-T G.652D, Fiber Optic Connector Intermateability Standard (FOCIS), and Telcordia GR-20 CORE requirements where applicable.
    c. EIA/TIA-455 Testing procedures
    d. Applicable Telcordia (Bellcore) Testing Standards
    e. Fiber optic cable physical requirements and cable construction shall be in accordance with ICEA S-87-640, ASTM D 4976
    f. Fiber optic cables shall be tested in accordance with Telcordia GR-20-CORE
2. Upon request of the Engineer, provide certification from a nationally recognized, independent testing laboratory that certifies that the cable conforms to industry standards.
3. Furnish fiber optic infrastructure materials recommended by the manufacturer for outside plant use and the intended application.

4. Furnish all optical fiber, fiber optic cable, fiber optic drop cable, integrated fiber optic termination unit, optical termination and connectorization materials, and all ancillary and incidental materials that are single-mode and/or compatible. All materials shall meet the following requirements:

    a. All cables and termination infrastructure shall be factory installed and fusion spliced to an approved equivalent single-mode optical fiber.

    b. All fibers and buffer tubes shall follow EIA/TIA-598B identification using colors. Do not use printed legends.

    c. All cables shall have been manufactured and labeled no earlier than 3 calendar months preceding the TDOT letting date of the contract.

5.2.2 Fiber Optic Cable (144 F)

1. Provide fiber optic cable that meets the following requirements:

    a. All-dielectric outside plant loose tube cable shall have central strength/anti-buckling member or outer aramid yarn strength member.

    b. Dry, water blocking materials and construction.

    c. Reverse oscillating “SZ” stranded buffer tube construction

    d. Medium density polyethylene outer jacket shall be a consistent thickness that is free of holes, splits, and blisters, and containing no metal elements. Outer jacket polyethylene shall contain carbon black for ultraviolet light protection and does not promote the growth of fungus.

    e. 144 fiber cable with 12 active buffer tubes and 12 individual stranded fibers per buffer tube

    f. Cable construction design that allows no more than 12 buffer tube positions

    g. Maximum diameter 0.7”

    h. Maximum weight 0.2 pounds per foot

    i. Rated for conduit installations

    j. Rated attenuation: 0.4dB/km and 0.3dB/km at 1310nm and 1550nm, respectively

2. Designate this cable as a trunk cable.

3. Ensure that the cable can withstand a maximum pulling tension of 600 lbf during installation and 180 lbf installed long term (at rest).

4. Provide cable with shipping, storage, and operating temperature range of -30°C to +70°C.

5. Provide cable with a minimum installation temperature range of -10°C to +40°C.

6. Provide cable with outer jacket marking using the following template:

    a. Manufacturer’s Name – “Optical Cable” – Month/Year of Manufacture – Telephone Handset Symbol – “TDOT ITS” – “144F SM”

7. Contractor shall include in the outer jacket marking the cable sequential length in accordance with the following:

a. In English units every 2’
b. Within -1%/+1% of the actual length of the cable
c. In contrasting color to the cable jacket
d. Marking font height no less than 0.10”
e. On any single length of cable on a reel, the sequential length markings do not run through “00000”

5.2.3 Fiber Optic Drop Cable (12 F)

1. Provide fiber optic drop cable that meets the following requirements:
   a. All-dielectric outside plant loose tube cable shall have central strength/anti-buckling member or outer aramid yarn strength member.
   b. Dry water blocking materials and construction
   c. Reverse oscillating “SZ” stranded buffer tube construction
   d. Medium density polyethylene outer jacket shall be a consistent thickness that is free of holes, splits, and blisters, and containing no metal elements. Outer jacket polyethylene shall contain carbon black for ultraviolet light protection and does not promote the growth of fungus.
   e. 12-fiber cable with 1 active buffer tube and 12 individual stranded fibers
   f. Maximum diameter 0.48”
   g. Maximum weight 0.07 pounds per foot
   h. Rated for conduit installations
   i. Rated attenuation: 0.4dB/km and 0.3dB/km at 1310nm and 1550nm, respectively
2. Designate this cable as a drop cable.
3. Ensure that the cable can withstand a maximum pulling tension of 600 lbf during installation and 180 lbf installed long term (at rest).
4. Provide cable with shipping, storage, and operating temperature range of -30°C to +70°C.
5. Provide cable with an installation temperature range of -30°C to +60°C.
6. Provide cable with outer jacket marking using the following template:
   a. Manufacturer’s Name – “Optical Cable” – Month/Year of Manufacture – Telephone Handset Symbol – “TDOT ITS” – “12F SM”
7. Include in the outer jacket marking the cable sequential length in accordance with the following:
   a. In English units every 2’
   b. Within -1%/+1% of the actual length of the cable
   c. In contrasting color to the cable jacket
   d. Marking font height no less than 0.10”

e. On any single length of cable on a reel, the sequential length markings do not run through “00000”

5.2.4 Fiber Optic Micro-Cable (144 F)

1. Provide fiber optic micro-cable that meets the following requirements:
   a. All-dielectric outside plant loose tube cable shall have central strength/anti-buckling member or outer aramid yarn strength member.
   b. Dry, water blocking materials and construction
   c. Reverse oscillating “SZ” stranded buffer tube construction
   d. Medium density polyethylene outer jacket shall be a consistent thickness that is free of holes, splits, and blisters, and containing no metal elements. Outer jacket polyethylene shall contain carbon black for ultraviolet light protection and does not promote the growth of fungus.
   e. 144 fiber cable with 12 active buffer tubes and 12 individual stranded fibers per buffer tube
   f. Cable construction design that allows no more than 12 buffer tube positions
   g. Maximum outside diameter 0.32”
   h. Maximum weight 0.04 pounds per foot
   i. Rated for micro-conduit installations
   j. Rated attenuation: 0.35 dB/km and 0.25 dB/km at 1310nm and 1550nm, respectively
2. Designate this cable as a trunk cable.
3. Install only within micro-conduit to a minimum fill ratio of 50% and a maximum fill ratio of 80%.
4. Ensure that the cable can withstand a maximum air assisted install speed of at least 490 ft/min during installation.
5. Provide cable with minimum shipping, storage, and operating temperature range of -30°C to +70°C.
6. Provide cable with a minimum installation temperature range of -10°C to +60°C.
7. Provide cable with outer jacket marking using the following template:
   a. Manufacturer’s Name – “Optical Cable” – Month/Year of Manufacture – Telephone Handset Symbol – “TDOT ITS” – “144F SM”
8. Contractor shall include in the outer jacket marking the cable sequential length in accordance with the following:
   a. In English units every 2’
   b. Within -1%/+1% of the actual length of the cable
   c. In contrasting color to the cable jacket

d. Marking font height no less than 0.10”

e. On any single length of cable on a reel, the sequential length markings do not run through “00000”

5.2.5 Fiber Optic Splice Fusion

1. Provide fusion splices for splicing of all fibers on the project. Do not provide any other type of fiber splicing.

2. Perform fusion splicing with a fully automatic portable fusion splicer that provides consistent low loss (maximum 0.10db) splices. Splicer shall provide three-axis fiber core alignment using light injection and loss measurement techniques or the splicer shall utilize an active alignment Profile Alignment System. The fusing process shall be automatically controlled. The splicer shall provide splice loss measurements on an integral display, as well as a magnified image of the fiber alignment. The Contractor shall retain ownership of the fusion splicer.

5.2.6 Fiber Optic Connectors

1. Provide fiber optic connectors compliant with this SP725 for all fiber optic infrastructure including but not limited to fiber optic termination cabinets, fiber optic drop panels, and fiber optic patch cords.

2. Provide only factory-installed keyed LC compatible connectors for all fiber optic infrastructure.

3. Provide only factory-installed connectors of a type other than LC when required by the Network Switches. Do not use field-installed mechanical connectors. Do not use adapter couplers to change connector types.

4. Use ceramic ferule connectors factory-installed with a thermal-set heat-cured epoxy and machine polished mating face. Install connectors as per manufacturer application and recommendations, including proper termination to the outer-tubing (900-micron tubing, 3 mm fanout tubing, etc.) required for the application.

5. Use connectors rated for an operating temperature of -40°C to +75°C.

6. Provide connectors that have an installed insertion loss of less than 0.50db, a typical loss of 0.20db, and an optical return loss less than or equal to -45db.

7. Use simplex connectors for all male LC connectors. Provide latching cover for 2 male connectors being used in a duplex configuration. Female couplers may be duplex but must allow simplex mating connectors.

8. Label each fiber position on panels and termination cabinets containing duplex couplers with the port/position ID as shown on the Plans.

9. Provide dust caps for all exposed male connectors and female couplers at all times until permanent connector installation.

10. LC connectors shall comply with TIA/EIA-4750000-C and TIA/EIA-604-10A.

5.2.7 Fiber Optic Termination Cabinet (144 F)

1. Provide fiber optic termination cabinet in communications hubs, field junctions, and the TDOT Regional TMC as shown and quantified on the Plans for full termination of 144 fiber outside plant (OSP) cables.

2. Use termination panels that are fully compatible with all components of the fiber optic infrastructure as specified including but not limited to fiber optic cable, fiber optic fusion splices, and fiber optic connectors.
3. Use rack-mount termination panels designed to fit standard 19” EIA equipment racks.
4. Provide all mounting hardware and supports to mount the termination panels in the locations shown on the Plans.
5. Use termination panels providing 144 fiber connectors and capable of storing 144 fusion splices in splice trays.
6. Use termination panels that integrate the splice trays and connector modules into 1 compartment within 1 panel or house the splice trays and connector modules in separate compartments integrated into 1 panel.
7. Maximum dimensions of a complete termination panel shall be 7 rack units high (12.25”) by 17” deep.
8. Use termination panels with fully enclosed metallic construction and with a protective hinged front cover for the connector ports.
9. Provide cable access on all sides of the enclosed area behind the connector port panel.
10. Provide a unique serial number permanently attached on the enclosure body of each fiber optic termination panel.
11. Provide an outer non-metallic cable strain-relief boot where the fiber optic cable enters the fiber optic termination panel and that secures the cable to the fiber optic termination panel; the strain-relief boot shall fully encircle the cable for a minimum of 2” from the panel’s outer surface.
12. Provide sufficient splice trays for storing 144 fusion splices in 12 splice increments.
13. Provide termination panels with fiber optic connector modules in a 12-fiber configuration of 6 rows of 1 duplex LC connector couplers.
14. Connector modules shall mount vertically in the fiber optic termination front panel.
15. Connector modules shall include clearly legible and permanent labeling of each of the 12-fiber connector couplers and shall be labeled and identified as shown on the Plans.
16. Provide factory-assembled 12-fiber termination interconnect cables (pigtail cables) to be fusion spliced to the outside plant cable and connected to the rear of the connector modules.
    a. Termination interconnect cables shall be all-dielectric single jacketed cable with high tensile strength yarn surrounding 12 individual single mode fibers following EIA/TIA-598B color identification with factory-installed connectors.
17. Provide all incidental and ancillary materials including but not limited to grommets, cable strain relief and routing hardware, blank connector panels, and labeling materials.

5.2.8 Fiber Optic Closure

1. Provide fiber optic closures designed for underground outside plant use for splicing cables in pull boxes.
2. Use fiber optic closures that are impact and corrosion resistant and waterproof when immersed in 20’of water. GR-771 documentation shall be provided for the enclosure.

3. Use fiber optic closures that are fully compatible with all components of the fiber optic infrastructure as specified including but not limited to fiber optic trunk cable, fiber optic drop cable, integrated fiber optic termination unit, and fiber optic fusion splices.
4. Use a cylindrical dome-type splice closure with cable entry at one end only and a sealed single-molded piece dome body of high-density polyethylene or equivalent non-metallic material.
    a. The cable entry end shall be manufactured of a similar material as the dome body and shall seal the closure with flexible thermoplastic rubber or polymer gasket seals.
    b. The cable entry end shall include cable entrance ports that shall seal the cable and port opening with flexible thermoplastic rubber or polymer gasket seals with mechanical compression.
    c. Closures shall be re-enterable and re-sealed without the need for specialized tools or equipment, or the use of any additional parts.
    d. Do not use any heat shrink or caulk/encapsulate materials for sealing the assembled closure or terminated cables.
5. Provide splice closures with maximum outer dimensions of 12” diameter and 24” length.
    a. Splice closures shall provide cable entrance ports for at least 5 fiber optic cables.
    b. At least 2 cable entrance ports shall accommodate cables of at least 0.7” outer diameter.
    c. The closure shall allow for the storage and express of at least 6 unopened buffer tubes.
6. Provide a splice closure with a cable entry end with pre-template cable ports and a split-plate design permitting installation of the closure in mid-span cable segments.
7. The splice closure size shown on the Plans specifies the minimum number of fusion splices to be accommodated by the closure. With the splice closure, provide all materials to accommodate the number of splices specified by the closure size, including splice tray, storage, and organizing materials.

5.2.9 Fiber Optic Drop Panel (12 F)

1. Provide fiber optic drop panels designed for outside plant use for terminating drop cables in equipment cabinets.
2. Use fiber optic drop panels that are fully compatible with all components of the fiber optic infrastructure as specified including but not limited to fiber optic trunk cable, fiber optic splice closures, integrated fiber optic termination unit, fiber optic fusion splices, and fiber optic connectors.
3. Use fiber optic drop panels that are factory manufactured assemblies of fiber optic drop 12-fiber termination interconnect cables (pigtail cables) with factory-installed fiber connectors and integral ruggedized fiber connector enclosures. Pigtail cables to be fusion spliced to the outside plant cable and connected to the rear of the connector modules.
    a. Termination interconnect cables shall be all-dielectric single jacketed cable with high tensile strength yarn surrounding 12 individual single mode fibers following EIA/TIA-598B color identification with factory-installed connectors.
4. Use drop panels with 12 duplex LC fiber connectors.

5. Use ruggedized fiber connector enclosures of thermally stable rigid plastic housings fully potted with a thermally stable epoxy filling that encapsulates the drop cable fanout, fibers, and connector bodies or enclosures made of metal with smooth black powder coat finish.

6. Use permanent labels on the enclosure with contrasting color to identify each connector body by its associated fiber number.

7. Fiber connectors shall be arranged in rows of 1 duplex connector couplers. All fiber connectors shall be arranged on one of the long (vertical) faces of the enclosure.

8. Provide a unique serial number permanently attached on the enclosure body of each drop panel.

9. Provide an outer non-metallic cable strain-relief boot where the drop cable enters the fiber connector enclosure and that secures the cable to the enclosure; the strain-relief boot shall fully encircle the cable for a minimum of 2" from the enclosure's outer surface.

10. Use fiber connector enclosures that are no more than 2" wide and 2" deep and no more than 11" long.

11. Provide a mounting plate that has at least 4 mounting holes near the enclosure's corners that permit horizontal or vertical mounting flush to a panel and are spaced appropriately for vertical mounting to an EIA equipment rack rail using 2 of the mounting holes.

5.2.10 Pre-Terminated Fiber Optic Drop Cable

1. The pre-terminated fiber optic drop cable shall provide the connectivity between the fiber optic splice enclosure and the end of line termination at field cabinets.

2. The pre-terminated fiber optic drop cable shall conform to the following:

   a. The cable shall be of a pre-terminated, rugged, and modular design.

   b. The termination component shall include 12-port, single mode duplex LC connectors.

   c. The termination component shall be constructed out of a rugged molded unit of ABS plastic to ensure that the component is not vulnerable to the elements.

   d. The installed insertion loss shall be less than 0.50db, a typical loss of 0.20db, and have an optical return less than or equal to -45db.

   e. The fiber cable should be a maximum length of 275' including 100' of coiled cable in the adjacent Type E pull box.

   f. The components must be pretested by manufacturer to ensure quality and safety.

   g. The pre-terminated fiber optic drop cable shall be provided with factory testing results.

5.2.11 Cable Labels

1. Provide cable labels that meet the following requirements:

   a. Self-coiling wrap-around type.

   b. PVC or equivalent plastic material with UV and fungus inhibitors.

   c. Base materials and graphics/printing inks/materials designed for underground outside plant use including solvent resistance, abrasion resistance, and water absorption.

   d. Minimum size of 2.5" wide by 2.5" long.

e. Minimum thickness of 0.010”.

f. Orange label body with pre-printed text in bold black block-style font with minimum text height of 0.375”.

2. Pre-print the following text legibly on labels used for all fiber optic trunk cables (FO Cable):

TDOT ITS OPTICAL CABLE

3. On all cable labels, print the text specified above twice on the label with the text of the second image inverted. The result shall be text which “reads correctly” when the label is coiled onto a cable.

5.2.12 Fiber Optic Patch Cords

1. Provide fiber optic patch cords consisting of a length of fiber optic cable terminated on both ends.
2. All patch cords shall be factory preconnectorized assemblies adhering to all applicable cable and fiber specifications stated in this SP725.
3. The length of all patch cords shall be of a specific length for each necessary connection, maintaining minimum bend radius, and with no residual strain at the connector or anywhere on the patch cord itself beyond self-support.
4. All patch cords shall be duplex zip-cord fiber cable with simplex LC connectors, except as otherwise allowed in Section 5.2.6.
    a. The 2 connectors of each end of the patch cord shall be differentiated by distinct colors or have markings on each connector identifying each fiber.
    b. Contractor shall provide sufficient flexibility at each end to disconnect 1 connector without disturbing the other, or to allow swapping of the 2 connectors within the same duplex coupler without disturbing the remainder of the patch cord.
    c. Contractor shall provide strain relief and reinforcement at the point where the duplex cable separates for the individual simplex connectors.
5. Fiber cable shall be 2mm jacketed cable with high tensile strength yarn protecting the inner fiber manufactured into a duplex zip-cord configuration. All Inside Plant patch cords shall meet NEC jacketing requirements.
6. Connector strain relief boots to the outer jacket and strength yarn of fiber patch cords.
7. Use yellow outer jackets for single mode fiber.
8. No splices of any type are allowed within a patch cord assembly.

5.2.13 Fiber Optic Attenuators

1. Fiber optic attenuators shall be fixed in-line.
2. Provide fiber optic attenuator that meet all requirements of Section 5.2.12 for fiber optic patch cords.
3. The fiber in the attenuator shall contain a passive optical attenuator with the following performance characteristics:
    a. Dual-wavelength capability (1310 and 1550nm)

b. Fixed attenuation value of 6dB +/- 15%.

c. Minimum optical return loss 40db

d. Operating temperature range no less than -30ºC to +65ºC

5.2.14 Project Submittal Program Requirements

1. General Requirements

    a. The Contractor shall provide project submittals for all fiber optic infrastructure as required in Section 2.7 of this SP725, including scheduling requirements. The project submittals for fiber optic infrastructure shall include but are not limited to the additional specific requirements in this Subsection.

2. Fiber Optic Installation and Testing Tools

    a. Provide project submittals including manufacturer-recommended operations, maintenance, and calibration procedures for the following equipment:

        i. Fusion splicers

        ii. Cable pulling strain dynamometers and breakaway links

        iii. Cable air jetting/blowing systems

        iv. OTDRs

        v. Optical attenuation testers (light sources and power meters)

    b. Submit documentation and proof of manufacturer-recommended operator training and certification for the following equipment:

        i. Fusion splicers

        ii. Cable air jetting/blowing systems

        iii. OTDRs

        iv. Optical attenuation testers (light sources and power meters)

5.3 Installation Requirements

Contractor shall abide by the installation requirements in the following sections.

5.3.1 General

1. Install all fiber optic infrastructure according to the manufacturer's recommended procedures and specifications.

2. Fiber optic installation tools shall be maintained and calibrated in accordance with the tool manufacturer's recommendations. Tool manufacturer certified calibration documentation shall be provided upon Engineer's request. Installation tools include:

    a. Fusion splicers

    b. Cable pulling strain dynamometers and breakaway links

    c. Cable air jetting/blowing systems

3. Fiber optic installation tools shall be operated only by Contractor personnel who have been trained and certified by the tool manufacturer. Installation tools requiring certified operators include:
    a. Fusion splicers
    b. Cable air jetting/blowing systems
    c. Cable tension dynamometers

5.3.2 Fiber Optic Cable

5.3.2.1 Cable Shipping and Delivery

1. Cable Manufacturer shall package the cable for shipment on factory reels. Each package shall contain only one continuous length of cable. Radius of the reel drum shall not be smaller than the minimum bend radius recommended by the manufacturer for the media. Manufacturer shall construct the packaging to prevent damage to the cable during shipping and handling.
2. Cable Manufacturer shall seal both ends of the cable to prevent the ingress of moisture.
3. Cable Manufacturer shall include with each reel a weatherproof reel tag attached identifying the reel and cable that can be used by the manufacturer to trace the manufacturing history of the cable and the fiber. Include with each cable a cable data sheet containing the following information:
    a. Cable Manufacturer name
    b. Cable part number
    c. Factory order number
    d. Cable length
    e. Factory measured attenuation of each fiber
4. Cable Manufacturer shall cover the cable with a protective and thermal wrap.
5. Cable Manufacturer shall securely fasten the outer end of the cable to the reel head to prevent the cable from becoming loose in transit.
6. Cable Manufacturer shall project the inner end of the cable a minimum of 6.5’ into a slot in the side of the reel or into a housing on the inner slot of the drum, in such a manner to make it available for testing.
7. Cable Manufacturer shall plainly mark each reel to indicate the direction in which it is to be rolled to prevent loosening of the cable on the reel.

5.3.2.2 Cable Handling and Installation

1. See Section 5.3.2.3 for Micro-Cable Handling and Installation Requirements.
2. Do not exceed the maximum recommended pulling tension during installation as specified by the cable manufacturer.
3. Continuously monitor pulling tensions with calibrated measuring devices, such as a strain dynamometer.
4. Protect all pulled installations with calibrated breakaway links.

5. Do not violate the minimum recommended bend radius during installation as specified by the cable manufacturer. Unless the manufacturer's recommendations are more stringent, use the following guidelines for minimum bend radius:
    a. 20 X Cable Diameter Short Term – During Installation
    b. 10 X Cable Diameter Long Term – Installed
6. Before cable installation, carefully inspect the cable reels and reel stands for imperfections or faults such as nails that might cause damage to the cable as it is unreeled.
7. Take all necessary precautions to protect reeled cable from vandals or other sources of damage while unattended. Any damage to reeled cable or the reel itself shall necessitate replacement of the entire cable section at Contractor's expense.
8. Whenever unreeled cable is placed on the pavement or surface above a pull box, Contractor shall provide means of preventing vehicular or pedestrian traffic through the area in accordance with the approved Maintenance of Traffic provisions.
9. Keep the cable continuous throughout the pull. Cable breaks and reel end splices are permitted only as shown on the Plans.
10. Where a cable ends in an underground fiber optic splice closure, Contractor shall secure and store all unused fibers and buffer tubes in splice trays in preparation for future reel end splicing and continuation.

5.3.2.3 Micro-Cable Handling and Installation

1. Micro-Cable shall only be installed within Micro-Conduit.
2. Micro-Cable shall be installed by blowing into the Micro-Conduit. Do not exceed the maximum air assisted install speed during installation as specified by the cable manufacturer.
3. Continuously monitor air assisted install speed with calibrated measuring devices.
4. Do not violate the minimum recommended bend radius during installation as specified by the cable manufacturer. Unless the manufacturer's recommendations are more stringent, use the following guidelines for minimum bend radius:
    a. 20 X Cable Diameter Short Term – During Installation
    b. 15 X Cable Diameter Long Term – Installed for Micro-Cable
5. Before cable installation, carefully inspect the cable reels and reel stands for imperfections or faults such as nails that might cause damage to the cable as it is unreeled.
6. Take all necessary precautions to protect reeled cable from vandals or other sources of damage while unattended. Any damage to reeled cable or the reel itself shall necessitate replacement of the entire cable section at Contractor's expense.
7. Whenever unreeled cable is placed on the pavement or surface above a pull box, Contractor shall provide means of preventing vehicular or pedestrian traffic through the area in accordance with the approved Maintenance of Traffic provisions.
8. Keep the cable continuous throughout the pull. Cable breaks and reel end splices are permitted only as shown on the Plans.

9. Where a cable ends in an underground fiber optic splice closure, Contractor shall secure and store all unused fibers and buffer tubes in splice trays in preparation for future reel end splicing and continuation.

5.3.2.4 Cable Storage

1. Safely store all cable to minimize susceptibility to damage.
    a. Maintain proper bend radius, both short and long term, during cable storage.
    b. Storage coils shall be neat in even length coils, with no cross over or tangling.
    c. Storage coils of different cables shall be kept separate except when the cables terminate in the same splice closure.
    d. Storage coils shall be secured to cable racking hardware with tie wraps, Velcro straps, or non-metallic cable straps with locking/buckling mechanism.
    e. Do not use adhesive or self-adhering tapes, metal wires and straps, or rope/cord.
2. Unless otherwise noted on the Plans, the following are the requirements for cable slack storage:
    a. Trunk fiber optic cable in Type "D" Pull Box – 50'
    b. Trunk fiber optic cable in Type "E" Pull Box – 200'
    c. Trunk fiber optic cable in Structure Mounted Pull Box – 10'
    d. Trunk fiber optic cable in pad-mounted cabinet – 25'
    e. Trunk fiber optic cable in pole-mounted cabinet – 25'
    f. Drop fiber optic cable in Type "D" Pull Box – 25'
    g. Drop fiber optic cable in Type "E" Pull Box – 100'
    h. Drop fiber optic cable in Structure Mounted Pull Box – 10'
    i. Drop fiber optic cable in pad-mounted cabinet – 25'
    j. Drop fiber optic cable in pole-mounted cabinet – 25'

5.3.3 Pre-Terminated Fiber Optic Drop Cable

1. Follow installation procedures detailed in Section 5.3.2 of this SP725.
2. Secure pre-terminated fiber optic drop cable to inner wall of equipment cabinet in an accessible location.
3. Install dust covers on all connector terminations.
4. Coil 100' of cable in the adjacent Type E pull box.

5.3.4 Fiber Optic Closure

1. Install fiber optic closures where, and of the size, shown on the Plans. Install splice closures in the center ± 3' of the entire length of stored cable coils or install at the end of cables that terminate in the pull box.

2. Store FO closures and cable coils on the pull box cable rack hooks. Keep all closures and cable coils off the bottom of the pull box. Secure closures and/or cable coils as needed to hold them in place.

5.3.5 Fiber Optic Splice Fusion

1. Perform fusion splicing of all fiber optic splices as shown on the Plans in the locations shown.
2. Perform fusion splicing only in enclosed spaces such as splice trailers or tents specifically intended for this operation.
3. Completed fusion splices shall have no more than 0.10dB optical loss as measured in accordance with Section 5.2.5.
4. Adequately protect all fusion splices in splice trays in a splice closure or termination cabinet. Provide the splice with strain relief and protection of the stripped fiber splice in a manner recommended by the fiber and the splice tray manufacturers.
5. Use fusion splice protectors of a heat shrink tubing that protects the splice and extends over the fiber coating. Splice protectors shall be compatible with and as recommended by the fiber and the splice tray manufacturers.
6. No bare fiber may be exposed.

5.3.6 Fiber Optic Termination Cabinet (144 F)

1. Install only 1 cable per termination panel, including within the separate splice tray storage compartment if so equipped. Contractor shall install the connector modules for fibers 1 through 144 as shown on the Plans. Equip any remaining unused connector module slots with blank panels.
2. Install all fibers, buffer tubes, and cables following minimum internal and external bend radius, proper management, routing, fastening and protection, and with no residual strain on any connector, fiber, buffer tube or cable.
3. Install 1 cable buffer tube to 1 termination panel interconnect cable, matching fiber to fiber. Keep all fibers of the outside plant cable buffer tube and their corresponding termination-interconnect cables complete within the same splice tray.
4. Label the front and rear of the termination panels with the trunk cable segment ID of the cable terminated within; use permanent clearly legible labels with minimum 0.5” text height.
5. Label each end of termination panel interconnect cables to identify the 12 trunk cable fibers/buffer tube connected; use permanent overlapping cable labels with clearly legible text.
6. Install dust covers on all connector terminations.

5.3.7 Fiber Optic Drop Panel (12 F)

1. Prior to factory manufacturing of fiber optic drop panels, Contractor shall verify the final installed location of all portions of each drop cable route from the splice closure to the equipment cabinet (including the cabinet location, all conduit and pull boxes, and the splice closure location) to determine the required length of drop cable, including all splice closure and storage coils, to be factory manufactured with each drop panel. Do not use the Plans quantity for determining the drop cable length to be factory manufactured.
2. If using factory installed connectorized fanout kit, splice all 12 fibers into the drop cable.

3. Using the drop panel mounting plate, Contractor shall install drop panels on the side panel or equipment cabinets. Mount the fiber optic drop panel with the connectors horizontal or facing downward and route the drop cable up or down as necessary. Route and secure the drop cable such that it is fully strain-relieved, does not violate the manufacturer's recommended bending radius, and does not interfere with the operation of or access to any cabinet equipment or electrical components.

4. Contractor shall place 1 copy of the manufacturer test documentation in the equipment cabinet, where the drop panel is installed and submit an electronic copy to the Engineer.

5.3.8 Cable Labels

1. Install cable labels on all trunk cables. Clean the installed cable of all dirt and grease before applying any label.

2. Label all cables in or at every location where the cable is exposed outside of a conduit, innerduct or pole, using the cable IDs for trunk cables. As a minimum, install cable labels in the following locations:

    a. Within 12" of every cable entry to a pull box, equipment cabinet, communications hub, or the TDOT Regional TMC.

    b. Within 12" of the exterior entry point of every fiber optic splice closure, termination cabinet, and drop panel.

    c. Every 30' for the entire length of cable in any storage coil in pull boxes.

5.3.9 Fiber Optic Patch Cords

1. Install fiber optic patch cords to connect all electronic equipment with the fiber optic infrastructure. Follow port assignments as shown on the Plans.

2. Install fiber optic patch cords to connect all active optical paths between fiber optic termination cabinets in communications hubs as shown on the Plans.

3. Neatly route and dress all patch cords to the connected devices and within cable management facilities.

5.3.10 Fiber Optic Attenuators

1. Provide fiber optic attenuators in accordance with Section 5.2.13.

5.4 Testing Requirements

5.4.1 General Requirements

1. The Contractor shall conduct a project testing program for all materials specified in this section and as required in Section 2.5 of this SP725.

2. All test results shall confirm physical and performance compliance with this SP725.

3. All test results shall confirm physical and performance compliance with this SP725 including optical fibers and fusion splices. The total loss in each test segment shall not exceed the calculated allowable loss based on the formulas listed below.

    a. 1310 nm wavelength

i. (X * 0.35) + (Y * 0.1) + (Z * 0.5) = calculated loss (dB)

1. X = span length (km)
2. Y = number of fusion splices within the span (ea)
3. Z = number of connectors within the span (ea)

b. 1550 nm wavelength

i. (X * 0.25) + (Y * 0.1) + (Z * 0.5) = calculated loss (dB)

1. Same variables as above

If the Contractor is unable to achieve the calculated allowable loss after at least 2 attempts of correction, alternative resolution can be discussed with the Engineer.

4. In addition to the notification requirements of Section 2.4, Contractor shall provide the tentative date, time, and location of fiber optic infrastructure testing no less than 7 days in advance of the test. Provide confirmed date, time, and location of fiber optic infrastructure testing no less than 48 hours before conducting the test.
5. Provide test results documentation in electronic format. Electronic format shall be readable in Microsoft Excel or other approved application.
6. Provide all test results in English units of measure of length.
7. The Contractor shall submit all test results documentation to the Engineer within 7 calendar days of completion of the tests. The Engineer will review test documentation in accordance with the Submittal Review Process in Section 2.7. Test documentation shall include:

a. Cable & Fiber Identification

i. Cable & Fiber ID and Location – Physical location (device ID and station number of FO Termination Cabinet, FO Drop Panel, or cable end FO closure), fiber number, and trunk or drop cable ID for both the beginning and end point.

ii. Operator Name

iii. Engineer's Representative

iv. Date & Time

b. Setup and Test Conditions Parameters

i. Launch Cable Length

ii. Wavelength

iii. Pulse width Optical Time Domain Reflectometer (OTDR)

iv. Refractory index (OTDR)

v. Range (OTDR)

vi. Scale (OTDR)

vii. Ambient Temperature

c. Test Results for OTDR Test (each direction and averaged)

i. Total Fiber Trace (miles)

ii. Splice Loss/Gain (dB)

iii. Events > 0.05db

iv. Measured Length (Cable Marking)

v. Total Length (OTDR Measurement)

d. Test Results for Attenuation Test (each direction and averaged)

i. Measured Cable Length (Cable Marking)

ii. Total Length (OTDR Measurement from OTDR Test)

iii. Number of Splices (Determined from as-builts)

iv. Total Link Attenuation

8. Fiber optic testing tools shall be maintained and calibrated in accordance with the tool manufacturer's recommendations. Tool manufacturer certified calibration documentation shall be provided upon Engineer's request. Testing tools include:

   a. OTDRs

   b. Optical attenuation testers (light sources and power meters)

9. Fiber optic testing tools shall be operated only by Contractor personnel who have been trained and certified by the tool manufacturer. Testing tools requiring certified operators include:

   a. OTDRs

   b. Optical attenuation testers (light sources and power meters)

5.4.2 Factory Acceptance Test

FAT is not required for Fiber Optic Infrastructure.

5.4.3 Bench Test Component

BTC shall be performed in the presence of the Engineer. The BTC shall include the following tests and inspections:

1. Contractor shall test each connectorized fiber in the fiber optic drop panel to demonstrate compliance with all requirements for cables and connectors as detailed in this SP725. Include in the test documentation the site number where the drop panel is to be installed, the serial number of the drop panel, the drop cable sequential length markings at each end of the drop cable, and the total drop cable distance.

2. Contractor shall test all fiber optic cables prior to any cable removal from the shipping reels. Each cable reel delivered to the job site shall be tested. The testing shall include:

   a. A visual inspection of each cable and reel

   b. An OTDR Test and documentation, as required in the SAT below, for 3 randomly selected fibers from each buffer tube.

c. An Optical Attenuation Test is not required. If the Contractor decides to perform one for their own protection, said test should be documented and provided to the Engineer.

5.4.4 Bench Test System

BTS shall be performed in the presence of the Engineer. BTS of fiber optic components will be performed in conjunction with other components in this SP725 that are reliant upon the Fiber Optic Infrastructure.

5.4.5 Stand Alone Site Test

SAT shall be performed in the presence of the Engineer. The SAT shall include the following tests and inspections:

1. Verify all components have been installed per manufacturer requirements.
2. Verify the Fiber Optic Infrastructure has no internal or external damage.
3. Test all Fiber Optic Infrastructure on this project after field installation is complete including but not limited to all splicing and terminations.
4. Test each fiber in each fiber optic cable including OTDR Tests and Optical Attenuation Tests. The testing shall consist of all fiber optic cables and drop cables from termination point to termination point including:
    a. Fibers from Fiber Optic Termination Cabinet to Fiber Optic Termination Cabinet.
    b. Fibers from Fiber Optic Termination Cabinet to Fiber Optic Drop Panel.
    c. Fibers from Fiber Optic Drop Panel to Fiber Optic Drop Panel.
    d. Fibers from Fiber Optic Termination Cabinet to the end of the cable run in the last Fiber Optic Closure. Fiber that is not terminated shall be temporarily terminated in order to perform testing.
5. The OTDR Testing shall conform to the following requirements:
    a. OTDR Test shall be conducted using the standard operating procedure and recommended materials as defined by the manufacturer of the test equipment.
    b. A factory patch cord (“launch cable”) of a length equal to the “dead zone” of the OTDR to connect the OTDR and the fiber under test shall be used. The launch cable shall not be greater than 820 feet in length.
    c. Bi-directional OTDR Tests for each fiber shall be conducted with the bi-directional averages calculated and used as the result.
    d. All tests shall be conducted at 1310 nm and 1550 nm for single mode cable.
6. The Optical Attenuation Testing shall conform to the following requirements:
    a. Optical Attenuation Test shall be conducted using the standard operating procedure and recommended materials as defined by the manufacturer of the test equipment.
    b. Bi-directional Optical Attenuation Tests for each fiber shall be conducted with the bi-directional averages calculated and used as the result.
    c. All tests shall be conducted at 1310 nm and 1550 nm for single mode cable.

5.5 Warranty

All materials specified in this section shall carry a minimum one-year manufacturer's warranty from the date of Final Acceptance against any imperfections in workmanship or materials. Warranties shall cover complete replacement at no charge for the equipment. Warranties shall be transferred to TDOT upon Final Acceptance of the project as per the requirements in Section 2.6 of this specification.

5.6 Method of Measurement

5.6.1 Fiber Optic Testing

Payment for the testing of new fiber optic shall be included in the cost of the Fiber Optic Cable. Payment for the testing of any existing fiber optic shall be included in the cost of Network Integration.

5.6.2 Fiber Optic Cable (144 F)

Single Mode Fiber Optic Cable (144 F) will be measured in units of linear feet and paid for at the contract price per linear feet. The bid price shall include the length in feet of actual cable installed as measured from the cable sequential length markings, cable labels, patch cords, ancillary and incidental materials, mounting brackets, testing, documentation, and all labor and equipment necessary to complete the work. No measurement for payment will be made for cable storage amounts in excess of that required in this SP725 or the Plans. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

5.6.3 Fiber Optic Micro-Cable (144 F)

Single Mode Fiber Optic Micro-Cable (144 F) will be measured in units of linear feet and paid for at the contract price per linear feet. The bid price shall include the length in feet of actual cable installed as measured from the cable sequential length markings, cable labels, patch cords, ancillary and incidental materials, mounting brackets, testing, documentation, and all labor and equipment necessary to complete the work. No measurement for payment will be made for cable storage amounts in excess of that required in this SP725 or the Plans. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

5.6.4 Fiber Optic Drop Cable (12 F)

Single Mode Fiber Optic Drop Cable (12 F) will be measured in units of linear feet and paid for at the contract price per linear feet. The bid price shall include the length in feet of actual cable installed as measured from the cable sequential length markings, cable labels, patch cords, ancillary and incidental materials, testing, documentation, and all labor and equipment necessary to complete the work. No measurement for payment will be made for cable storage amounts in excess of that required in this SP725 or the Plans. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

5.6.5 Fiber Optic Closure (12 F)

Fiber Optic Closure (12 F) will be measured in units of each and paid for at the contract price per each. The bid price shall include but not be limited to cable labels, 1 splice tray, mounting hardware, ancillary and incidental materials, testing, documentation, and all labor, tools, materials, equipment, and incidentals necessary to complete the work.

5.6.6 Fiber Optic Closure (144 F)

Fiber Optic Closure (144 F) will be measured in units of each and paid for at the contract price per each. The bid price shall include but not be limited to cable labels, 12 splice trays, mounting hardware, ancillary and incidental materials, testing, documentation, and all labor, tools, materials, equipment, and incidentals necessary to complete the work.

5.6.7 Fiber Optic Splice Fusion

Fiber Optic Splice Fusion will be measured in units of each splice and paid for at the contract price per each individual splice. The bid price shall include but not be limited to all ancillary and incidental materials, testing, documentation, and all labor and equipment necessary to complete the work. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

5.6.8 Fiber Optic Termination Cabinet (144 F)

Fiber Optic Termination Cabinet (144 F) will be measured in units of each and paid for at the contract price per each and shall include but not be limited to rack-mounted fiber optic cabinet, fiber optic connectors, cable labels, patch cords, splice tray, splices, mounting hardware, ancillary and incidental materials, testing, documentation, and all labor, tools, materials, equipment, and incidentals necessary to complete the work.

5.6.9 Fiber Optic Drop Panel (12 F)

Fiber Optic Drop Panel (12 F) will be measured in units of each and paid for at the contract price per each. The bid price shall include but not be limited to fiber optic drop panel, fiber optic connectors, cable labels, patch cords, splicing of the fiber optic drop cable into the fiber optic drop panel, mounting hardware, ancillary and incidental materials, testing, documentation, and all labor, tools, materials, equipment, and incidentals necessary to complete the work.

5.6.10 Pre-Terminated Fiber Optic Drop Cable

Pre-Terminated Fiber Optic Drop Cable will be measured in units of each and paid for under the Fiber Optic Drop Panel (12 F) pay item at the contract price per each. The bid price shall include but not limited to cable lengths up to 275’, cable labels, factory terminations, integrated patch panel, mounting hardware, ancillary and incidental materials, testing, documentation, and all labor, tools, materials, equipment, and incidentals necessary to complete the work.

5.6.11 Fiber Optic Connectors

Fiber Optic Connectors are incidental to other items and will not be measured separately for payment.

5.6.12 Cable Labels

Cable Labels are incidental to other items and will not be measured separately for payment.

5.6.13 Fiber Optic Patch Cords

Fiber Optic Patch Cords are incidental to other items and will not be measured separately for payment.

5.6.14 Fiber Optic Attenuators

Fiber Optic Attenuators are incidental to other items and will not be measured separately for payment.

5.7 Payment

The contract unit price shall be full compensation for all work specified in this section.

Payment will be made under:

Item No.	Description	Unit
725-23.02	FIBER OPTIC TESTING	LS
725-23.16	FIBER OPTIC CABLE (144 F)	LF
725-23.17	FIBER OPTIC MICRO-CABLE (144 F)	LF
725-23.21	FIBER OPTIC DROP CABLE (12 F)	LF
725-23.26	FIBER OPTIC CLOSURE (12 F)	EA
725-23.27	FIBER OPTIC CLOSURE (144 F)	EA
725-23.28	FIBER OPTIC SPLICE FUSION	EA
725-23.30	FIBER OPTIC TERMINATION CABINET (144 F)	EA
725-23.31	FIBER OPTIC DROP PANEL (12 F)	EA

Fiber Optic Infrastructure, except as specified below, will be paid per linear foot or per each, as applicable, as follows:

1. 25% of the contract unit price upon delivery and satisfactory completion of Bench Test Component test.
2. Additional 35% of the contract unit price for complete installation of cables.
3. Additional 30% of the contract unit price for satisfactory completion of Stand Alone Site Test testing and documenting of all fibers in any lineal foot and in each splice or termination/connectorization location, and submission of and acceptance of all test documentation.
4. Final 10% of the contract unit price upon Final System Acceptance

Fiber optic splices, fusion, will be paid per each as follows:

1. 60% of the contract unit price upon completion of the splice.
2. Additional 30% of the contract unit price for satisfactory completion of Stand Alone Site Test and documenting of all fibers in any lineal foot and in each splice or termination/connectorization location, and submission of and acceptance of all test documentation.
3. Final 10% of the contract unit price upon Final System Acceptance.

Fiber optic testing will be paid at the lump sum price upon completion of testing as approved by the Engineer.

6 WIRELESS ETHERNET RADIO COMMUNICATIONS

6.1 Description

This section specifies the minimum requirements for the wireless ethernet radio communications to be furnished and installed. The radio will provide one end of the wireless communications link for locations as shown on the Plans. The work includes complete Federal Communications Commission (FCC) licensing services, where required, and all documentation necessary to operate and maintain the equipment. The wireless system shall operate in the FCC unlicensed (license-exempt) ISM band of 2.4 GHz or 5 GHz. The wireless devices shall be FCC certified. The FCC identification number shall be displayed on an external label and all system devices shall operate within their FCC frequency allocation. The radio link shall transmit data and multicast video across the link with minimal latency in the data transmitted across the link.

The radio equipment in this contract includes the following type:

1. Radio & Antenna (Type A): This is a CFR47 Part 15 License Exempt Point-to-Point (PTP) Wireless Ethernet Link that is used to support video and data communications.

2. Radio & Antenna (Type B): This is a CFR47 Part 15 License Exempt Point-to-Multipoint (PMP) Wireless Ethernet Link that is used to support video and data communications.

6.2 Materials

Contractor shall provide all materials according to the requirements in the following sections.

All equipment shall be new and constructed using the highest quality, commercially available components and techniques to assure high reliability and minimum maintenance. Prior to installation, the Contractor shall submit and receive approval from the Engineer on a complete set of shop drawings of all the equipment and components listed within this Special Provision and included as part of the installation.

The Contractor is responsible for the propagation study and assessment of the wireless link prior to submitting the product and desired frequency following the International Telecommunication Union (ITU) recommendation ITU-R P.530-17. The Contractor shall perform this study with industry approved test equipment and submit the study to the Engineer for review and approval. Propagation study shall confirm a wireless link path availability of 99.99% for each wireless link.

6.2.1 Point-to-Point and Point-to-Multipoint Wireless Ethernet Radio and Antenna

1. The radio shall directly interface with the field 10/100/1000 Ethernet Gigabit port at the radio field sites indicated on the Plans. Software to remotely control the radios will be provided and included in the price of the radios. No additional payment will be made for licensing (where required as indicated on the Plans), configuration and troubleshooting software.

2. The radios shall be a truly Time Division Duplex (TDD) or Frequency Division Duplexing (FDD) point to point microwave system that delivers the Full Duplex data rate link at a bandwidth and distance specified for each link as shown on the Plans. The link shall supply very low latency of less than 250µsec over long distances.

3. Security

    a. Tiered security layering
    b. Use of AES 256-bit Encryption
    c. Federal Information Processing Standard Publication 197 (FIPS 197) for symmetric encryption
    d. Other Security functions are preferred HTTPS, SNMPv3, SFTP
    e. Security Log

4. Network Features:

    a. Bridging-Q in Q IEEE 802.1ad
    b. Layer 1 Link Bonding IEEE 802.1AX
    c. Syslog
    d. SyncE or IEEE1588 Timing
    e. IPv6
    f. NPTV3 and V4

5. Network QoS:

    a. Packet Classification
    b. Scheduling
    c. MTU sizes >9200Bytes
    d. Y.1731 Ethernet OAM
    e. Y.1731 Ethernet Bandwidth Notification (ETH-BN)
    f. WRED

6. The radio shall adhere to the 802.1Q Management VLAN with Transparent, Access and Trunk mode.

7. Wired Ethernet Interface

    a. 2 ports (minimum)
        a. 1 Port RJ-45 - Electric Multi-Rate 1/2.5/10 Gbps traffic interface/PoE
        b. 1 Out of band management port
    b. Industrial Weatherproof Ethernet Connector
    c. Category 6 Industrial outdoor rated cable

8. Channel Size of 5 MHz-40 MHz, Based on the regulations defined in CFR47 Part15

9. Management

    a. Telnet
    b. SSH
    c. SNMPv3
    d. SSL
    e. Web GUI

10. Wireless Modulation shall utilize BPSK, up to 256 QAM , with support for Enhanced MIMO techniques where applicable.

11. Radio Transmit Power

    a. Up to 28 dBm

12. Antenna Configurations

    a. Wireless Ethernet Radio shall be capable of direct mounting to an external antenna up to 6FT in size. Integrated high-gain antennas are acceptable for Point-to-Point radios.

13. Electrical

    a. <30 Watts typical
    b. POE power injector with PoE Surge Arrestor and power cords to allow the radio to be powered from a minimum 24-volt power supply. Provide any required PoE or PoE+ devices that are 802.3af or 802.3at compliant, meeting the power requirements of the radio equipment.

14. Environmental

    a. Hardened
    b. Operating Temperature: -40°C to 60°C
    c. Operating Humidity: 0% to 100% relative humidity, non- condensing
    d. 125 MPH wind loading
    e. Meet or exceed IP67 requirements
    f. Mean Time Between Failure shall not be less than 80,000 hours.

6.2.2 Cabling

1. Provide outdoor-rated Category 6 cables for integrated radio/antenna sites.

2. Provide outdoor-rated, shielded Category 6 cabling from the PoE injector to the Wireless Ethernet Radio meeting the following minimum requirements:

    a. Comply with TIA-568-C.2 standard.

    b. Comply with ICEA S-56-434 standard or equivalent industry standard as approved by the Engineer for communications cables for outdoor use including weathertight, outdoor CMX UV-rated, abrasion-resistant jacket.

    c. Provide cable that is UL 444 sunlight resistant listed.

    d. Provide insulated No. 22 to 23 AWG, solid bare copper conductors with polyolefin insulation, arranged in four color-coded shielded twisted-pairs with drain wire incorporating a cross-web separator design.

    e. Provide modular IP67-rated shielded RJ-45 8P8C male push-pull connectors with eight-position non-keyed and eight gold anodized pins or other Ethernet-compatible locking weathertight connector.

6.2.3 Surge Protection

1. Category 6 Ethernet PoE Surge Protection

a. Provide SPD that is listed per UL 497B.

b. Comply with TIA-568-B.

c. Comply with IEEE 802.3af or IEEE 802.3at as required.

d. Support 10Base-T, 100Base-T, and 1000Base-T transmission speeds.

e. Provide a peak surge current rating (Imax) of a minimum of 10 kA (8/20 µs waveform).

f. Provide a clamping voltage of up to 90V ±20% for L-G and 20V ±20% for L-L

g. Provide surge protection for all connector pins.

h. Provide input and output connections with shielded RJ-45 connectors.

i. Provide an in-line, series-connected configuration.

j. Provide system capable of being either wall/panel or DIN-rail mounted.

k. Provide an SPD that is constructed of aluminum metal housing.

l. Provide hardware and materials to bond SPDs to the field cabinet ground bus bar.

6.2.4 Grounding

The contractor shall install a grounding system for the Wireless Ethernet Radio. The grounding system shall be designed to meet the following:

1. Provide a complete Wireless Ethernet Radio grounding and bonding system.
2. The grounding and bonding system materials and installation given in this SP are a minimum. Design and shall be installed to provide a maximum ground impedance of 5 ohms for the Wireless Ethernet Radio.

6.3 Installation Requirements

1. Before submitting shop drawings for poles or Wireless Ethernet Radio units and Antennas, the Contractor shall verify all wireless links for proper frequency, height and line of sight, based on the plan design, specifications, and accepted propagation study. Should the Contractor encounter interference in the path, or immoveable objects that interfere with the wireless path, the Contractor shall prepare and submit a solution for review and acceptance by the Engineer.

2. The Contractor shall furnish, install, configure, and integrate Wireless Ethernet Radio units between sites shown on the Plans. Antenna alignment shall be performed in accordance with the manufacturer's installation requirements. Testing of the link and attached Ethernet switches shall occur prior to the cut over of all existing devices to the radio link.

3. The Contractor shall furnish and install all supports, clamps, cables, connections and other materials to secure the Wireless Ethernet Radio and Antenna at the selected locations for a complete installation. All cables shall be permanently labeled at all access points. Each cable shall have a unique identifier. Label identification with unique identifier shall be stamped or

engraved on metal tags, or neatly and legibly lettered with permanent ink on nylon tags. Cables shall be labeled immediately upon installation.

4. The type of mounting poles to be supplied and the location of their installation shall be as depicted on the Plans unless otherwise approved by the Engineer.

5. If a steel or concrete monopole is used as the mounting pole, any cabling run between the top of the pole and base of pole or cabinet conduit shall be run within conduit inside the pole to avoid conflicts with lowering device equipment, where present.

6. Contractor shall obtain permission from TDOT Regional TMC IT in advance of any work being performed to access existing sites that call for new Wireless Ethernet Radio equipment on the Plans.

7. If any network or existing device downtime is anticipated due to the installation of or switchover to the wireless network, the Contractor shall coordinate the downtime at least 2 weeks in advance of the planned outage with TDOT Regional TMC IT.

8. The Contractor shall coordinate with the TDOT Network Administrator representative for all necessary configuration of the radio link. The radio link shall be configured to operate in the current network configuration and shall allow all new and existing video and data to transmit across the link with no degradation. After coordinating with the TDOT Network Administrator representative, the Contractor shall submit the network configuration to the TDOT Network Administrator representative and Engineer for approval.

9. Contractor shall connect the Wireless Ethernet Radio to the L2 or L3 ethernet switch in the equipment cabinet via a Category 6 cable.

10. Contractor shall connect the Wireless Ethernet Radio and/or PoE injector to the cabinet UPS to maintain continuous, conditioned power to the radio and antenna.

6.4 Testing Requirements

6.4.1 General Requirements

1. The Contractor shall conduct a project testing program for Wireless Communications equipment as required in Section 2.5 of this SP725.

2. All test results shall confirm physical and performance compliance with this SP725.

3. The Contractor shall submit all test results documentation to the Engineer within 7 calendar days of completion of the tests. The Engineer will review test documentation in accordance with the Submittal Review Process in Section 2.7.

4. Payment for all testing is included in the cost of the Wireless Ethernet Radio Communications.

5. The Contractor shall provide all equipment, such as but not limited to volt/ohm meters and laptop, to test installed systems at their own expense.

6.4.2 Factory Acceptance Test

FAT is not required for Wireless Communications.

6.4.3 Bench Test Component

BTC shall be performed in the presence of the Engineer. The BTC shall include the following tests and inspections:

1. Verify the Radio and Antenna has no internal or external damage.

2. Test all Wireless Ethernet Radio functionality using manufacturer software.

6.4.4 Bench Test System

BTS shall be performed in the presence of the Engineer. BTS of Wireless Ethernet Radio Communications equipment will be performed in conjunction with other components in this SP725 that are reliant upon the Wireless Ethernet Radio equipment for communications. The test shall include demonstration of manufacturer's link speed and number of simultaneous links without signal degradation.

6.4.5 Stand Alone Site Test

SAT shall be performed in the presence of the Engineer. The SAT shall include the following tests and inspections:

1. Verify FCC approval and licensure has been obtained for the site link, where required as indicated on the Plans.

2. Verify all components have been installed per manufacturer requirements and this SP725.

3. Verify all items have been attached properly (as per manufacturer recommendations and the Plans) to each other and to any applicable structures.

4. Verify the Wireless Ethernet Radio equipment has no internal or external damage.

5. Verify that security bolts are in place and properly fastened to covers.

6. Verify the antenna is properly aligned with the target antenna with direct line of sight.

7. Verify the Wireless Ethernet Radio equipment has been properly connected to the UPS for continuous, conditioned power.

8. Verify all links' receive signal strength and bit error rate reflect the designed values from the RF engineering study.

9. Demonstrate that the manufacturer's link speed and number of simultaneous links is achieved without signal degradation.

10. Verify all grounding, lightning protection, and surge projection systems are in place and properly installed.

11. A ground resistance test shall be performed at each Wireless Ethernet Radio site. Ground resistance tests shall be conducted using a 3- or 4-Point Fall-of-Potential method defined by IEEE Standard #81 or other industry approved test method. Each grounding electrode shall be tested prior to connection to the ground system. Resistance-to-Ground of the ground system shall not exceed 5 ohms. Ground resistance measurements shall be conducted in normally dry conditions not less than 48 hours after the latest rainfall. All ground resistance tests shall be conducted in the

presence of the Engineer. The Contractor shall document all test recordings and provide a copy of all test reports to the Engineer upon completion in accordance with the Project Submittal Program Requirements in Section 2.7.

6.5 Warranty

All materials specified in this section shall carry a minimum one-year manufacturer's warranty from the date of Final Acceptance against any imperfections in workmanship or materials. Warranties shall cover complete replacement at no charge for the equipment. Warranties shall be transferred to TDOT upon Final Acceptance of the project as per the requirements in Section 2.6 of this specification.

6.6 Method of Measurement

Wireless Communication will be measured in units of each and paid for at the contract price per each, but shall act as one seamless pair of point to point radios. The prices bid shall include furnishing, installing, and testing of the unit and shall include the radio transceiver/ modem unit, mounting hardware, RF coaxial cables, ethernet cables, power cables, connectors, power control unit, surge suppressors, antenna with mounting accessories, SWR/wattmeter test equipment and all work, equipment and appurtenances as required to provide a fully functioning radio and antenna. The price bid shall also include all configuration and system software and documentation including shop drawings, operations and maintenance manuals, wiring diagrams, block diagrams, and other materials necessary to document the operation of the unit. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

6.6.1 Radio and Antenna (Type A)

Radio & Antenna (Type A) will be measured in units of each and paid for at the contract price per each unit furnished, installed, and accepted. All radio transceiver/ modem unit, mounting hardware, RF coaxial or Ethernet cables and connectors, power control unit or power injectors, surge suppressors, antenna with mounting accessories, configuration, system software, and testing or other equipment, labor or materials required to integrate the wireless radio and antenna will be considered incidental and not be paid for separately. The contract price shall also include all documentation including as-built drawings, operations and maintenance manuals, wiring diagrams, block diagrams, and other materials necessary to document the operation of the unit.

6.6.2 Radio and Antenna (Type B)

Radio & Antenna (Type B) will be measured in units of each and paid for at the contract price per each unit furnished, installed, and accepted. All radio transceiver/ modem unit, mounting hardware, RF coaxial or Ethernet cables and connectors, power control unit or power injectors, surge suppressors, antenna with mounting accessories, configuration, system software, and testing or other equipment, labor or materials required to integrate the wireless radio and antenna will be considered incidental and not be paid for separately. The contract price shall also include all documentation including as-built drawings, operations and maintenance manuals, wiring diagrams, block diagrams, and other materials necessary to document the operation of the unit.

6.6.3 Radio and Antenna (Description)

Radio & Antenna (Description) will be measured in units of each and paid for at the contract price per each unit furnished, installed, and accepted. All radio transceiver/ modem unit, mounting hardware, RF coaxial or Ethernet cables and connectors, power control unit or power injectors, surge suppressors, antenna with mounting accessories, configuration, system software, and testing or other equipment, labor or materials required to integrate the wireless radio and antenna will be considered incidental and not be paid for separately. The contract price shall also include all documentation including as-built drawings, operations and maintenance manuals, wiring diagrams, block diagrams, and other materials necessary to document the operation of the unit.

6.7 Payment

The contract unit price shall be full compensation for all work specified in this section.

Payment will be made under:

Item No.	Description	Unit
725-20.81	RADIO AND ANTENNA (TYPE A)	EA
725-20.82	RADIO AND ANTENNA (TYPE B)	EA
725-20.84	RADIO AND ANTENNA (DESCRIPTION)	EA

Wireless Communication will be paid per each as follows:

1. 50% of the contract unit price upon approval of Bench Test Component, Bench Test System, and Pre-installation test results.
2. Additional 20% of the contract unit price upon approval of Stand Alone Site Test results.
3. Additional 20% of the contract unit price upon approval of Conditional System Acceptance Test results.
4. Final 10% of the contract unit price upon Final System Acceptance.

7 ELECTRICAL EQUIPMENT

7.1 Description

This section describes the minimum requirements for the electrical systems to be furnished and installed on this project. The work required includes all materials, labor, coordination, auxiliaries, and incidentals necessary to furnish, install, and test a complete electrical system as indicated on drawings and as specified in this section. The electrical systems will provide power to the ITS devices installed as part of this project including but not limited to communications hubs and field cabinets.

7.2 Materials

Contractor shall provide all materials according to the requirements in the following sections.

All equipment shall be new and constructed using the highest quality, commercially available components and techniques to assure high reliability and minimum maintenance. Prior to installation, the Contractor shall submit and receive approval from the Engineer on a complete set of shop drawings of all the equipment and components listed within this Special Provision and included as part of the installation.

7.2.1 Electrical Cable

1. Electrical cable shall be stranded copper wire with XHHW (XLPE (cross-linked polyethylene) high heat-resistant, water-resistant) insulation, rated at 600V.

7.2.2 Demarcation Site (Overhead Power) for Electrical Service

1. Demarcation sites for overhead power service installations shall include a service power meter base, fusible disconnect switch with fuse(s) and/or power distribution breaker panel (Mini Load Center) and enclosure, wood pole, weather head, SPD, wire, conduit and appurtenances, wire splices, and all labor materials associated with the installation of these devices except as approved by the Engineer. Where multiple power circuits are originating from the same demarcation point, the demarcation point shall include all equipment needed for all circuits.
2. All demarcation site conduit shall be Rigid Galvanized Steel (RGS).
3. Conduit for the pole mounted electrical service pertains to the RGS riser assembly and any underground conduit connected to the riser and extending to the nearby pull box.

7.2.3 Demarcation Site (Underground Power) for Electrical Service

1. Demarcation sites for underground power service installations shall include a service power meter base, fusible disconnect switch with fuse(s) and/or power distribution breaker panel (Mini Load Center) and enclosure, Unistrut rack, incidental concrete paving, SPD, wire, conduit and appurtenances, wire splices, and all labor materials associated with the installation of these devices except as approved by the Engineer. Where multiple power circuits are originating from the same demarcation point, the demarcation point shall include all equipment needed for all circuits.
2. All demarcation site conduit shall be Rigid Galvanized Steel (RGS).
3. Conduit for the rack mounted electrical service pertains to the RGS riser assembly and any underground conduit connected to the riser and extending to the nearby pull box.

7.2.4 Transformers (Types A and B)

1. Provide transformer (Type A) – 10kVA step up or step down transformers as indicated on the Plans.
2. Provide transformer (Type B) – 5kVA step up or step down transformers as indicated on the Plans.
3. Each of the transformer Types shall conform to the following requirements:
    a. UL listing.
    b. Operate at 60 Hz.
    c. Built in accordance with ANSI short term overload capability.
    d. Meet or exceed NEMA ST-20 sound levels (37dB for 0-9KVA; 42dB for 10-30KVA).
    e. Tested in accordance with NEMA, ANSI, and IEEE Standards.
    f. Dry Type Transformers: ANSI/NEMA ST 20: factory-assembled, non-vented, dry type transformers; ratings as shown on the Plans.
    g. Voltage rating for transformers shall be as indicated on the Plans.
    h. The average temperature rise shall be 115°C.
    i. Shall comply with NEC standards for transformers and disconnects.
    j. Basic Impulse Level (BIL): 10 KV for transformers less than 300kVA.
    k. Coil Conductors shall be continuous copper windings with terminations brazed or welded.
    l. Enclosure: Non-Ventilated, NEMA 3R enclosure standard. Suitable for outdoors. Provide lifting lugs or brackets.
    m. Isolate core and coil from enclosure using vibration-absorbing mounts.
    n. Nameplate: Include transformer connection data and rating.
    o. Include lug kits which are compatible with the type and amperage of the windings.
    p. All cores to be constructed of high grade, non-aging silicon steel with high magnetic permeability and low hysteresis and eddy current losses. Magnetic flux densities are to be kept well below the saturation point.
    q. Terminations shall consist of wire leads with minimum insulation rating of 125ºC.
4. Pad Mounted Transformers shall conform to the following requirements:
    a. Include transformers capable of being pad mounted.
    b. Include a concrete pad for pad mounted transformers as indicated on the Plans.
    c. Pad shall be installed to allow safe working clearances per NEC or NESC and avoid obstructing access doors to any equipment.
5. Rack Mounted Transformers shall conform to the following requirements:

a. Include transformers mounted on a channel steel frame as indicated on the Plans.

b. Include a concrete pad as an extension of proposed cabinet foundation or stand alone as indicated on the Plans.

c. Include a galvanized steel stand constructed of 3” channel with welded construction.

d. Legs shall be bolted to or buried into concrete pad to depths indicated on the Plans.

e. Include knee bracing as required to prevent excess stand movement.

f. Stand shall be installed to allow safe working clearances per NEC or NESC and avoid obstructing access doors to any equipment.

g. Bond equipment grounding conductor to the steel frame.

7.2.5 Equipment Cabinet Uninterruptible Power Supply

The Uninterruptible Power Supply (UPS) shall be line interactive or on-line (double conversion) type with 120VAC single phase input and output. All components shall be UL 1778 listed. The UPS shall be designed to meet the following:

1. The UPS system must be sized to provide:
   a. 1 hour of run time for total load (minimum 200W) supported in cabinets with a Layer 2 Switch
   b. 2 hours of run time for total load (minimum 200W) supported in cabinets with a Layer 3 Switch

2. Loads supported include all devices controlled and energized from the equipment power terminal block in each ITS cabinet. The exception to this is a DMS housing, which shall not be connected to and supported by the UPS.

3. The UPS assembly including batteries must be compliant with the environmental testing specified in NEMA TS2, Sections 2.2.7, 2.2.8 and 2.2.9 and provide continuous power with specified wattage and operate per the requirements specified during and after subjected to the aforementioned environmental testing.

4. The UPS assembly shall support remote environmental sensing hardware and software integrated with SNMP, capable of monitoring temperature.

5. The unit and supplemental battery packs (if required) shall include mounting hardware for a 19” equipment rack.

6. 8 output receptacles, type NEMA5-15R.

7. The UPS and associated assembly, including batteries shall have an operating temperature range of -20°C to +55°C.

8. The UPS and associated assembly, including batteries shall have an operating relative humidity rating of 0 – 95%, noncondensing.

9. The UPS shall automatically return to utility power after an event.

10. The UPS shall include SNMP manageable hardware and software with 10Base-T connection (RJ-45).

11. The Contractor shall provide the cabinet vendor with a list of all the loads to be powered at each ITS cabinet.
12. The vendor shall provide for submittal approval, cabinet internal wiring, and load calculations, as well as cabinet layout showing the UPS unit physically sized adequately to fit within the cabinet spaces available.
13. All calculations and layouts, wiring, and overcurrent protection shall meet NEC.
14. Should there be any changes in the configuration of each cabinet, it shall be the responsibility of the Contractor to advise the cabinet vendor for any adjustments required to the sizes of the cabinets or the UPS as required to meet any new load demands.

7.2.6 Surge Protective Device (SPD)

1. All SPD shall be UL listed and bear the UL label.
2. All metal oxide varistors used for surge protection shall be rated in the appropriate voltages.
3. Surge suppressors operating temperature shall be between -40°C to +75°C.
4. Power Carrying Conductors shall conform to the following requirements:
    a. The SPD shall be installed on the load side of the main circuit breaker with leads as short and straight as possible. This shall be required for all voltage levels.
    b. The SPD shall have a clamping voltage response time of less than 5 nanoseconds.
    c. The SPD shall have a Voltage Protection Rating (VPR) of 700V or less for L-N, L-G, & N-G for 120V, 120/240V, 208Y/120V systems. The SPD shall have a Voltage Protection Rating (VPR) of 1200V or less for L-N, L-G, & N-G for 240/480V and 480Y/277V systems.
    d. The SPD shall have a Maximum Continuous Operating Voltage (MCOV) of 150V for 120, 120/240V, 208Y/120V systems. The SPD shall have a Maximum Continuous Operating Voltage (MCOV) of 320V for 240/480V and 480Y/277V systems.
    e. The SPD peak surge current shall be equipped with a minimum surge current rating of 70kA per phase.
    f. The SPD shall have Nominal Discharge Current Rating (I_n) of 20kA.
    g. The SPD shall be UL1449 listed.
    h. The SPD shall be located adjacent to the electrical power service and distribution panel.
    i. The SPD shall have a visual indicator of loss protection.
    j. The SPD shall include 1 set of Normally Open (NO), Normally Closed (NC) Form C contacts for remote monitoring.

7.2.7 Power Distribution Breaker Panel

1. Power distribution breaker panels shall be rated as indicated on the Plans, 12 space maximum, 4 space minimum, and Main Circuit Breaker (MCB) panels. Shall be in a NEMA 3R enclosure for use in outdoor locations. Ampere rating of each power distribution breaker panel shall be as indicated on the Plans.

2. Panels shall be bottom fed and capable of being surface mounted inside a cabinet.

3. Power distribution breaker panel schedules shall be filled in with descriptions of each circuit in accordance with Article 110-22 of the National Electric Code and placed in a protective sleeve mounted securely inside the panel door.

4. Molded Case, bolt-on thermal magnetic trip circuit breakers, with common trip handle for all poles shall be provided factory installed in accordance with the power distribution breaker panel schedules on the Plans.

7.2.8 Disconnect Switches

1. Provide fused and non-fused disconnect switches, ampere rating, voltage rating, number of poles, and fuse size as indicated on the Plans.

2. Disconnect switches shall be in a NEMA 3R enclosure for use in outdoor locations and able to be locked in both the on and off positions.

7.2.9 Labeling

1. Provide labels for all electrical service equipment including Transformers, Power Distribution Panels, Disconnect Switches and device cabinets identifying the equipment being served and, when required, its function.

2. Labels shall be 4" x 6" (minimum) unless specified otherwise, self-adhesive, water and chemical resistant, flexible vinyl, outdoor rated, protected from UV radiation, moisture, oxidation, and other pollutants.

3. If any equipment is rated 240/480V, provide a 5” x 7” (minimum) label indicating “Danger 240/480V” on relevant equipment including disconnects and transformers.

4. Each panel board shall have a laminated, typed circuit schedule permanently mounted inside the panel board. The circuit schedule shall list which loads are controlled by each circuit breaker.

7.3 Installation Requirements

7.3.1 Electrical Cable

Contractor shall abide by the following installation requirements:

1. Conductors of the type, size, and specification shall be installed at the location shown on the Plans or as directed by Engineer.

2. Conductors in conduits shall be carefully pulled into place using methods in conformance with standard industry practice and the cable manufacturer’s recommendations.

3. When wire or cable is brought up into the base of a foundation, sufficient slack shall be left to enable the connections to be made outside the foundation.

4. Powdered soapstone, talc, or other approved inert, non-oily cable lubricant shall be used in placing conductors in conduit.

5. Conductors shall be handled and installed in such a manner as to prevent kinks, bends, or other distortion, which could cause damage to the conductor or outer covering.

6. All wires and cables within a single conduit shall be pulled at the same time. When cables are pulled through hand holes, in pole shafts, etc., a pad of firm rubber or other suitable material shall be placed between the cable and the edges of the opening to prevent cable damage.
7. Cable, entrances into panels, transformers, cabinets, and conduit outlets shall be sealed from moisture, insects, rodents, and foreign material with a sealing compound manufactured for this application.
8. Splices and taps for circuits rated below 600V shall be performed in accordance with the National Electrical Code and materials shall be used that will be compatible with the sheath and insulation of the cable and suitable for direct burial.
9. Straight splices shall be made with tubular copper compression type connectors, or bronze or copper split bolt connectors.
10. Tap splices shall be made with parallel tubular copper compression type connectors or parallel groove bolted connectors.
11. Compression connectors shall be crimped with the connector manufacturer's recommended compression tool and die.
12. The compression tool shall be of the type which will prevent removal of the tool until the crimp has been completely closed.
13. After a conductor splice is made, it shall be insulated with a rubber insulating tape and then covered with material suitable for direct burial.
14. The tape shall be applied half-lap with a minimum of 2 full laps of each tape to a point approximately 3" from the conductor splice.
15. All sharp points and edges of the connector shall be padded, and all voids filled with insulating putty.
16. The tape shall not be stretched in such a manner as to cause creeping. All spliced joints shall be watertight.
17. Splices and taps for circuits rated above 600V shall be made using a splice kit as supplied by the cable manufacturer suitable for direct burial and splices shall be made in accordance with manufacturer instructions and recommendations for the particular cable and voltage level.
18. Splices shall be completed the same day started and shall not be done during damp or inclement weather.
19. Medium and high voltage cables exposed at equipment terminations shall be provided with a suitable insulating sleeve from over the cable insulation to terminal points of the equipment.
20. Special attention shall be given to the shielded cable to maintain the continuity of the metallic shielding tape and to the proper termination and grounding of the shield at each splice of the cable run and at each end.
21. Cable warning tape shall be installed in all conduit trenches as specified.
22. Junction boxes containing conductors of different voltages shall be permanently labeled to identify voltage and disconnecting location. Conductors shall be color coded to identify voltage.

7.3.2 Grounding Wire

Contractor shall abide by the following installation requirements:

1. Grounding splices shall not be insulated.
2. The grounding conductor shall be continuous and shall be connected to the ground system at all supporting poles and structures, to each transformer, to each sign support assembly, to each gate, and to each grounding conductor in a multi-conductor cable assembly. Additional grounding rod electrodes shall be installed to obtain a maximum value of 10 ohms to ground.
3. Single ground rods shall be driven vertically until the top of the rod is at least 12" below the finished ground.
4. A length of #6 base copper, seven-stranded wire shall be attached to the ground rod with suitable ground rod clamps and connected to the grounding system.
5. Bolted grounding connections of solder-less type made of the high strength electrical bronze with silicon bronze clamping bolts and hardware may be used; designed such that, bolts, nuts, lock washers and similar hardware which might nick or otherwise damage the ground wire will not directly contact the ground wire.
6. Non-dielectric circuit(s) going into and leaving communication equipment cabinet(s) shall be equipped with TDOT-approved Surge Protective Device (SPD) system.
7. Exothermic welded ground connections shall be used where specified on the Plans.

7.3.3 Electrical Connection

Electrical power service, from the power service provider, shall be provided at the Demarcation Points as indicated on the Plans. The Contractor shall be responsible for all coordination with the power service provider as well as all materials, labor, or any other means to install electrical service to the field cabinets as indicated on the Plans.

7.3.4 Demarcation Site for Electrical Service

Contractor shall abide by the following installation requirements:

1. The installation of all electrical devices including wire sizing, conduit sizing, electrical conductor splicing in pull boxes, transformers, and grounding/bonding shall be as shown on the Plans and in accordance with the National Electrical Code (NEC) and National Electrical Safety Code (NESC).
2. See Plans for identification of electrical utility companies involved on this project.
3. Contractor is responsible for contacting each electrical utility company for service feed information. Each utility company may vary in its procedure for obtaining and providing electrical service.
4. It is the Contractor’s responsibility to coordinate with each electrical utility well ahead of the desired (scheduled) date for electrical service, so that proper procedures can be followed for each electrical utility provider.
5. The address for each electrical demarcation point is shown on the Plans.

6. The Contractor shall get all finished electrical demarcation points inspected by the appropriate authority, as determined by each electrical utility provider, prior to asking for required activation from the electrical utility.
7. The Contractor shall coordinate with the electrical utility to ensure conformance with interface requirements for point of attachment and metering.
8. The Contractor shall not order service activation more than 60 calendar days before anticipated installation of the ITS equipment cabinet to be served, so as not to incur unwarranted service costs.
9. Electrical service may not be connected to a cabinet or other device until all required grounding installation is complete.
10. If the site is an Overhead installation, the wood pole for demarcation equipment shall be embedded a minimum of 5' into the ground and in accordance with the power service utility's requirements.

7.3.5 Transformer (Types A and B)

Contractor shall abide by the following installation requirements:

1. Set transformer plumb and level on concrete pads. The pad is to extend a minimum of 6" from the edge of all sides of the transformer.
2. All transformers shall be installed to form a complete installation ready for operation.
3. Check for damage and tight connections prior to energizing transformer.
4. Measure primary and secondary voltages and make appropriate tap adjustments with transformer 100% design load.
5. After installation is completed, the transformer shall be tested prior to acceptance as defined in the Testing Subsection of this SP725 Section.

7.3.6 Equipment Cabinet Uninterruptible Power Supply

Contractor shall abide by the following installation requirements:

1. Install in equipment rack the location designated on the Plans.
2. Ensure area around vents are free of obstructions.
3. All UPS and supplemental battery packs (if required) shall be mounted adjacent within the equipment rack.
4. Connect UPS input directly to the cabinet equipment receptacle. Extension cords or power strips are not acceptable.
5. Connect all battery packs and allow UPS to charge completely prior to connecting loads.
6. All load connections shall be clearly identified with printed labels, and cables neatly routed within the cabinet.

7.3.7 Surge Protective Device (SPD)

Contractor shall abide by the following installation requirements:

1. The Contractor shall provide SPD on all electrical service points at the load side of distribution panels.
2. The Contractor shall install SPD as follows:
    a. The placement of equipment and wiring within an outside enclosure shall be arranged so that the surge suppressors are located near the conductor's point of entry.
    b. Surge suppressors shall be located as close as possible to the electrical panel board.
    c. SPD shall be mounted on the underside of riser and ground-mounted demarcation point breaker panel enclosures.
    d. The surge suppressor grounding conductor shall be free from sharp bends.

7.3.8 Power Distribution Breaker Panel

1. Contractor shall install power distribution breaker panels on the hub, cabinets, and equipment support racks as indicated on the Plans.
2. All breakers shall be clearly labeled with printed schedules.

7.3.9 Disconnect Switch

1. Contractor shall fuse and secure disconnect switches installed at the demarcation to the demarcation pole or equipment support rack at the locations indicated on the Plans.
2. Disconnect switches installed at transformer locations shall be fused and secured to the primary side of the transformer.

7.4 Testing Requirements

7.4.1 General Requirements

1. The Contractor shall conduct a project testing program for all materials specified in this section and as required in Section 2.5 of this SP725.
2. All test results shall confirm physical and performance compliance with this SP725.
3. Testing shall be performed in accordance with TDOT Standard Specifications Section 714.
4. The Contractor shall submit all test results documentation to the Engineer within 7 calendar days of completion of the tests. The Engineer will review test documentation in accordance with the Submittal Review Process in Section 2.7.
5. Payment for all testing is included in the cost of the Electrical Equipment.

7.4.2 Factory Acceptance Test

FAT is not required for Electrical Equipment.

7.4.3 Bench Test Component

BTC is not required for Electrical Equipment.

7.4.4 Bench Test System

BTS shall be performed in the presence of the Engineer. BTS of Electrical Equipment will be performed in conjunction with other components in this SP725 that are reliant upon the Electrical Equipment.

7.4.5 Stand Alone Site Test

SAT shall be performed in the presence of the Engineer. The SAT shall include the following tests and inspections:

1. Verify all components have been installed per manufacturer requirements.
2. Verify all items have been attached properly (as per manufacturer recommendations and the Plans) to each other and to any applicable structures.
3. Verify the Electrical Equipment has no internal or external damage.
4. Verify that grounding has been installed as required and installation follows NEC and other applicable codes/standards.
5. Test and document transformer voltage, current, and insulation resistance.
6. Test and document the duration for which the UPS can run all connected equipment at the site autonomously by disconnecting the site from grid power. The test shall be performed from 100% battery charge to 5% battery charge. At 5% battery charge remaining, the site shall be reconnected to grid power. Include the average load over the course of the test in the documentation.

7.5 Warranty

All materials specified in this section shall carry a minimum one-year manufacturer's warranty from the date of Final Acceptance against any imperfections in workmanship or materials. Warranties shall cover complete replacement at no charge for the equipment. Warranties shall be transferred to TDOT upon Final Acceptance of the project as per the requirements in Section 2.6 of this specification.

7.6 Method of Measurement

7.6.1 Electrical Cable (1/C #14 AWG - #4/0 AWG)

The Electrical Cable will be measured in units of linear feet per cable installed and paid for at the contract price per linear feet of each cable. The bid price shall include furnishing, installing, configuring, and testing of the electrical power cable including all required splices and other ancillary items required for complete installation of the cable. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

7.6.2 Electrical Connection

Electrical Connections shall be paid for on a lump sum basis wherein no measurement will be made. Electrical Connections shall cover the Contractor's time and costs for coordinating with the utility companies as described in these SP725. This price shall include any charges from the utilities for installation charges associated with providing power to the demarcation points which may include overhead primary or secondary conductors, overhead transformer, pad mount transformer, and utility poles (excluding demarcation site).

7.6.3 Demarcation Site (Overhead Power)

Demarcation Site (Overhead Power) shall be measured in units of each and shall include the power service meter base, power distribution breaker panel or mini load center, wood pole, SPD, all RGS conduit risers and weather head, conduit from nearest pull box to the pole, connection hardware, grounding, wiring, and all related appurtenances as necessary to provide power service to each site. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

7.6.4 Demarcation Site (Underground Power)

Demarcation Site (Underground) shall be measured in units of each and shall include the power service meter base, fusible disconnect switch, power distribution breaker panel, Unistrut rack, incidental concrete paving, SPD, mounting brackets, concrete poles, RGS conduit from nearest pull box to the demarcation point, connection hardware, grounding, wiring, and all related appurtenances as necessary to provide power service to each site. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

7.6.5 Transformer (Types A and B)

The transformer will be measured in units of each and paid for at the contract price per each. The bid price shall include but not be limited to furnishing and installing of the transformer, mounting brackets, transformer disconnect switch, SPD, incidental connecting wire and conduit to an adjacent equipment cabinet, equipment support rack, conduit riser or ground-mounted brackets and all work, equipment, and appurtenances as required effecting the full operation of the transformer. The bid price shall also include all documentation including configuration drawings, equipment interconnect diagrams, full operation documentation, block diagrams, and other material necessary to document the installation of the cabinet transformer and testing according to this SP725 detailed herein, on the Plans and/or in the contract document. This price shall be full compensation for all labor, tools, materials, equipment and incidentals necessary to complete the work.

7.6.6 Uninterruptible Power Supply

Equipment Cabinet Uninterruptible Power Supply (UPS) shall be measured in units of each and shall include furnishing, installing, configuring, and testing for an operational battery backup system that meets the requirements within this SP725. The bid price shall also include electronic user documentation for all management, configuration and operation hardware and firmware settings, installation procedures, and the MIB. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

7.6.7 Surge Protective Device (SPD)

The SPD is included in the quantities of other pay items and will not be measured separately for payment.

7.6.8 Power Distribution Breaker Panel

The Power Distribution Breaker Panel is included in the quantities of “Demarcation Point Riser Assembly” and will not be measured separately for payment.

7.6.9 Disconnect Switch

Fused disconnect switch shall be included in the quantities of other pay items and shall include connection hardware, grounding, wiring, and all related appurtenances as necessary to provide a disconnecting means to equipment and is inclusive of coordination efforts for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

7.7 Payment

The contract unit price shall be full compensation for all work specified in this section.

Payment will be made under:

Item No.	Description	Unit
725-20.51	CABLE (1/C #14 AWG.)	LF
725-20.52	CABLE (1/C #12 AWG.)	LF
725-20.53	CABLE (1/C #10 AWG.)	LF
725-20.54	CABLE (1/C #8 AWG.)	LF
725-20.55	CABLE (1/C #6 AWG)	LF
725-20.56	CABLE (1/C #4 AWG)	LF
725-20.57	CABLE (1/C #2 AWG)	LF
725-20.58	CABLE (1/C #1/0 AWG)	LF
725-20.59	CABLE (1/C #2/0 AWG)	LF
725-20.60	CABLE (1/C #3/0 AWG)	LF
725-20.61	CABLE (1/C #4/0 AWG)	LF
725-20.71	ELECTRICAL CONNECTION	LS
725-21.43	DEMARCATION SITE (OVERHEAD POWER)	EA
725-21.44	DEMARCATION SITE (UNDERGROUND POWER)	EA
725-21.71	TRANSFORMER TPAE A (10KVA)	EA
725-21.72	TRANSFORMER TYPE B (5KVA)	EA
725-21.85	UNINTERRUPTIBLE POWER SUPPLY	EA

All 725 Electrical Equipment items listed will be paid per each as follows:

1. Stored materials will be paid per TDOT Standard Specifications.
2. Final Payment will be made after complete installation and satisfactory completion of Stand Alone Site Test of all items for which it is specified.

8 EQUIPMENT CABINETS

8.1 Description

This section specifies the minimum requirements for equipment cabinets furnished and installed on this project as shown on the Plans. The cabinet will provide a protective outdoor housing enclosure in which to install field hardware required for ITS devices to communicate with the TDOT Regional TMC. Major elements of the equipment cabinet include the cabinet housing and equipment mounting hardware, interior wiring and termination facilities, power supplies, electrical accessories, and field installation.

8.2 Materials

Contractor shall provide all materials according to the requirements in the following sections.

All equipment shall be new and constructed using the highest quality, commercially available components and techniques to assure high reliability and minimum maintenance. Prior to installation, the Contractor shall submit and receive approval from the Engineer on a complete set of shop drawings of all the equipment and components listed within this Special Provision and included as part of the installation.

8.2.1 General

1. Furnish only new equipment and materials.
2. Furnish equipment cabinets and integral materials recommended by the manufacturers for outside plant use and the intended application. This requirement includes wiring, electrical materials and configurations (including connector pinouts) that are wholly or partially related to the field device applications (CCTV, RDS, DMS, ESS, RSU, OVDS, WIM, HAR, Wireless Ethernet Radio and Antenna, etc.).
3. Furnish and configure equipment cabinets to be installed at locations as shown on the Plans. Furnish and configure all equipment and materials for each specific location as shown on the Plans.
4. Provide electrical system and components with UL-listings for the appropriate application.
5. Unless otherwise specified, provide wire and cable with stranded copper conductors, 75°/90°C wet/dry rated insulation, and sized for the maximum voltage and current in the circuit.
6. All components specified as rail-mounted shall be compliant as follows:
    a. DIN EN 50022 (NS35) component rails
    b. Component rails shall be the perforated type and of sufficient length as to protrude beyond the mounted components for fastening to cabinet panels as specified herein
    c. UL 1059
    d. UL 486E
    e. NEMA ICS-4
7. Terminal blocks and component terminals shall be nickel-plated copper, copper alloy, or brass.
8. Terminal blocks shall have voltage and current ratings greater than or equal to the ratings of the wires that are terminated and shall be assembled into housing enclosures such that all exposed

surfaces are touch safe. Conductor fastening screws shall be captive. Incoming power service terminals shall be able to terminate wires from #8 AWG to #4/0 AWG wiring. Terminal block housings shall be colored as follows:

a. 120VAC line/hot: black

b. 120VAC neutral: white

c. 24VDC positive: red

d. 24VDC negative: gray

e. RS485 communications: orange

f. Ground: green or green/yellow

9. Provide door locks for all cabinet doors, keyed to TDOT standard Corbin #B4R01365 using #8960 heavy-duty blanks and mastered to #B4R87965. Provide 1 key with each cabinet.

10. Provide sunshields and mounting fasteners on all cabinets (except Type D). Sunshields and fasteners shall meet the following minimum requirements:

    a. Sunshields shall be 0.125" aluminum with smoothed, deburred edges and rounded corners. Provide cutouts for door handles and/or locks as required.

    b. Cabinets shall be equipped with press-in threaded inserts on the cabinet wall interior surface. Sunshields shall be mounted by fasteners and aluminum or stainless-steel standoffs tightened into the threaded inserts.

    c. Provide a minimum of 4 inserts/fasteners for top face sunshields.

    d. Provide a minimum of 6 inserts/fasteners for any door or side sunshield.

    e. For doors or sides greater than 54" tall, provide inserts and fasteners sufficient for a maximum vertical or horizontal distance of 27" between any fasteners.

    f. Furnish and install a top face sunshield on all cabinets.

    g. Furnish and install door or side sunshields on all cabinet faces except for pole attachment faces (for pole-mounted cabinets only).

11. Provide agency name, device name, and ID labels on all cabinets. Labels shall meet the following minimum requirements:

    a. Labels shall be flat black lettering on a reflective white background. Lettering shall be a minimum of 1" in height.

    b. Labels shall be manufactured from pre-coated adhesive backed reflective sheeting material meeting the minimum requirements of AASHTO M268 Type 1.

    c. The agency name labels shall be "TDOT ITS" in one continuous adhesive sheet.

    d. The device ID labels shall include the device ID(s) and shall be one continuous adhesive sheet. Device ID shall include including region number, device type letter designation, route designation, mile marker, and direction as indicated on the Plans. Examples: "R4A-0I040-XXX.XE", "R4E-0I040-XXX.XE", "R4G-0I040-XXX.XE".

    e. Labels shall be installed along the top of the cabinet door (front cabinet door on Type B cabinets), with TDOT ITS label at the top and the device ID labels immediately underneath.

12. Provide a voltage label on all cabinets or enclosures in accordance with the NEC labeling requirements. Voltage labels shall meet the following minimum requirements:
    a. Labels shall be flat black lettering on a reflective yellow background. Lettering shall be a minimum of 1” in height.
    b. Labels shall be manufactured from pre-coated adhesive backed reflective sheeting material meeting the minimum requirements of AASHTO M268 Type 1.
    c. Labels shall include the voltages entering the cabinet and shall be one continuous adhesive sheet. Examples are “120VAC“ or “24VDC”.
    d. Labels shall be installed on all cabinet doors.

8.2.2 Type A Cabinet

Type A shall meet the following requirements:

1. Provide a Type A cabinet intended for outdoor use with a minimum NEMA 3R rating.
2. The cabinet enclosure shall be manufactured from 0.125” aluminum.
3. The cabinet shall provide a minimum of 1 ventilation louver on at least 2 sides. Any louver opening greater than 3/16” in any dimension shall be screened to prevent insect entry.
4. The cabinet shall be intended for strapped pole-mounting; provide all mounting hardware necessary including ½” stainless steel mounting straps.
5. Provide a Type A cabinet enclosure with dimensions of 18” (H) by 14” (W) by 8” (D) with a tolerance of +/- 0.25”.
6. Cabinet door shall reveal the entire front opening of the cabinet for accessibility. The hinge shall be designed to prevent the door from sagging.
7. Include a single-piece 0.125” aluminum back panel covering no less than 90% of the cabinet back wall. Back panel shall be affixed to the enclosure with threaded fasteners and shall be removable from the enclosure with hand tools only and without requirement to remove the cabinet door, mounting straps, or any other components other than communications or device wiring.
8. The cabinet shall be furnished with doorstops, which retain the doors open in 90 degree and 120-degree positions.
9. Din Rail mount, main cabinet surge protector for single-phase 120VAC service entrance, UL 1449 Current Edition Listed, parallel wired with a Voltage Protective Rating (VPR) of 700V or less for L-N & N-G, and a nominal discharge current (I_n) of 10kA.
10. Din Rail mount, UL 497B Listed, series connected SPD for each data/Ethernet connection. SPD shall consist of 3 stages of surge suppression.
11. Provide on the back panel a grounding lug capable of terminating #6 AWG wire and directly bonded to the back panel.
12. All Type A cabinets supporting RDS units shall meet the following requirements:

a. Identical in manufacture and assembly regardless of the number of RDS units shown on the Plans at a specific location.

b. Provide a remote RDS communications wiring module, comprised of DIN rail-mounted components, which includes the following:

    i. Component rail physically and electrically fastened to the cabinet back panel.

    ii. Strain relief brackets for the RDS cable(s) and the RDS unit harness cables.

c. Din Rail mount, UL 497B Listed, Parallel or Series-connected surge protector for the 12-24VDC power supply for the RDS units with integral or separate terminals for a minimum of 3 RDS cables and 2 RDS unit harness cables.

d. Local/remote communications disconnect module for the ethernet data signals that includes the following:

    i. Terminal facilities for 1 remote RDS cable connection from the surge protector, bus-connected to 2 separate local/remote disconnect switches, 1 for each RDS unit that simultaneously makes/breaks all the ethernet signal lines for a given RDS unit.

    ii. Separate terminal facilities for each of the RDS unit harness cables on the local side of the local/remote disconnect switch.

    iii. Separate RJ45 connectors for each of the RDS units, bus-connected with the RDS unit harness cable terminals on the local side of the local/remote disconnect switches. Provide protective covers for RJ45 connectors.

    iv. Provision for installing ethernet terminating resistors on the terminals on the remote side of the local/remote disconnect switch. Provide terminating resistors at cabinet locations in accordance with the RDS manufacturer's recommendations.

    v. Alternately, provide 2 separate local/remote communications disconnect modules, 1 per RDS unit, with jumper wiring between the remote side terminals of the 2 modules.

e. Connection/jumper wiring between the surge protectors and the local/remote communications disconnect module(s) shall be of the same conductor size, type, and insulation color as in the RDS cable.

8.2.3 Type B Cabinet

Type B cabinets shall meet the following requirements:

1. All Type B cabinets shall be identical in manufacture and assembly, capable of supporting 2 RDS units, 2 CCTV cameras, 3 ESS units, 1 RSU, 1 Type A network switch, 2 Wireless Ethernet Radios and Antennas, RDS cable, ESS cable, uninterruptible power supply (UPS), and fiber drop panel terminations, regardless of the devices shown on the Plans at a specific location.

2. A complete Type B cabinet shall be an assembly consisting of a cabinet housing, electrical subsystems, and an RDS communications subsystem.

3. Provide a Type B cabinet housing meeting the following requirements:

a. Conforms to the standards for a Type 170 336S (approximate exterior dimensions 46" H x 24" W x 23" D), including standard EIA 19" rack cabinet cage, as defined in the latest version of the Caltrans Transportation Electrical Equipment Specifications (TEES). The minimum clear vertical inside dimension of the 19" rack for equipment mounting shall be 39.5". Standard cabinet accessories for traffic signal operations, such as controller, power distribution assembly, input/output file, and termination panels, and the police panel, are not required as part of this cabinet assembly.

b. Provide a thermostatically controlled 100 CFM fan and louvered air intake in door with a pleated filter.

c. Provide all pole mounting hardware necessary including ¾" stainless steel mounting straps.

d. Includes hooks, welded to the inside of each cabinet door, for hanging a side-opening, re-sealable, opaque, heavy-duty plastic documentation pouch with metal or hard-plastic reinforced holes for the door hooks. Provide 1 pouch with each cabinet.

e. Includes a rack-mounted cabinet sliding storage drawer in accordance with the following:

   i. Approximate exterior dimensions 1.75" H x 16" W x 14" D.

   ii. Telescoping drawer guides to allow full extension from the rack cage.

   iii. Opening storage compartment lid to access storage space for cabinet documentation and other items.

   iv. Supports a weight of 25 lb. when extended.

   v. Non-slip plastic laminate surface attached to the compartment lid which covers a minimum of 90% of the surface area of the lid.

   vi. Mounted in the rack cage with the bottom surface approximately 9" above the bottom of the rack cage.

f. Includes side panels within the 2 sides of the rack cabinet cage, inserted and fastened from the inside of the cage. Use side panels fabricated from 0.125" 5052 sheet aluminum alloy and sized to the full inside dimensions of the rack cabinet cage. Side panel surfaces for equipment mounting are denoted by cabinet side, with the "right" side being the support pole side, and by upper or lower as related to the sliding storage drawer. Upper right-side panel (support pole side of cabinet, above the drawer) and lower left side panel (opposite side from the support pole, below the drawer) are example side panel surface names.

g. Includes a 12" long DIN rail (for future components) mounted in the horizontal and vertical center of the lower left side panel.

4. Provide Type B cabinet electrical subsystems meeting the following requirements:

   a. Includes an electrical distribution module comprised of the following DIN rail-mounted components:

      i. Service entrance terminal block with positions for 120VAC line, neutral, and ground and capable of terminating minimally #8 through #4/0 AWG wire, located at one end of the mounting rail with an approximately 0.75" blank spacer module adjacent to the main cabinet breaker.

ii. Main cabinet overcurrent 15A circuit breaker that is UL-listed and of the thermal-magnetic type rated for use from -18°C to 40°C minimum.

iii. Main cabinet surge protector for single-phase 120VAC service entrance, UL 1449 Current Edition Listed, parallel wired with a Voltage Protective Rating (VPR) of 700V or less for L-N & N-G, and a nominal discharge current (I_n) of 10kA. SPD peak surge current rating shall equal or exceed 10kA per mode. Per phase rating shall equal or exceed 20kA per phase.

iv. Main cabinet filter for power line noise and switching transient suppression, integral to, or separate from and wired to, the main cabinet surge protector. The noise filter shall be UL 1283 listed.

v. Electrical distribution terminal block fed from a 3.5A circuit breaker for line and neutral conductors parallel wired to the main cabinet surge protector but non-filtered, with a minimum terminating capability of 6 conductors of #10 to #18 AWG. Label the terminal block as "ACCY POWER."

vi. Electrical distribution terminal block fed from a 3.5A circuit breaker for line and neutral conductors for circuits on the load/equipment side of the power line filter, with a minimum terminating capability of 6 conductors of #10 to #18 AWG. Label the block as "EQUIP POWER."

vii. Electrical distribution terminal block for grounding and bonding conductors located on the same rail but separate from the service entrance terminal block and connected to the entrance ground with a #6 AWG green insulated wire. The grounding block shall have a minimum terminating capability of 2-#2 AWG conductors and 10-#10 to #18 AWG conductors.

viii. Ground fault circuit interrupter duplex receptacle (NEMA 5-15R) with 2.5A circuit breaker connected to the ACCY POWER distribution block. Permanently affixed to the receptacle, provide 2 red, orange, or green/yellow labels with minimum 0.25" lettering with the legend "300 WATTS MAX". This receptacle is for technician use only and shall not be used to power equipment.

ix. Interconnection wiring between all electrical distribution module components and the other systems included in or housed in the Type B cabinet.

b. Include a cabinet lighting subsystem comprised of the following components:

i. Two LED lighting assemblies, minimum 600 lumens, mounted on the inside top front and top rear portion of the cabinet, with a white color temperature (4000K or higher) with shatter-proof cover.

ii. A resistor-capacitor network noise suppressor installed across the light fixture power terminals.

iii. Two door-actuated switches installed to turn on the cabinet lights when either door is opened.

iv. Powered from the ACCY POWER distribution block.

c. Include 2 duplex non-GFCI equipment power receptacles (NEMA 5-15R) connected to the EQUIP POWER distribution block mounted on the upper rear corner of the cabinet upper right-side panel. Provide 2 red, orange or green/yellow labels with minimum 0.25" lettering with the legend "350 WATTS MAX" permanently affixed to the receptacle.

5. Provide a Type B cabinet RDS communications subsystem meeting the following requirements:
    a. Include a remote RDS communications wiring module as specified in Section 8.2.2 item 12, regardless of the number of RDS units shown on the Plans at a specific location.
    b. Include a headend RDS communications wiring module, comprised of DIN rail-mounted components, which includes the following:
        i. Nominal 24VDC output power supply, capable of user setting between 23 and 28VDC minimum, with minimum 1A output rating and minimum operating temperature range of -25°C to +70°C. Power supply shall provide terminal facilities for a minimum of 3 sets of #14 AWG conductors (in the RDS cable). Maximum size of the power supply shall be 1" W X 7" H X 7" D. Connect the power supply to the EQUIP POWER distribution block for 120VAC input.
        ii. UL 497B Listed, series connected surge protector for the RS485 data signal. The surge protector shall protect the 4-wire RS485 data signal with hybrid multi-stage suppression components including gas tube and silicon avalanche diode. The surge protector shall have a response time no greater than 1 nanosecond. The surge protector shall provide terminal facilities for a minimum of 4 two-pair cables of #22 AWG conductors (in the RDS cable or wired to the adjacent remote RDS communications wiring module).
        iii. UL 497B Listed, series connected surge protector for the ethernet data signal. The surge protector shall protect the 8-wire ethernet data signal with hybrid multi-stage suppression components including gas tube and silicon avalanche diode. The surge protector shall have a response time no greater than 1 nanosecond. The surge protector shall provide protection for power over ethernet for both data and power and shall use RJ-45 connectors.
    c. Complete subsystem of remote and head end modules mounted on the same DIN rail located on the bottom half of the cabinet upper right-side panel.

8.2.4 Type C Cabinet

The Type C cabinet shall meet the following requirements:

1. If Type C Cabinet is used for DMS, see Section 11 of this SP725 for additional Requirements.
2. Shall meet the same 19" rack, and ventilation requirements as Caltrans Type 170 model 332 cabinet.
3. Shall be ground mounted.
4. Shall be constructed of 5052 sheet aluminum alloy with a minimum thickness of 1/8".
5. All inside and outside edges shall be free of burrs.
6. The outside surface of the cabinet shall have a smooth, uniform, and natural aluminum finish.
7. All welds shall be neatly formed and free of cracks, blow holes, and other irregularities.
8. All welds shall be made by using the Heliarc welding method.
9. The cabinet should be of sufficient size to hold all the Field Junction support equipment as shown on the Plans.

10. Cabinet hinges shall be 14 Gauge diameter stainless steel or 1/8” diameter aluminum.
11. The hinge pins shall be constructed of stainless steel.
12. Shall be furnished with a three-point latching system (top, bottom, center locations).
13. Shall be furnished with a doorstop, which retains the door at 90 degree and 120-degree positions.
14. Shall have thermostatically controlled fan located at the top of the cabinet.
15. Minimum fan rating of 100 CFM.
16. Fan thermostat shall have a user adjustable range from 80ºF to 125ºF.
17. Minimum of 2-½” (length) galvanized anchor bolts shall be used to secure the cabinet to the foundation.
18. Includes hooks, welded to the inside of each cabinet door, for hanging a side-opening, re-sealable, opaque, heavy-duty plastic documentation pouch with metal or hard-plastic reinforced holes for the door hooks. Provide 1 pouch with each cabinet.
19. Includes a rack-mounted cabinet sliding storage drawer in accordance with the following:
    a. Approximate exterior dimensions 1.75” H x 16” W x 14” D.
    b. Telescoping drawer guides to allow full extension from the rack cage.
    c. Opening storage compartment lid to access storage space for cabinet documentation and other items.
    d. Supports a weight of 25 lb. when extended.
    e. Non-slip plastic laminate surface attached to the compartment lid which covers a minimum of 90% of the surface area of the lid.
20. If indicated on the Plans, provide a Type C cabinet RDS communications subsystem meeting the following requirements:
    a. Include a remote RDS communications wiring module as specified in Section 8.2.2 item 12, regardless of the number of RDS units shown on the Plans at a specific location. This may be required even for locations where no RDS units are shown on the Plans at a specific location.
    b. Include a headend RDS communications wiring module, comprised of DIN rail-mounted components, which includes the following:
        i. Nominal 24VDC output power supply, capable of user setting between 23 and 28VDC minimum, with minimum 1A output rating and minimum operating temperature range of -25°C to +70°C. Power supply shall provide terminal facilities for a minimum of 3 sets of #14 AWG conductors (in the RDS cable). Maximum size of the power supply shall be 1”(W) X 7”(H) X 7”(D). Connect the power supply to the EQUIP POWER distribution block for 120VAC input.
        ii. UL 497B Listed, series connected surge protector for the RS485 data signal. The surge protector shall protect the 4-wire RS485 data signal with hybrid multi-stage suppression components including gas tube and silicon avalanche diode. The surge protector shall have a response time no greater than 1 nanosecond. The surge protector shall provide terminal facilities for a minimum of 4 two-pair

cables of #22 AWG conductors (in the RDS cable or wired to the adjacent remote RDS communications wiring module).

iii. UL 497B Listed, series connected surge protector for the ethernet data signal. The surge protector shall protect the 8-wire ethernet data signal with hybrid multi-stage suppression components including gas tube and silicon avalanche diode. The surge protector shall have a response time no greater than 1 nanosecond. The surge protector shall provide protection power over ethernet for both data and power and shall use RJ-45 connectors.

c. Complete subsystem of remote and head end modules mounted on the same DIN rail located on the bottom half of the cabinet upper right-side panel.

21. Provide Type C cabinet electrical subsystems meeting the following requirements:

a. An electrical distribution module comprised of the following DIN rail-mounted components:

i. Service entrance terminal block with positions for 120/240VAC line, neutral, and ground and capable of terminating minimally #8 through #4/0 AWG wire, located at one end of the mounting rail with an approximately 0.75" blank spacer module adjacent to the main cabinet breaker.

ii. Main cabinet automatic overcurrent 30A (minimum) circuit breaker that is UL-listed and of the thermal-magnetic type rated for use from -18°C to 40°C minimum.

iii. Main cabinet surge protector for single-phase 120/240VAC service entrance, UL 1449 Listed, parallel wired with a Voltage Protection Rating (VPR) of 700V or less for L-L, L-N & N-G, and a nominal discharge current (I_n) of 20kA. SPD peak surge current rating shall equal or exceed 50kA per mode. Per phase rating shall equal or exceed 100kA per phase.

iv. Main cabinet filter for power line noise and switching transient suppression, integral to, or separate from and wired to, the main cabinet surge protector. The noise filter shall be UL 1283 listed.

v. Electrical distribution terminal block fed from a 3.5A circuit breaker for line and neutral conductors parallel wired to the main cabinet surge protector but non-filtered, with a minimum terminating capability of 6 conductors of #10 to #18 AWG. Label the terminal block as "ACCY POWER."

vi. Electrical distribution terminal block fed from a 3.5A circuit breaker for line and neutral conductors for circuits on the load/equipment side of the power line filter, with a minimum terminating capability of 6 conductors of #10 to #18 AWG. Label the block as "EQUIP POWER."

vii. Electrical distribution terminal block for grounding and bonding conductors located on the same rail but separate from the service entrance terminal block and connected to the entrance ground with a #6 AWG green insulated wire. The grounding block shall have a minimum terminating capability of 2-#6 AWG conductors and 10-#10 to #18 AWG conductors.

viii. Ground fault circuit interrupter duplex receptacle (NEMA 5-15R) connected to the ACCY POWER distribution block. Permanently affixed to the receptacle, provide 2 red, orange or green/yellow labels with minimum 0.25” lettering with the legend “300 WATTS MAX”. This receptacle is for technician use only and shall not be used to power equipment.

ix. Interconnection wiring between all electrical distribution module components and the other systems included in or housed in the Type C cabinet.

x. Branch overcurrent (size as required) circuit breaker that is UL-listed and of the thermal-magnetic type rated for use from -18°C to 40°C minimum to supply external equipment or cabinets, when present.

b. Include a cabinet lighting subsystem comprised of the following components:

i. Two LED lighting assemblies, minimum 600 lumens, mounted on the inside top front and top rear portion of the cabinet, with a white color temperature (4000K or higher) with shatter-proof cover.

ii. A resistor-capacitor network noise suppressor installed across the light fixture power terminals.

iii. Two door-actuated switches installed to turn on the cabinet lights when either door is opened.

iv. Powered from the ACCY POWER distribution block.

c. Include 2 duplex non-GFCI equipment power receptacles (NEMA 5-15R) connected to the EQUIP POWER distribution block mounted on the upper rear corner of the cabinet upper right-side panel. Provide 2 red, orange or green/yellow labels with minimum 0.25” lettering with the legend “300 WATTS MAX” permanently affixed to the receptacle.

8.2.5 ITS Communications Hub (Cabinet)

The ITS Communications Hub Cabinet shall meet the following requirements:

1. Shall meet the same 19” rack, and ventilation requirements as Caltrans Type 170 model 342 cabinet.
2. Shall be ground mounted.
3. Shall be constructed of 5052 sheet aluminum alloy with a minimum thickness of 1/8”.
4. All inside and outside edges shall be free of burrs.
5. The outside surface of the cabinet shall have a smooth, uniform, and natural aluminum finish.
6. All welds shall be neatly formed and free of cracks, blow holes, and other irregularities.
7. All welds shall be made by using the Heliarc welding method.
8. The cabinet should be of sufficient size to hold all the ITS Communications support equipment as shown on the Plans.
9. Cabinet hinges shall be 14 Gauge diameter stainless steel or 1/8” diameter aluminum.
10. The hinge pins shall be constructed of stainless steel.
11. Shall be furnished with a three-point latching system (top, bottom, center locations).
12. Shall be furnished with a doorstop, which retains the door at 90 degree and 120-degree positions.

13. Shall have thermostatically controlled fans located at the top of the cabinet.

14. Minimum fan rating of 100 CFM.

15. Fan thermostat shall have a user adjustable range from 80ºF to 125ºF.

16. Minimum of 2-½” (length) galvanized anchor bolts shall be used to secure the cabinet to the foundation.

17. Includes hooks, welded to the inside of each cabinet door, for hanging a side-opening, re-sealable, opaque, heavy-duty plastic documentation pouch with metal or hard-plastic reinforced holes for the door hooks. Provide 1 pouch with each cabinet.

18. Includes a rack-mounted cabinet sliding storage drawer in accordance with the following:

    a. Approximate exterior dimensions 1.75” H x 16” W x 14” D.

    b. Telescoping drawer guides to allow full extension from the rack cage.

    c. Opening storage compartment lid to access storage space for cabinet documentation and other items.

    d. Supports a weight of 25 lb. when extended.

    e. Non-slip plastic laminate surface attached to the compartment lid which covers a minimum of 90% of the surface area of the lid.

19. Provide ITS Communications Hub Cabinet electrical subsystems meeting the following requirements:

    a. An electrical distribution module comprised of the following DIN rail-mounted components:

        i. Service entrance terminal block with positions for 120/240VAC line, neutral, and ground and capable of terminating minimally #8 through #4/0 AWG wire, located at one end of the mounting rail with an approximately 0.75” blank spacer module adjacent to the main cabinet breaker.

        ii. Main cabinet automatic overcurrent 30A (minimum) circuit breaker that is UL-listed and of the thermal-magnetic type rated for use from -18°C to 40°C minimum.

        iii. Main cabinet surge protector for single-phase 120/240VAC service entrance, UL 1449 Listed, parallel wired with a Voltage Protection Rating (VPR) of 700V or less for L-L, L-N & N-G, and a nominal discharge current (I_n) of 20kA. SPD peak surge current rating shall equal or exceed 50kA per mode. Per phase rating shall equal or exceed 100kA per phase.

        iv. Main cabinet filter for power line noise and switching transient suppression, integral to, or separate from and wired to, the main cabinet surge protector. The noise filter shall be UL 1283 listed.

        v. Electrical distribution terminal block fed from a 3.5A circuit breaker for line and neutral conductors parallel wired to the main cabinet surge protector but non-filtered, with a minimum terminating capability of 6 conductors of #10 to #18 AWG. Label the terminal block as “ACCY POWER.”

vi. Electrical distribution terminal block fed from a 3.5A circuit breaker for line and neutral conductors for circuits on the load/equipment side of the power line filter, with a minimum terminating capability of 6 conductors of #10 to #18 AWG. Label the block as “EQUIP POWER.”

vii. Electrical distribution terminal block for grounding and bonding conductors located on the same rail but separate from the service entrance terminal block and connected to the entrance ground with a #6 AWG green insulated wire. The grounding block shall have a minimum terminating capability of 2-#6 AWG conductors and 10-#10 to #18 AWG conductors.

viii. Ground fault circuit interrupter duplex receptacle (NEMA 5-15R) connected to the ACCY POWER distribution block. Permanently affixed to the receptacle, provide 2 red, orange or green/yellow labels with minimum 0.25” lettering with the legend “300 WATTS MAX”. This receptacle is for technician use only and shall not be used to power equipment.

ix. Interconnection wiring between all electrical distribution module components and the other systems included in or housed in the Type C cabinet.

x. Branch overcurrent (size as required) circuit breaker that is UL-listed and of the thermal-magnetic type rated for use from -18°C to 40°C minimum to supply external equipment or cabinets, when present.

b. Include a cabinet lighting subsystem comprised of the following components:

i. Four LED lighting assemblies, minimum 600 lumens, mounted on the inside top front and top rear portion of the cabinet, with a white color temperature (4000K or higher) with shatter-proof cover.

ii. A resistor-capacitor network noise suppressor installed across the light fixture power terminals.

iii. Four door-actuated switches installed to turn on the cabinet lights when any door is opened.

iv. Powered from the ACCY POWER distribution block.

Include 2 duplex non-GFCI equipment power receptacles (NEMA 5-15R) connected to the EQUIP POWER distribution block mounted on the upper rear corner of the cabinet upper right-side panel. Provide 2 red, orange or green/yellow labels with minimum 0.25” lettering with the legend “300 WATTS MAX” permanently affixed to the receptacle.

8.2.6 Maintenance Work Pad

Provide concrete pad or wood platform for technician to stand on while performing maintenance activities at each cabinet. Wood platform may be required on sloped areas to provide appropriate dimension to the bottom of the cabinet as required by the Plans. If wood platform is to be used, Contractor shall provide proposed solution to the Engineer for approval.

1. Provide a 2’ x 3’ concrete pad with 1.5” thickness or 4’ x 8’ wood platform as required by the Plans and slope at each cabinet site.

2. Concrete pads shall be precast polymer concrete reinforced with woven fiberglass. Top surface shall have 0.5 coefficient of friction, skid resistant surface. Pad shall be installed per manufacturer's specifications.
3. Wood platform shall be of a composite material such as trek and all wood used must be pressure treated.
4. Maintenance Work pad shall be level in all directions as best as practical.
5. Provide shop drawings and proposed design for maintenance work pad for Engineer approval prior to beginning construction on pad.
6. Areas around the work pad shall be sloped appropriately and backfilled with compacted backfill as allowed by the Engineer and as per the Plans and TDOT Standard Specifications.

8.3 Installation Requirements

Contractor shall abide by the installation requirements in the following sections.

8.3.1 General

1. Install and configure cabinets as shown on the Plans, including installations and dimensions given for pole-mounting in relationship to the surrounding grade.
2. Bond all cabinets to the pole grounding lug with #6 AWG (minimum) stranded copper bare or green-insulated cabinet grounding wire. Alternately on existing poles only, bond the cabinet grounding wire to an existing pole grounding wire with a cast brass or copper alloy threaded compression connector within 4" of the existing pole grounding lug.
3. Do not install electrical service or electronic devices in the cabinet or connect to the cabinet until ground testing for the pole or structure has been successfully completed and accepted, and the cabinet ground connection has been installed.

8.3.2 Type A Cabinets

1. Install and configure equipment in the Type A cabinet in accordance with the requirements for that equipment, including RDS units, ESS units, HAR and/or fog flashing warning beacons, Wireless Ethernet Radios and Antennas, and/or fiber distribution or drop panels.
2. Do not install electronic devices in the cabinet until electrical service has been installed and activated, and the cabinet ventilation fan is operational.
3. If required, install fiber drop panels as per the Plans.
4. Couple Type A Cabinet to the Pole Structure using a 45 degree Type LU conduit body.

8.3.3 Type B and C Cabinets

1. Install and configure equipment in the Type B and C cabinet in accordance with the requirements for that equipment, including RDS units, CCTV, ESS, RSU, DMS controller, UPS, Type A network switches, Wireless Ethernet Radios and Antennas, UPS, and/or fiber distribution or drop panels.
2. UPS shall be installed and powered using the equipment receptacle.
3. Do not install electronic devices in the cabinet until electrical service has been installed and activated, and the cabinet ventilation fan is operational.

4. Provide protection bollards at every Type C Cabinet location.
5. Install Type A network switches in the topmost area of the cabinet rack. Use the UPS for the power source.
6. Install supporting equipment/electronics for CCTV on the lower area of the cabinet upper left side panel. Ensure there is no physical or access conflict with the network switch. Use the UPS for the power source.
7. Install fiber drop panels in a vertical configuration on the lower rear edge of the cabinet upper right-side panel.
8. Couple Type B Cabinet to the Pole Structure using a 45 degree Type LU conduit body.

8.3.4 ITS Communications Hub (Cabinet)

1. Install and configure equipment in the ITS Communications Hub Cabinet in accordance with the requirements for that equipment, including Type A network switches, Type B field aggregation ethernet switches, Wireless Ethernet Radio and Antennas, UPS, and/or fiber distribution or drop panels.
2. UPS shall be installed and powered using the equipment receptacle.
3. Do not install electronic devices in the cabinet until electrical service has been installed and activated, and the cabinet ventilation fan is operational.
4. Provide protection bollards at every ITS Communications Hub Cabinet location.
5. Install network switches in the topmost area of the cabinet rack. Use the UPS for the power source.
6. Install fiber drop panels in a vertical configuration on the lower rear edge of the cabinet upper right-side panel.

8.3.5 Maintenance Work Pad

1. Install a concrete pad or wooden deck maintenance work pad at each equipment cabinet location as indicated on the Plans. The maintenance work pad shall be installed level to provide a safe and sturdy location for a maintenance technician to open and work inside the equipment cabinet from.

8.4 Testing Requirements

8.4.1 General Requirements

1. The Contractor shall conduct a project testing program for all materials specified in this section and as required in Section 2.5 of this SP725.
2. All test results shall confirm physical and performance compliance with this SP725.
3. The Contractor shall submit all test results documentation to the Engineer within 7 calendar days of completion of the tests. The Engineer will review test documentation in accordance with the Submittal Review Process in Section 2.7.
4. Payment for all testing is included in the cost of the Equipment Cabinet.

8.4.2 Factory Acceptance Test

FAT is not required for Equipment Cabinets.

8.4.3 Bench Test Component

BTC shall be performed in the presence of the Engineer. The BTC shall include the following tests and inspections:

1. Verify the Equipment Cabinets have no internal or external damage.
2. Verify that manufacturer-supplied electrical components are properly connected and attached to the ground bus.
3. Verify that Equipment Cabinet doors properly seal, lock, unlock, and smoothly open and close.
4. Test all Equipment Cabinet components including circuit breakers, receptacles, fan, thermostat, lights, and door switches to verify functionality.

8.4.4 Bench Test System

BTS shall be performed in the presence of the Engineer. The BTS shall include the following tests and inspections:

1. Test and verify the functionality of one completely assembled Type A Equipment Cabinet that includes all potential field devices hosted from a Type A cabinet in the project (RDS, CCTV, ESS, RSU, communications, electronics, etc.). This test is not required if there are no Type A cabinets included in the project.
2. Test and verify the functionality of one completely assembled Type B Equipment Cabinet that includes all potential field devices hosted from a Type B cabinet in the project (RDS, CCTV, ESS, RSU, communications, electronics, etc.). This test is not required if there are no Type B cabinets included in the project.
3. Test and verify the functionality of one completely assembled Type C Equipment Cabinet that includes all potential field devices hosted from a Type C cabinet in the project (DMS, RDS, CCTV, ESS, RSU, communications, electronics, etc.). This test is not required if there are no Type C cabinets included in the project.
4. Test and verify the functionality of one completely assembled ITS Communications Hub Cabinet that includes all potential field devices hosted from a Hub Cabinet in the project (RDS, CCTV, ESS, RSU, communications, electronics, etc.). This test is not required if there are no Hub Cabinets included in the project.

8.4.5 Stand Alone Site Test

SAT shall be performed in the presence of the Engineer. Contractor shall perform SAT on all Equipment Cabinets on this project after field installation is complete including but not limited to all field devices (DMS, RDS, CCTV, ESS, RSU, communications, electronics, etc.) to be installed in or connected to that given cabinet. SAT for a given Equipment Cabinet shall only be performed in conjunction with the SAT for all devices installed in or connected to that given cabinet. The SAT shall include the following tests and inspections:

1. Verify all components within the Equipment Cabinets have been installed per manufacturer requirements.

2. Verify all items have been attached properly (as per manufacturer recommendations and the Plans) to each other and to any applicable structures.
3. Verify the Equipment Cabinets have no internal or external damage.
4. Verify that grounding has been installed as required and installation follows NEC and other applicable codes/standards.
5. Verify that cabinet documentation is present.
6. Test all cabinet equipment including circuit breaker, receptacles, fan, thermostat, lights, and door switches to verify functionality.
7. Test DC power supplies operating under full load. Test shall include measuring voltage and current input and output to ensure that both are within acceptable ranges according to manufacturer ratings.
8. A ground resistance test shall be performed at each electrical service grounding point. Ground resistance tests shall be conducted using a 3- or 4-Point Fall-of-Potential method defined by IEEE Standard #81 or other industry approved test method. Each grounding electrode shall be tested prior to connection to the ground system. Resistance-to-Ground of the ground system shall not exceed 10 ohms. Ground resistance measurements shall be conducted in normally dry conditions not less than 48 hours after the latest rainfall. All ground resistance tests shall be conducted in the presence of the Engineer. The Contractor shall document all test recordings and provide a copy of all test reports to the Engineer upon completion in accordance with the Project Submittal Program Requirements in Section 2.7.

8.5 Warranty

All materials specified in this section shall carry a minimum one-year manufacturer’s warranty from the date of Final Acceptance against any imperfections in workmanship or materials. Warranties shall cover complete replacement at no charge for the equipment. Warranties shall be transferred to TDOT upon Final Acceptance of the project as per the requirements in Section 2.6 of this specification.

8.6 Method of Measurement

8.6.1 Cabinet (Type A, Type B, Type C, and ITS Communications Hub (Cabinet)

Cabinets will be measured in units of each and paid for at the contract price per each. The bid price shall include furnishing and installing the equipment cabinet and all related material and equipment specified on the Plans and this SP725, and all labor, device integration, testing, system documentation, and miscellaneous materials necessary for a complete and accepted installation. The unit price shall also include but not be limited to the cabinet and all interior materials, mounting hardware foundations, protection bollards, external conduit entrances including conduit bodies and nipples, electrical service and pole grounding terminations, and protection bollards. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

8.6.2 Maintenance Work Pad (Concrete Pad or Wood Platform)

Maintenance work pads will be measured in units of each and paid for at the contract price per each. The bid price shall include furnishing and installing the work pad and all related material specified on the Plans and this SP725, and all labor and miscellaneous materials necessary for a complete and accepted installation. The unit price shall also include but not be limited to the work pad and all related materials not already included in payment for the cabinet. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

8.7 Payment

The contract unit price shall be full compensation for all work specified in this section.

Payment will be made under:

Item No.	Description	Unit
725-20.09	MAINTENANCE WORK PAD (CONCRETE PAD)	EA
725-20.10	MAINTENANCE WORK PAD (WOOD PLATFORM)	EA
725-24.01	CABINET (TYPE A)	EA
725-24.02	CABINET (TYPE B)	EA
725-24.03	CABINET (TYPE C)	EA
725-24.12	ITS COMMUNICATIONS HUB (CABINET)	EA

Equipment Cabinet will be paid per each as follows:

1. 40% of the contract unit price for delivery of the cabinet housings and satisfactory completion of Bench Testing Component test.

2. Additional 40% of the contract unit price for complete installation of equipment cabinet and all interior components, electrical service feed (activated), interior cabinet components, all conduit entrances, grounding connection, and satisfactory completion of Bench Test System testing.

3. Additional 10% of the contract unit price for satisfactory completion of Stand Alone Site Test of all field devices housed or connected to the equipment cabinet.

4. Final 10% of the contract unit price upon Final System Acceptance.

9 POLES AND STRUCTURES

9.1 Description

This section specifies the minimum requirements for equipment poles and structures furnished and installed in accordance with this SP725 and the Plans. This work shall consist of furnishing, installing, and testing 50’ and 80’ galvanized steel camera poles with foundations; 20’, 25’, and 35’ light standards and foundations; and overhead sign structures all in accordance with this SP725 and the TDOT Standard Specifications.

9.2 Materials

Contractor shall provide all materials according to the requirements in the following sections.

All equipment shall be new and constructed using the highest quality, commercially available components and techniques to assure high reliability and minimum maintenance. Prior to installation, the Contractor shall submit and receive approval from the Engineer on a complete set of shop drawings of all the equipment and components listed within this Special Provision and included as part of the installation.

9.2.1 Light Standards (for CCTV, RDS, ESS, WIM, or OVDS)

1. This work shall consist of furnishing detection poles with foundations. Heights shall be as indicated on the Plans or as directed by the Engineer. All work shall be in accordance with the TDOT Standard Specifications. The poles shall be galvanized steel or aluminum and shall be designed in accordance with the American Association of State Highway and Transportation Officials (AASHTO) standard "LRFD Specifications for Structural Supports for Highway Signs, Luminaries, and Traffic Signals,” current issue with interims.
2. Poles heights shall be as indicated on the Plans.
3. The Contractor shall supply poles as specified on the Plans and install as shown on the Plans.
4. Light Standards for CCTV, RDS, ESS, WIM, or OVDS shall include but not be limited to a pole, anchor bolts, breakaway base, base plate, ground rod array, communication and power conduit inside foundations, grounding conduit, spare conduit, and foundation as shown on the Plans.
5. Pole foundations shall be constructed with Class A Concrete (f’c = 3,000 psi) in accordance with Section 604.03 of the TDOT Standard Specifications. Reinforcing steel shall be Grade 60 and conform to ASTM A615 in accordance with Section 907.01 of the TDOT Standard Specifications.
6. Design computations for the poles shall be completed and provided to the Engineer and shall include but not be limited to the following:
    a. Consideration for all parts of the structure.
    b. Consideration for all possible loading combinations including wind and ice loads.
    c. Design stresses and allowable stresses for all components which comprise the proposed structure.
    d. All complete shop drawings and design computations shall bear the stamp and signature of a Professional Engineer registered in the state of Tennessee.

e. Shop drawings shall be approved prior to fabrication. Approval of the shop drawings does not relieve the Contractor of responsibility for the design, fabrication, and erection of the structure.

f. The Engineer reserves the right to reject a pole design if the calculated deflection exceeds that specified herein.

g. The calculations shall include a pole, base plate, and anchor bolt analysis. The pole calculations shall be analyzed at the pole base, 5' pole intervals, and at each slip joint splice.

7. For each pole as shown on the Plans, the following information shall be provided to the Engineer:

   a. The pole's diameter, thickness, section modulus, moment of inertia, and cross-sectional area.

   b. The centroid, weight, projected area, drag coefficient, velocity pressure, and wind force of each trapezoidal pole segment.

   c. The axial force, shear force, primary moment, total moment, axial stress, bending stress, allowable axial stress, allowable bending stress, and combined stress ratio (CSR) at each elevation.

   d. The pole's angular and linear deflection at each elevation.

9.2.2 CCTV Pole & Foundation

Contractor shall provide Fifty-foot (50') CCTV pole and foundation, Eighty-foot (80') CCTV pole and foundation with lowering device, One-hundred-ten-foot (110') CCTV pole and foundation with lowering device, conduit, connections, clamps, anchor bolts, shoe bases, and all other members in conformance with the following specifications. Poles, foundations, and all related items shall be designed and fabricated in accordance with the Standards and requirements listed below. Design and materials documentation shall be furnished as part of the approval request submittal. Certifications will be furnished upon request by the Engineer.

1. The CCTV Pole shall be designed in accordance with the American Association of State Highway and Transportation Officials (AASHTO) standard "LRFD Specifications for Structural Supports for Highway Signs, Luminaries, and Traffic Signals," current issue with interims.

2. The Contractor shall submit manufacturer's shop drawings signed and sealed by a Professional Engineer registered in the state of Tennessee, layout drawings and specifications for equipment and appurtenances for the approval of the Engineer within 90 calendar days of Notice to Proceed.

3. Fabricator: The Fabricator shall be certified under Category I, "Conventional Steel Structures" as set forth by the American Institute of Steel Construction Quality Certification Program. Contractor shall submit proof of this certification along with the structural submittal(s).

4. Welding: All welding shall be in accordance with Sections 1 through 8 of the American Welding Society (AWS) DI. 1 Structural Welding Code.

5. Tackers and welders shall be qualified in accordance with the American Welding Society Structural Welding code.

6. Tube longitudinal seam welds shall be free of cracks and excessive undercut, performed with automatic processes, and be visually inspected. Contractor shall furnish inspection records to the Engineer.

7. Longitudinal welds suspected to contain defects shall be magnetic particle inspected. All circumferential butt-welded pole and arm splices shall be ultrasonically and radiographically inspected. Inspection records will be furnished to the Engineer.

8. Camera Pole System shall consist of a pole, anchor bolts, base plate, ground rod array, communication and power conduits inside foundations, grounding conduit, spare conduit, and foundation.

9. Design computations for the camera poles shall be completed and provided to the Engineer and shall include but not be limited to the following:

   a. Consideration for all parts of the structure.

   b. Consideration for all possible loading combinations including wind and ice loads.

   c. Design stresses and allowable stresses for all components which comprise the proposed structure.

   d. The top of the pole deflection shall not exceed the following:

      i. 1” deflection from center (2” deflection diameter) due to 30 mph (non-gust) winds for the 50’ poles.

      ii. 1.5” deflection from center (3” deflection diameter) due to 30 mph (non-gust) winds for the 80’ poles.

      iii. 2” deflection from center (4” deflection diameter) due to 30 mph (non-gust) winds for the 110’ poles.

   e. All complete shop drawings and design computations shall bear the stamp and signature of a Professional Engineer registered in the state of Tennessee.

   f. Shop drawings shall be approved prior to fabrication. Approval of the shop drawings does not relieve the Contractor of responsibility for the design, fabrication, and erection of the structure.

   g. The Engineer reserves the right to reject a pole design if the calculated deflection exceeds that specified herein.

   h. The calculations shall include a pole, base plate, and anchor bolt analysis. The pole calculations shall be analyzed at the pole base, 5’ pole intervals, and at each slip joint splice.

10. For each pole as shown on the Plans, the following information shall be provided to the Engineer:

    a. The pole’s diameter, thickness, section modulus, moment of inertia, and cross-sectional area.

    b. The centroid, weight, projected area, drag coefficient, velocity pressure, and wind force of each trapezoidal pole segment.

    c. The axial force, shear force, primary moment, total moment, axial stress, bending stress, allowable axial stress, allowable bending stress, and combined stress ratio (CSR) at each elevation.

    d. The pole’s angular and linear deflection at each elevation.

11. Pole foundations shall be constructed with Class A Concrete (f'_c = 3,000 psi) in accordance with Section 604.03 of the TDOT Standard Specifications. Reinforcing steel shall be Grade 60 and conform to ASTM A615 in accordance with Section 907.01 of the TDOT Standard Specifications.

12. Pole foundation piling shall conform to Section 606 of the TDOT Standard Specifications.

13. Pole Mounted Cabinet Access Conduit Nipple shall conform to the following requirements:

    a. Each pole will be manufactured with a 3" diameter rigid threaded nipple for conduit connection to a pole mounted cabinet.

    b. The height of this nipple above the base of the pole shall be such that a cabinet mounting height of 2.5' above ground height can be achieved as shown in the typical details on the Plans.

14. Hand Holes shall conform to the following requirements:

    a. The hand hole openings are reinforced with 2" wide hot rolled steel bar. The opening shall be rectangular and at least 5" x 8" nominal.

    b. The cover shall be 11-gauge steel and shall be secured to a clip-on lock with a tamper-proof screw.

    c. The reinforcing rim shall include a ½" tapped hole and ½" hex head cap screw for grounding.

    d. For poles with lowering devices 2 hand holes shall be approximately 18" apart, center to center, or as recommended by the lowering device manufacturer.

    e. The hand holes shall be fully compatible with the Camera Lowering Device and Portable Lowering Tool. If desired and compatible with the lowering device, 1 larger hand hole may be provided in place of 2 separate hand holes.

    f. Hand holes on poles with pole mounted cabinets and transformers shall be placed toward oncoming traffic. For all other poles, hand holes shall face away from traffic.

15. Pole Top Junction Box shall conform to the following requirement: All camera poles shall have a pole top connector box fastened to the pole top for cable strain relief.

16. Cable Supports (J-Hooks & Eyelets) shall conform to the following requirement: Top and bottom J-hooks and eyelets shall be located within the pole directly aligned with each other.

17. Base Plates shall conform to the following requirements:

    a. Base plates shall conform to ASTM A572.

    b. Plates shall be integrally welded to the tubes with a telescopic welded joint or a full penetration butt weld with backup bar.

    c. Plates shall be hot dip galvanized.

18. Anchor Bolts shall conform to the following requirements:

    a. Anchor bolts in foundation shall be ASTM F1554 in accordance with Section 730.11 of the TDOT Standard Specifications. All anchor bolts shall be fitted with 2 heavy hex nuts; all nuts and not less than 10" of the threaded ends of anchor bolts shall be hot-dip galvanized according to ASTM A153.

b. Each anchor bolt shall be supplied with 2 hex nuts and 2 hardened washers.

c. The strength of the nuts shall equal or exceed the proof load of the bolts.

d. The top nut shall be torqued to produce 60% yield stress of anchor bolt.

e. The Contractor shall not grout between bottom of base plate and top of concrete foundation.

9.2.3 Camera Lowering Device Requirements for 50', 80', and 110' Poles

All 50', 80', and 110' poles shall have a heavy-duty Camera Lowering Device(s) (CLD) with the design capabilities of supporting IP based CCTV cabling. The camera lowering system shall be designed to support and lower IP closed circuit television camera, lens, housing, PTZ mechanism, cabling, connectors and other supporting field components without damage or causing degradation of camera operations. The camera lowering system device(s) and the pole are interdependent; and thus, must be considered a single unit or system. The lowering system shall consist of a suspension contact unit, divided support arm, and a pole adapter for attachment to a pole top tenon, pole top junction box, conduit mount adapter, and camera connection box. The CLD shall also meet the following requirements.

1. The CLD shall be safely operable by 1 technician working alone, to lower the Camera Assembly to ground level for maintenance as necessary and return the Camera Assembly to the pole top mounting and secure it in place, eliminating the need for access by a bucket truck.
2. Weatherproof connectors (camera to the lowering device) shall allow for adaptation of the camera and the dome type housing for lowering and hoisting and be provided as an integral part of the design to provide a water-resistant seal when the camera is raised and secured in place for surveillance operation.
3. Lifting and lowering shall be done with a motorized gear box (winch).
4. The CLD should be a stand-alone device mounted on a camera pole to be supplied by the Contractor and included in the cost of the associated pole.
5. An integrated CLD with pole assembly may be procured provided it meets all specifications.
6. The Camera Lowering Device shall be designed to preclude the lifting cable from contacting the power, control or video cabling. In the case where there are dual lowering devices each lifting cable shall not come in contact with the other CCTV's lifting cable, power or video cabling. The only cable permitted to move within the pole or lowering device shall be the stainless-steel lowering cable(s). All other cables must remain secure and separate from the lowering cable(s).
7. The Camera Lowering Device shall support the Camera Assembly a minimum of 20" from the pole.
8. The composite cable between the camera and the CCTV cabinet will be a continuous run with available slack. No pole top interconnections or splices will be permitted.
9. The tenon top shall be a plate mounted tenon that allows for field modification of the arm/camera orientation up to 360 degrees. The tenon shall have mounting holes and slots as required for the mounting of the CLD. Unless otherwise noted, when DUAL mount lowering devices, the mounting slots shall be 180 degrees apart.

10. For dual lowering devices on the same pole the lowering devices shall be designed and installed to work independently of the other. The CLD shall be installed such that the cables from either CCTV will not come into contact with the other's cabling.

9.2.4 Lowering Tool for Camera Lowering Device

The Contractor shall furnish 1 Portable Lowering Tool capable of being operated by a hand winch and an electric drill motor, which is fully compatible with the Camera Lowering Device and the Steel Camera Pole and meets the following requirements:

1. The Portable Lowering Tool shall be one recommended by the manufacturer of the Camera Lowering Device and compatible with the installed CLD.
2. The Portable Lowering Tool shall have a minimum load capacity of 200 lbs. with a 4 to 1 safety factor.
3. The tool shall consist of a lightweight metal frame and winch assembly with cable, a quick release cable connector, an adjustable safety clutch, and a variable speed industrial duty electric drill motor.
4. This tool shall be compatible with the hand hole of the pole and the Camera Lowering Device inside the hand hole.
5. When attached to the hand hole, the tool will support itself and the load assuring lowering operations and provide a means to prevent freewheeling when loaded.
6. The Portable Lowering Tool shall be delivered to the Engineer upon project completion.
7. The Portable Lowering Tool shall have a reduction gear to reduce the manual effort required to operate the lifting mechanism.
8. The Portable Lowering Tool shall be provided with an adapter for operating the lowering device with a portable drill using a clutch mechanism. The Portable Lowering Tool shall be equipped with a positive locking mechanism to secure the cable reel during raising and lowering operations.

9.2.5 Steel Overhead Sign Structure

This section describes the requirements for the span type structures (Sign Bridge) to support the DMS elements.

1. The work to be completed by the Contractor includes the verification of field dimensions, assembly of the component parts and installation including sign span type structures, footings, associated attachment hardware, conduit, wiring, and testing of the structure.
2. The sign structure shall have demonstrated long-term durability to withstand extreme temperatures and weather conditions.
3. Each structure shall be fully warranted for rust, corrosion, and structural failure at a minimum as a complete assembly by the manufacturer for a period of 5 years and prorated for up to 7 years.
4. The following are the DMS structure criteria that must be verified by the Contractor:
    a. Minimum vertical clearance between pavement or shoulder to the lowest DMS or DMS mounting structure component: 20'.

b. The sign design area for wind load shall be 1.5 times the width of the entire roadway under the sign truss times the maximum height of the DMS sign per Section 11.2.7.

c. The DMS Support shall be designed in accordance with the American Association of State Highway and Transportation Officials (AASHTO) standard "LRFD Specifications for Structural Supports for Highway Signs, Luminaries, and Traffic Signals," current issue with interims.

d. Support structure steel shall conform to ASTM A709 Grade 50 or 50W for plates or ASTM A709 Grade 50S for rolled shapes in accordance with Section 908.01 of the TDOT Standard Specifications.

e. Bolts shall conform to ASTM F3125, Grade 325 and Grade 490. Nuts shall conform to ASTM A563. Washers shall conform to ASTM F436. See Section 908.04 of the TDOT Standard Specifications.

f. Foundation steel reinforcement shall be ASTM A615 Grade 60 in accordance with Section 907.01 of the TDOT Standard Specifications.

g. Anchor bolts in foundation shall be ASTM F1554 in accordance with Section 730.11 of the TDOT Standard Specifications. All anchor bolts shall be fitted with 2 heavy hex nuts; all nuts and not less than 10" of the threaded ends of anchor bolts shall be hot-dip galvanized according to ASTM A153.

h. Cast-in-place foundation concrete shall be Class A (f'_c = 3,000 psi) in accordance with Section 604.03 of the TDOT Standard Specifications.

i. Foundation piling shall be in accordance with Section 606 of the TDOT Standard Specifications.

5. The Contractor shall provide to the Engineer additional calculations as necessary to design the connections between DMS and the structure and special attachment details.

6. The sign manufacturer shall consider truck induced wind loading in deflection calculations. The natural frequency response of the structure to truck induced wind loads when span type DMS structures are used shall be considered. More information can be obtained on this subject in the Transportation Research Board (National Research Council) "Truck Induced Wind loads on Variable Message Signs," Research Record No. 1594, published in 1997.

7. The Contractor shall verify the actual length of support columns for all sign structures based on existing field conditions and as indicated on the Plans.

9.2.6 Suspension Unit

1. The Manufacturer shall design the required pole mounting adapters, brackets, and mounting hardware for review and approval by the Engineer.

2. The Camera Lowering Device shall have a minimum load capacity 200 lbs. with a 4 to 1 safety factor.

3. The enclosure receptacle and camera enclosure shall incorporate a mating device.

4. The mating device shall have a minimum of 2 latching devices. These latching devices shall securely hold the camera housing and its control equipment free of vibration or motion between the enclosure receptacle and camera enclosure.

5. The latching devices shall lock and unlock by alternately raising and lowering the camera enclosure.
6. When the camera enclosure is latched, all weight shall be removed from the lowering cable.
7. The enclosure receptacle and camera enclosure shall have a heavy-duty tracking guide.
8. The tracking guide and latching devices shall lock the camera enclosure in the same position each time.
9. Electrical contacts shall be provided to support all camera functions for IP based CCTVs. The electrical contacts shall be brass or copper and be gold coated to prevent corrosion. The contacts shall be minimum 0.09” diameter, or as approved by the Engineer.
10. Replaceable gaskets shall be provided to seal the electrical contacts and latching devices from moisture and dust.
11. The Camera Lowering Device shall be designed to permit a ±3 degree of horizontal adjustment for leveling the dome enclosure.
12. The lowering cable shall be a minimum 5/32” diameter stainless steel aircraft cable with a minimum breaking strength of 1740 lbs.
13. Weights and/or counterweights shall be provided to assure the alignment pin and connectors for the camera connection can be raised into position without binding and that it can be lowered properly.

9.3 Installation Requirements

Contractor shall install all equipment according to the manufacturer’s recommendations and as indicated on the Plans. Materials and associated accessories/adapters shall not be applied contrary to the manufacturer’s recommendations and standard practices.

9.3.1 Pole and Foundation

The camera and detection poles shall be installed as indicated on the Plans and shall conform to the following requirements:

1. All poles shall be installed in accordance with the National Electric Safety Code and AASHTO.
2. Foundations:
    a. Pole foundations shall be constructed at the locations indicated on the Plans. If the field locations of the pole foundations vary from the locations indicated on the Plans, the Contractor shall provide TDOT with the new foundation location and request if new borings are required. New soil borings shall be submitted to TDOT for verification of the foundation design indicated on the Plans. Soil data shall be included as part of the as-built design plan set for the project.
    b. The foundations shall be constructed in accordance with the TDOT Standard Specifications and as indicated on the Plans.
    c. If soil conditions require the use of any shoring, casings, or Sonotube for proper installation of the foundations, the cost of the shoring, casings or Sonotube shall be included in the cost of the pole and foundation.

d. Foundation dimensions and reinforcement details shall be as indicated on the Plans. Pour foundations after setting anchor bolts and reinforcing steel in their proper position.

e. Cast-in-place concrete pole foundation shall cure a minimum of 7 calendar days before any load is applied to the foundation.

f. Foundation piles shall be installed in accordance with Section 606 of the TDOT Standard Specifications.

g. Conduit shall be installed in the pole foundation for access and includes conduit to the nearest pull box as shown on the Plans.

3. A minimum of 1-2" spare conduit shall be installed in all camera pole foundations as shown on the Plans. Spare conduits in pole foundations shall be sealed with blank duct plugs as specified in Section 3.2.10.

4. Grounding System:

    a. The Contractor shall supply and install a grounding system with ground rod array at the base of all poles as shown on the Plans.

    b. The ground rod array system shall be connected to the pole through an appropriate UL listed ground clamp.

    c. A #6 AWG copper stranded bonding wire shall be installed between the pole and the field cabinet providing a common ground system for each site.

    d. All ground bonding wires shall be unspliced.

5. The installation method for the CCTV poles and cameras shall be such that the camera can be rotated as needed around the pole for optimum placement.

9.3.2 Steel Overhead Sign Structure

1. DMS Structures shall be installed according to the manufacturer's recommendations and as indicated on the Plans.

2. Shop drawings for all items associated with the manufacturing, construction, and installation of the DMS sign structure, and its attachments shall be submitted to and approved by the Engineer prior to erection of the DMS sign structure.

3. Materials certifications, including mill test reports, shall be submitted to and approved by the Engineer prior to erection of the DMS sign structure.

4. Foundations:

    a. DMS structure foundations shall be constructed at the locations indicated on the Plans. If the field locations of the DMS structure foundations vary from the locations indicated on the Plans, the Contractor shall provide TDOT with the new foundation locations and request if new soil borings are required. New soil borings shall be submitted to TDOT for verification of the foundation design indicated on the Plans. Soil data shall be included as part of the as-built design plan set for the project.

    b. The foundations shall be constructed in accordance with the TDOT Standard Specifications and the Plans.

c. If soil conditions require the use of any shoring, casings, or Sonotube for proper installation of the foundations, the cost of the shoring, casings or Sonotube shall be included in the cost of the DMS structure and foundation.

d. Foundation dimensions and reinforcement details shall be as indicated on the Plans. Pour foundation after setting anchor bolts and reinforcing steel in their proper position.

e. Cast-in-place concrete DMS structure foundations shall cure a minimum of 7 calendar days before any load is applied to the foundation.

f. Foundation piles shall be fabricated and installed in accordance with Section 606 of the TDOT Standard Specifications.

5. DMS structures shall be grounded in accordance with the DMS and the structure manufacturers' recommendations, TDOT Standard Specifications, and as indicated on the Plans.
6. Incidental paving shall be provided 18" around drilled shaft foundations as indicated on the Plans.
7. Grounding System:

    a. The Contractor shall supply and install a grounding system with ground rod array at the base of all structures as shown on the Plans.

    b. The ground rod array system shall be connected to the pole through an appropriate UL listed ground clamp.

    c. A #6 AWG copper solid bonding wire shall be installed between the structure and the field cabinet providing a common ground system for each site.

    d. All ground bonding wires shall be unspliced.

9.4 Testing Requirements

9.4.1 General Requirements

1. The Contractor shall conduct a project testing program for all materials specified in this section and as required in Section 2.5 of this SP725.
2. All test results shall confirm physical and performance compliance with this SP725.
3. The Contractor shall submit all test results documentation to the Engineer within 7 calendar days of completion of the tests. The Engineer will review test documentation in accordance with the Submittal Review Process in Section 2.7.
4. Payment for all testing is included in the cost of the Pole or Structure.

9.4.2 Factory Acceptance Test

FAT is not required for Poles and Structures.

9.4.3 Bench Test Component

BTC is not required for Poles and Structures.

9.4.4 Bench Test System

BTS is not required for Poles and Structures.

9.4.5 Stand Alone Site Test

SAT shall be performed in the presence of the Engineer. The SAT shall include the following tests and inspections:

1. Verify all components have been installed per manufacturer requirements and the Plans.
2. Verify all items have been attached properly (as per manufacturer recommendations and the Plans) to each other and to the structures.
3. Verify the Poles and Structures have no internal or external damage.
4. Test the functionality of the Portable Lowering Tool for both hand winch operation and electric drill motor operation.
5. Test the functionality of each Lowering Device by fully lowering each camera and raising back up. Verify functionality of the cameras after lowering and raising.
6. Test the functionality of each collapsible railing by raising, locking in position, and lowering the railing back down. The railing shall remain lowered down once testing is complete.
7. A ground resistance test shall be performed at each structure. Ground resistance tests shall be conducted using a 3- or 4-Point Fall-of-Potential method defined by IEEE Standard #81 or other industry approved test method. Each grounding electrode shall be tested prior to connection to the ground system. Resistance-to-Ground of the ground system shall not exceed 10 ohms. Ground resistance measurements shall be conducted in normally dry conditions not less than 48 hours after the latest rainfall. All ground resistance tests shall be conducted in the presence of the Engineer. The Contractor shall document all test recordings and provide a copy of all test reports to the Engineer upon completion in accordance with the Project Submittal Program Requirements in Section 2.7.

9.5 Warranty

All materials specified in this section shall carry a minimum one-year manufacturer's warranty from the date of Final Acceptance against any imperfections in workmanship or materials. Warranties shall cover complete replacement at no charge for the equipment. Warranties shall be transferred to TDOT upon Final Acceptance of the project as per the requirements in Section 2.6 of this specification.

9.6 Method of Measurement

9.6.1 Light Standards (20 FT, 25 FT, 35 FT Pole Height)

Light Standards, for CCTV, RDS, ESS, WIM, and OVDS, will be measured in units of each and paid for at the contract price of each. The bid price shall include but not be limited to a light standard pole, breakaway base, foundation, conduit inside foundation, connections to support structures, satisfactory completion of testing requirements, and all work, equipment, and appurtenances as required to effect the full operation of the light standard site complete, in place, and ready for installation of the CCTV, RDS, ESS, WIM, or OVDS. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

9.6.2 CCTV Pole & Foundation (50FT Pole w/Lwring Device)

CCTV Pole and Foundation (50' Pole) will be measured in units of each and paid for at the contract price per each. The bid price shall include but not be limited to a 50' steel strain pole, foundation, lowering devices (as quantified on the Plans), conduit inside foundation and to the nearest pull box, wiring between pole-mounted devices and field cabinet, connections to support structures, satisfactory completion of testing requirements, and all work, equipment, and appurtenances as required to effect the full operation including remote and local control of the CCTV site complete in place and ready for use. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

9.6.3 CCTV Pole and Foundation (80FT Pole w/Lwring Device)

CCTV Pole and Foundation (80' Pole) will be measured in units of each and paid for at the contract price of each. The bid price shall include but not be limited to a 80' steel strain pole, foundation, lowering devices (as quantified on the Plans), foundation, conduit inside foundation and to the nearest pull box, wiring between pole-mounted devices and field cabinet, grounding, connections to support structures, and satisfactory completion of testing requirements, and all work, equipment, and appurtenances as required to effect the full operation including remote and local control of the CCTV site complete, in place, and ready for use. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

9.6.4 CCTV Pole and Foundation (110FT Pole w/Lwring Device)

CCTV Pole and Foundation (110' Pole) will be measured in units of each and paid for at the contract price of each. The bid price shall include but not be limited to a 110' steel strain pole, foundation, lowering devices (as quantified on the Plans), foundation, conduit inside foundation and to the nearest pull box, wiring between pole-mounted devices and field cabinet, grounding, connections to support structures, and satisfactory completion of testing requirements, and all work, equipment, and appurtenances as required to effect the full operation including remote and local control of the CCTV site complete, in place, and ready for use. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

9.6.5 Lowering Tool for Camera Lowering Device

Lowering Tool for Camera Lowering Device will be measured in units of each and paid for at the contract price of each. The bid price shall include the complete operational device including all attachments. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

9.6.6 Steel Overhead Sign Structure (All Span Lengths)

DMS Structure will be measured in units of each and paid for at the contract price of each. The price shall include but not be limited to support structures, foundations, catwalk, connection hardware, conduit on the structure, conduit inside foundations, grounding, incidental paving and material restoration around the foundations, satisfactory completion of testing, and all work, equipment, and appurtenances as required to have the structure complete, in place, and ready for use. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

9.7 Payment

The contract unit price shall be full compensation for all work specified in this section.

Payment will be made under:

Item No.	Description	Unit
714-08.09	LIGHT STANDARDS (20 FT POLE HEIGHT)	EA
714-08.10	LIGHT STANDARDS (25 FT POLE HEIGHT)	EA
714-08.11	LIGHT STANDARDS (35 FT POLE HEIGHT)	EA
725-20.01	CCTV POLE & FOUNDATION (50FT POLE W/LWRNG DVICE)	EA
725-20.02	CCTV POLE & FOUNDATION (80FT POLE W/LWRNG DVICE)	EA
725-20.03	LOWERING TOOL FOR CAMERA LOWERING DEVICE	EA
725-20.11	CCTV POLE & FOUNDATION (110FT POLE W/LWRNG DVICE)	EA
725-20.21	STEEL OVERHEAD SIGN STRUCTURE (SPANS UP TO 50FT)	EA
725-20.22	STEEL OVERHEAD SIGN STRUCTURE (SPANS 51FT TO 70FT)	EA
725-20.23	STEEL OVERHEAD SIGN STRUCTURE (SPANS 71FT TO 90FT)	EA
725-20.24	STEEL OVERHEAD SIGN STRUCTURE (SPANS 91FT TO 110FT)	EA
725-20.25	STEEL OVERHEAD SIGN STRUCTURE (SPANS 111FT TO 120FT)	EA
725-20.26	STEEL OVERHEAD SIGN STRUCTURE (SPANS 121FT TO 130FT)	EA
725-20.27	STEEL OVERHEAD SIGN STRUCTURE (SPANS 131FT TO 150FT)	EA
725-20.28	STEEL OVERHEAD SIGN STRUCTURE (SPANS 151FT TO 180FT)	EA
725-20.29	STEEL OVERHEAD SIGN STRUCTURE (SPANS 181FT TO 200FT)	EA
725-20.30	STEEL OVERHEAD SIGN STRUCTURE (SPANS 201FT TO 250FT)	EA

The CCTV Pole and Foundation Items, Light Pole Standards Items, and Steel Overhead Sign Structures Items will be paid per each as follows:

1. 25% of the contract unit price upon complete installation of foundations.
2. Additional 45% of the contract unit price upon delivery of poles or structure to the site.
3. Additional 25% of the contract unit price upon satisfactory completion of Stand Alone Site Test of poles or structure.
4. Final 5% of the contract unit price upon Final System Acceptance

Lowering Tool for Camera Lowering Device will be paid at the unit price for each device when delivered to TDOT.

10 CCTV CAMERA SYSTEM

10.1 Description

This Section specifies the minimum requirements for CCTV Camera Systems furnished and installed on this project. The CCTV Camera System selected for use on this project shall be pre-approved and listed on the TDOT ITS Qualified Product List.

The CCTV Camera System will provide TDOT Regional TMC personnel with live streaming video of the roadway network via CCTV Camera Systems installed at locations shown on the Plans. It is the Contractor's responsibility to furnish, program, install, and integrate the CCTV camera system in the field and at the TDOT Regional TMC. The Contractor shall install and integrate CCTV cameras into the existing video display wall and TDOT ATMS software.

The Contractor shall submit a plan for display of the CCTV cameras on the existing video wall equipment and submit it to the Engineer for approval. The Contractor shall work with the video wall manufacturer and the CCTV manufacturer to create a plan for the integration of the cameras into the video wall. This coordination and integration effort shall be included in the cost of the CCTV.

10.2 Materials

Contractor shall provide all materials according to the requirements in the following sections.

All equipment shall be new and constructed using the highest quality, commercially available components and techniques to assure high reliability and minimum maintenance. Prior to installation, the Contractor shall submit and receive approval from the Engineer on a complete set of shop drawings of all the equipment and components listed within this Special Provision and included as part of the installation.

The firmware pre-installed on the device shall meet the minimum version listed in APPENDIX D at the time of device installation in the field.

10.2.1 General Capabilities and Performance Requirements

1. Overall CCTV Camera System capabilities and performance requirements include the following:
    a. CCTV Camera System shall be placed at fixed locations as shown on the Plans to provide coverage within the project limits including the mainline travel lanes and shoulders.
    b. The CCTV Camera System components shall be compatible with each other and be of rugged design and suitable for reliable operation when mounted in the configuration as specified in this SP725 and the Plans.
    c. The CCTV Camera System shall be capable of attended and unattended, continuous twenty-four hours per day operation at the sites as shown on the Plans.
2. The CCTV Camera System shall respond to camera control signals from an operator of the system and transmit video images to remote locations interfaced to the system for observation.
3. The camera shall be fully digital, IP addressable, and compliant with the H.264 video encoding standard.

4. The camera shall operate over wide dynamic light conditions ranging from low light/dusk to full sunlight having day (color)/night (monochrome) switchover and iris control, with user-selectable manual and automatic control capabilities.
5. The CCTV Camera System shall be capable of being remotely controlled and programmed.
6. The camera shall be mounted together with the zoom lens and integrated into the pan and tilt device within the enclosure forming a totally integrated, easily removable assembly.
7. The camera shall include a high-quality integrated camera/lens combination.
8. The camera shall be equipped with an auto-iris lens capability compatible with the zoom lens supplied.
9. Iris capability shall include a provision for manual override via software.
10. The camera shall be capable of auto-focus during zoom-in or zoom-out, with provisions for override via software.
11. Overexposure protection shall be provided – the camera shall not be degraded or damaged under normal reasonable operating conditions.
12. The capability for local control of pan, tilt, and zoom functions shall be provided at the ITS equipment cabinet using vendor-supplied software installed on a laptop computer.
13. The camera shall have image stabilization to reduce image jitter during viewing of the video.

10.2.2 IP Camera Unit

The minimum IP Camera Unit requirements include:

1. **Image Sensor Size**: Not less than Diagonal 6mm (1/3” type).
2. **Image Resolution**: Not less than 1280 x 720.
3. **Day/Night Operation**: Adjustable (Auto, Color, and Mono Modes) via removable IR cut filter.
4. **Maximum Lens Aperture**: Not less than f/1.6 (wide) to f/2.8 (tele).
5. **Optical Zoom Range**: Not less than 30X.
6. **Optical Zoom Speed**: 2 speeds.
7. **Horizontal Angle of View**: Optical: Not less than 55.2 degrees to 3.2 degrees.
8. **Minimum Focus Distance**: Not greater than 0.01m (wide), 1.0m (tele).
9. **Auto Focus**: Selectable Auto/Manual, Minimum Scene Illumination for Reliable Auto Focus shall be no more than 50% video output.
10. **Manual Shutter**: Selectable.
11. **Auto Iris**: Selectable auto/manual, Iris shall automatically adjust to compensate for changes in scene illumination to maintain constant video level output within sensitivity specifications.
12. **Sensitivity**: Scene Illumination minimums, F1.6 @ 50% Video
    a. 1.8 Lux (0.18 fc) @ 1/30 shutter, color mode
    b. 0.1 Lux (0.01 fc) @ 1/30 shutter, mono mode

10.2.3 H.264/MJPEG Encoding Engine

The IP Camera Positioning System (IPCPS) shall fully integrate within its enclosure an H.264/MJPEG encoding component with functions as specified below. The Contractor may submit a nonintegrated solution installed in the traffic control cabinet or separate CCTV cabinet if it provides the same capabilities and is hardened for extreme temperatures, under approval by the Engineer.

1. **Video Encoding**: H.264 (Main Profile/Level 3.1) and MJPEG standards.
2. **Video Streams**: 2 independently configurable streams: 1 H.264 and 1 MJPEG.
3. **Video Stream Configuration Properties**:
    a. Stream Settings:
        i. Video Stream 1: H.264.
        ii. Video Stream 2: MJPEG.
    b. Video Resolution: Not less than 480p and 720p.
    c. Streaming Mode: Capable of selectable CBR or VBR.
    d. Frame Rates: 30, 15, 7, 4, 2, 1 fps.
4. **Data Rate**: Adjustable in a range of not more than 256 Kbps up to 8 Mbps for streaming video.
5. **Connection Types**: Uni-cast and multi-cast.
6. **IPCPS Video Latency**: <150ms.
7. **Supported Network Protocols**: RTP, RTSP, UDP, TCP, IP, DHCP, DNS, HTTP, HTTPS, ARP, ICMP, IGMPv2 and SNMPv2c/v3 as a minimum.

10.2.4 Positioning Drive

1. **Pan Movement**: 360 degrees continuous rotation.
2. **Pan Speed**: Variable from 0.1 to 90 degrees/second or better.
3. **Pan Repeatability**: +/- 0.25-degree precision or better.
4. **Pan Preset Speed**: 180-degree movement < 2 Seconds.
5. **Tilt Movement**: Minimum of +90 to –90 degrees.
6. **Tilt Speed**: Variable from 0.1 to 45 degrees/second or better.
7. **Tilt Repeatability**: +/- 0.25-degree precision.
8. **Tilt Preset Speed**: 180-degree movement < 3 Seconds or better.

10.2.5 Operational

1. The CCTV camera shall utilize NTCIP 1205 v01.08 communication protocol.
2. **Presets**: Minimum of 64, with each preset consisting of a pan, tilt, zoom, and focus coordinate.
3. **Preset Tours**: Minimum 8 tours required, each tour shall consist of up to 32 pre-programmed presets, with individual dwell time property per preset per tour.

a. Tour presets shall be useable in any order.

b. Presets may be used multiple times in tour.

c. Tours shall stop upon receipt of any pan/tilt positioning command.

d. Tour data shall be stored in non-volatile memory and shall not be lost if a power failure occurs.

4. **Sector Zones**: Provide a minimum of up to 16 user defined sector zones with each zone having a unique 24-character ASCII title programmed for description purposes.

5. **Camera Site ID**: Provide up to 2 lines of up to 24 ASCII characters each on video for user site description ID. If both lines are programmed, line 1 of ID shall always appear above line 2 regardless of top or bottom selection.

6. **Preset ID**: Provide 1 line of up to 24 ASCII characters on video for Preset ID description. When a preset position is recalled the corresponding preset ID shall be displayed. The preset ID shall remain displayed until a pan, tilt, zoom, manual focus, auto focus select, or another preset command is received.

7. **Scalable Zoom**: Variable speed pan/tilt ranges based off zoom position. This adds the capability of limiting the maximum pan/tilt speed, while maintaining variable speed capability, throughout the zoom range of the camera.

8. **Updates**: The IPCPS shall allow updates of firmware for new features via the Ethernet network communication channel. An internal IPCPS web server shall be provided for performing this task.

9. The IPCPS shall return to previous position and state of operation upon power loss and restoration.

10.2.6 IP Management

The IPCPS shall provide at minimum the following network configuration properties.

1. **IP Configuration**: DHCP or Static IP address entry.
2. Net mask address entry.
3. Gateway address entry.

10.2.7 Power Input

The IPCPS shall fully comply with and include independent laboratory test results confirming compliance with the following electrical operating conditions.

1. **Power**: <100 Watts Maximum.
2. **Operating Voltage**: 24VAC.
3. The nominal voltage shall be 120VAC per NEMA-TS2.

10.2.8 Mechanical

1. **Connectors**: weatherproof non-corrosion type.
2. **Weight**: Maximum 25lbs.

3. **Construction**: Light Colored Powder Coated aluminum, all internal and external parts corrosion protected, stainless steel fasteners.
4. Faceplate shall be optically correct glass.
5. **Camera Mount**: Provided to match pole locations on the Plans. See the Plans for variable types of poles.
6. Camera housing shall be equipped with a 1.5” NPT pipe thread to allow for connection to the Camera Lowering Device connection box.

10.2.9 Environmental

The IPCPS shall fully comply with and include independent laboratory test results confirming compliance with the following environmental operating conditions.

1. **Temperature**: The operating ambient temperature range shall be from -34°C to 60°C.
2. **Vibration**: Per Nema-TS2, 5-30Hz sweep @ 0.5g applied in each of 3 mutually perpendicular planes.
3. **Shock**: Per Nema-TS2, 10g applied in each of 3 mutually perpendicular planes.
4. **Water Spray**: Per IEC 60529+A1, 1999, Solid water stream delivered thru 12.5mm nozzle @ 25 gallons/minute @ 9ft for 3 minutes.
5. **External Icing**: Per Nema-TS2 250-2003.
6. **Corrosion Protection**: Per NEMA 250-2003.
7. **Humidity**: The IPCPS shall withstand the effects of humidity up to 100% without condensation forming inside the unit.
8. **Minimum Standards**: IP66.

10.2.10 Certifications

1. CE (24VAC).
2. FCC Class A.

10.2.11 Surge Protection

All CCTV Camera System electrical interconnects shall be protected from transient over-voltages (surges) including lightning and external electromagnetic fields coming into the cabinet. All cables shall be protected from a surge coming in on the ground and load side of the cabinet. The minimum surge protection requirements include:

1. Surge protectors shall be furnished for all non-dielectric cable and conductors (video, data/signal, and device/assembly power) between the CCTV Camera System and the equipment cabinet.
2. The surge protectors shall have leads that are kept to a minimum length as recommended by the surge device manufacturer.
3. All surge protection devices shall be designed and selected to meet the temperature and humidity requirements specified in section 10.2.9. Surge suppressors including variable temperature components (i.e., PTCs) shall not impede signals at any elevated temperatures.

4. All Surge protectors shall be U.L. listed (UL 1449 Current Edition, UL 497, 497A, 497B,) and bonded to the same single-point ground point. Any DIN rail mounted SPDs shall be grounded via conductor and shall not rely solely upon the DIN rail's mechanical connection as a grounding point.
5. Any directional SPDs shall be clearly marked as "Protected Side" and "Unprotected Side" and installed such that the Protected Side faces the equipment, and the Unprotected Side faces the conductors coming into the cabinet.
6. Low Voltage/Signal Cable Surge protectors for data/signal/control cable shall meet/provide the following functionality:
    a. **Peak Surge Current**: 10,000-amperes for an 8x20 microsecond waveform.
    b. Shall be rated for the appropriate voltage.
    c. **Response Time**: 1 nanosecond or less.
    d. **Life Expectancy**: Capable of surviving at a minimum of 25 occurrences at 2000-amperes.
    e. Surge suppressor shall be self-resetting.
7. CCTV power surge protectors for power from equipment cabinet power distribution to the CCTV Camera System shall meet/provide the following functionality:
    a. **Frequency**: DC to 10MHz.
    b. **Clamping Voltage**: < 30VAC (rms) or 42VDC.
    c. **Insertion Loss**: < 0.2dB.
    d. **Input/Output Impedance**: 75 ohms, typical.
    e. **Peak Surge Current**: 3000-amperes.
    f. **Response Time**: 1 nanosecond or less.
    g. Surge suppressor shall be self-resetting.

10.3 Installation Requirements

Contractor shall abide by the installation requirements in the following sections. All equipment shall be installed according to the manufacturer's recommendations, the Plans and as follows:

1. Materials and associated accessories/adapters shall not be applied contrary to the manufacturer's recommendations and standard practices.
2. Shall include all materials needed to permanently mount the CCTV camera to the support structure as indicated on the Plans.
3. Furnish and install power, video, and data cables, and any and all ancillary equipment required to provide a complete and fully operational CCTV system site.
4. Verify all wiring meets NEC requirements where applicable.
5. All above requirements apply to both new CCTV sites as well as sites where an existing CCTV is being replaced under the contract.

6. Cameras shall be mounted in positions which allow 360-degree continuous rotation and mounting arm position shall be as indicated on the Plans and approved by the Engineer prior to pole placement.
7. Furnish and install all appropriate field surge protection devices and ensure proper ground per manufacturer recommendations.
8. Coordinate with TDOT Regional TMC IT for IP addresses, and video encoding settings for all CCTV camera sites prior to turn-on/installation and site testing.
9. The CCTV system shall be compatible with and integrated by the contractor into the existing TDOT Regional TMC video wall and TDOT ATMS software. It shall be the Contractor's responsibility to coordinate with the TDOT Regional TMC operations personnel for Contractor integration of the new CCTV cameras into the existing video wall and TDOT ATMS software. It is the Contractor's responsibility to integrate and test all PTZ control and video display of the cameras at the TDOT Regional TMC.

10.4 Testing Requirements

10.4.1 General Requirements

1. The Contractor shall conduct a project testing program for all materials specified in this section and as required in Section 2.5 of this SP725.
2. All test results shall confirm physical and performance compliance with this SP725.
3. The Contractor shall submit all test results documentation to the Engineer within 7 calendar days of completion of the tests. The Engineer will review test documentation in accordance with the Submittal Review Process in Section 2.7.
4. Payment for all testing is included in the cost of the CCTV Camera System.

10.4.2 Factory Acceptance Test

FAT is not required for CCTV Camera System.

10.4.3 Bench Test Component

BTC shall be performed in the presence of the Engineer. The BTC shall include the following tests and inspections:

1. Verify the Camera has no internal or external damage.
2. Test all Camera functionality including pan, tilt, zoom, iris, and focus to verify functionality.

10.4.4 Bench Test System

BTS shall be performed in the presence of the Engineer. The BTS shall include the following tests and inspections:

1. Verify Camera attachment compatibility with the camera lowering device.
2. Verify that the Camera is compatible and supports operational interoperability with the communication equipment, TDOT ATMS software, and any existing equipment at the camera site.

10.4.5 Stand Alone Site Test

SAT shall be performed in the presence of the Engineer. The SAT shall include the following tests and inspections:

1. Verify all components have been installed per manufacturer requirements.
2. Verify all items have been attached properly (as per manufacturer recommendations and the Plans) to each other and to the Pole Structure.
3. Verify the Camera has no internal or external damage.
4. Verify the Camera has been properly connected to the UPS for continuous, conditioned power.
5. Verify the Camera and cabinet equipment are protected by surge suppression.
6. Verify local PTZ, iris, and focus control.
7. Verify PTZ, iris, and focus control through the local Ethernet Switch.

10.5 Warranty

All materials specified in this section shall carry a minimum three-year manufacturer's warranty from the date of Final Acceptance against any imperfections in workmanship or materials. Warranties shall cover complete replacement at no charge for the equipment. Warranties shall be transferred to TDOT upon Final Acceptance of the project as per the requirements in Section 2.6 of this specification.

10.6 Method of Measurement

10.6.1 CCTV Camera System (Pan Tilt & Zoom)

CCTV Camera System will be measured in units of each and paid for at the contract price per each. The bid price shall include furnishing, installing, successful device integration, documentation, and testing of a complete CCTV Camera System including the CCTV Camera Assembly, positioner unit, zoom lens, enclosure, camera controller/receiver, required data and power cables, surge protectors and conduit between the camera and the cabinet, connections to support structures, attachment hardware and brackets and all incidental items to provide and install the CCTV Camera System as intended, as well as the satisfactory completion of all testing requirements and all work, equipment, and appurtenances as required for a full CCTV Camera System. The bid price shall also include all local configuration and control manufacturer software, system documentation including shop drawings, operations and maintenance manuals, wiring diagrams, block diagrams and other materials necessary to document the operation of the CCTV Camera System. The bid price shall include integration and configuration into the existing TDOT Regional TMC video wall and TDOT ATMS software, testing for camera control, and display of the video on the existing video wall. This price shall be full compensation for all labor, tools, materials, equipment, software development and incidentals necessary to complete the work and integrate the CCTV Camera system into the existing TDOT ATMS software platform.

10.7 Payment

The contract unit price shall be full compensation for all the work specified in this Section.

Payment will be made under:

Item No.	Description	Unit
725-20.91	CCTV CAMERA SYSTEM (PAN TILT & ZOOM)	EA

The CCTV Camera System will be paid per each as follows:

1. 50% of the contract unit price upon approval of Bench Test Component and Bench Test System test results.
2. Additional 20% of the contract unit price upon approval of Stand Alone Site Test results.
3. Additional 20% of the contract unit price upon approval of Conditional System Acceptance Test results including CCTV video display on existing video wall.
4. Final 10% of the contract unit price upon Final System Acceptance.

11 DYNAMIC MESSAGE SIGN

11.1 Description

This Section describes furnishing, installing, successfully integrating, and testing full color matrix Dynamic Message Sign (DMS) assemblies that may be mounted on a full span structure over the roadway, butterfly structure on the side of the road, or to a static sign structure. The Contractor shall supply a complete operating Light Emitting Diode (LED) sign including the sign case, sign controller unit (SCU), road side DMS controller cabinet, all cabling, conduits, electrical service, surge suppression, and all hardware associated with a complete installation as required by this SP725.

The DMS assemblies will provide TDOT Regional TMC personnel with a means to visually communicate with motorists regarding any incidents, accidents, special events, travel times, graphical representations of common road and construction signs, and the use of those graphics for lane management of the roadway during the roadway construction project. The DMS system shall also include manufacturer software that allows the creation, placement, and display of graphics on the DMS. This software shall be provided by the Contractor to TDOT Regional TMC IT to install on the TDOT Regional TMC Server with TMC operator access to the DMS field controller to allow display status and operational status.

11.1.1 Walk-In Dynamic Message Sign

The general purpose of the Walk-In DMS is to disseminate traveler information on a freeway from the TDOT Regional TMC including incident, construction, special event, and travel time information.

11.1.2 Front Access Dynamic Message Sign

The general purpose of the Front Access DMS is to disseminate traveler information on an arterial from the TDOT Regional TMC including incident, construction, special event, and travel time information. Front Access DMS shall not be mounted over lanes of traffic.

11.1.3 Travel Time Message Sign

The general purpose of the Travel Time Message Sign (TTMS) is to provide travel times on a fixed route that is stated on the accompanying static sign.

11.1.4 Over Lane Dynamic Message Sign Array

The general purpose of the Over Lane DMS Array is to disseminate lane control signs and variable speed limits from the TDOT Regional TMC on a lane-by-lane basis with one Over Lane DMS provided over each lane.

11.1.5 Over Shoulder Dynamic Message Sign

The general purpose of the Over Shoulder DMS is to disseminate lane control signs and variable speed limits from the TDOT Regional TMC with one Over Shoulder DMS provided over the right shoulder where Over Lane DMS are provided.

11.2 Materials

Contractor shall provide all materials according to the requirements in the following sections.

All equipment shall be new and constructed using high quality, commercially available components and techniques to assure high reliability and minimum maintenance. Prior to installation, the Contractor shall submit and receive approval from the Engineer on a complete set of shop drawings of all the equipment and components listed within this Special Provision and included as part of the installation.

The firmware pre-installed on the device shall meet the minimum version listed in APPENDIX D at the time of device installation in the field.

11.2.1 General

1. Each DMS assembly, regardless of use type, shall consist of the following minimum components and meet the following general requirements:

    a. Full color matrix LED sign.

    b. Mounting brackets.

    c. Associated SCU and software.

    d. Cabling between the various components.

    e. All electrical components shall be of the solid-state design. Use of vacuum or gaseous tube devices is not acceptable.

2. Provide door locks for all DMS cabinet doors, keyed to TDOT standard specified in Section 8.2.1 of this SP725. Provide 2 keys with each DMS location. If the DMS is a Walk-In type, the sign case doors shall include locking doors that use the same key as the associated DMS cabinet.

3. Provide a voltage label on all sign cases and DMS cabinets or enclosures in accordance with the NEC labeling requirements. Voltage labels shall meet the following minimum requirements:

    a. Labels shall be flat black lettering on a reflective yellow background. Lettering shall be a minimum of 1” in height.

    b. Labels shall be manufactured from pre-coated adhesive backed reflective sheeting material meeting the minimum requirements of AASHTO M268 Type 1.

    c. Labels shall include the voltages entering the cabinet and shall be one continuous adhesive sheet. Examples are “120VAC” or “120/240VAC”.

    d. Labels shall be installed on all sign cases and DMS cabinet doors.

4. Pixel columns and rows shall be perpendicular. The Pixel Matrix shall meet the following requirements per housing type:

    a. Walk-In DMS shall have a minimum of 96 rows x 400 columns

    b. Front Access DMS shall have a minimum of 80 rows x 272 columns

    c. TTMS shall have a minimum of 24 rows x 64 columns

    d. Over Lane DMS Array shall have a minimum of 64 rows x 48 columns

e. Over Shoulder DMS shall have a minimum of 64 rows x 80 columns

11.2.2 Sign Display

The sign display shall meet the following requirements:

1. Each sign display shall have a single plane surface constructed of a single array of pixels.
2. Each sign display shall be a full color matrix display.
3. The DMS system shall include manufacturer's central control software.
4. Each sign display shall be able to display full color, a minimum of 24-bit displayable color.
5. The DMS shall be capable of displaying graphics.
6. Vertical and horizontal spacing between pixel centers shall be equal.
7. A black border painted with semi-gloss PVDF or other outdoor-rated material shall surround the LED pixel array.
8. Provide an automated light intensity measurement through electronic light sensors that can be easily maintained. The sensors shall be mounted in a manner to measure front, rear, and ambient light conditions to set brightness levels.

11.2.2.1 Walk-In DMS

1. Sign display shall be able to display three lines of twenty-one 18" tall characters that adhere to the respective MUTCD font sizes for electronic changeable massage signs.
2. Pixel spacing shall be such that 3 lines of text shall each have a nominal height of 18" with appropriate inter-line spacing.
3. Sign shall be able to display graphic shapes including arrows, roadway signs, and interstate shields, each of which can be designed and/or altered by the user through the supplied software.

11.2.2.2 Front Access DMS

1. Sign display shall be able to display three lines of twenty-one 12" tall characters that adhere to the respective MUTCD font sizes for electronic changeable massage signs.
2. Pixel spacing shall be such that 3 lines of text shall each have a nominal height of 12" with appropriate inter-line spacing.
3. Sign shall be able to display graphic shapes including arrows, roadway signs, and interstate shields, each of which can be designed and/or altered by the user through the supplied software.

11.2.2.3 TTMS

1. Sign display shall be able to display one line of three 18" tall characters that adhere to the respective MUTCD font sizes for electronic changeable massage signs.

11.2.2.4 Over Lane DMS Array

1. Sign display shall be able to display three lines of three 12” tall characters that adhere to the respective MUTCD font sizes for electronic changeable massage signs.

2. Sign shall be able to display graphic shapes including lane status, variable speed limits, and HOV designations, each of which can be designed and/or altered by the user through the supplied software.

11.2.2.5 Over Shoulder DMS

1. Sign display shall be able to display three lines of six 12” tall characters that adhere to the respective MUTCD font sizes for electronic changeable massage signs.

2. Sign shall be able to display graphic shapes including lane status and variable speed limits, each of which can be designed and/or altered by the user through the supplied software.

11.2.3 Character Set

The signs shall support the following character display requirements:

1. Characters and/or shapes shall be formed on a matrix comprised of rows and columns forming a continuous line.

2. Individual characters shall be formed by pixels within a character matrix defined by the character font.

3. All upper-case characters shall be displayed over the entire height of each character matrix.

4. Character to character spacing shall be determined by the font selected by the user.

5. Lower case lettering – Lower case letters that extend below the bottom (ex. G, j, p, q, y) must be proportioned in location and style per line.

6. Both fixed-space and proportional spaced fonts shall be supported.

7. Each sign shall be able to display a message composed of any combination of the following characters and shapes:

    a. All upper-case letters “A” through “Z”.

    b. All lower-case letters “a” through “z”.

    c. All decimal digits “0” through “9”.

    d. A blank or space.

    e. Punctuation marks shown in brackets [. , ! ? – ‘ “ / ( )].

    f. Special characters shown in brackets [# $ % & * + < >].

    g. 32 (or more) special graphic shapes, each of which can be designed and/or altered by the user.

8. Character height to stroke width ratio and character spacing shall be designed and constructed to achieve optimum legibility.

9. Character sets shall be submitted for review and approval.

10. Pixel size, pixel center-to-center distance, character height to stroke width ratio, and character spacing shall be designed and constructed to achieve legibility at 900'with a standard 18" font.

11.2.4 Physical Properties

The sign physical properties shall meet the following requirements:

1. The sign design shall allow unobstructed and convenient access to all non-structural components. Structural components are defined as the metal sign case and polycarbonate or similar display cover with UV inhibitors to protect the LED display matrix and display cover itself from the effects of UV exposure.

2. All serviceable components shall be modular, interchangeable, and removable from within the sign case.

3. The sign display shall be composed of identical and readily interchangeable display modules and drivers.

4. Each display module shall contain 1 or more display pixels.

5. The replacement of any display module shall not require the use of any special tools.

6. All wiring interconnecting individual display modules shall be modular harness assemblies with latching push-on/pull-off or twist on/off connectors.

7. The removal of any combination of 1 or more display modules shall not alter the structural integrity of the sign display assembly, nor of the sign case.

8. The removal of any combination of display modules shall not affect the operation of the remaining operational modules in any way.

9. The performance of the sign shall not be impaired due to vibration caused by wind, traffic, or any other source.

10. All serviceable components shall weigh 50 lbs. or less.

11. Mating connectors shall be designated by the connector number and male/female relationship. Connectors shall be keyed or pinned to prevent improper insertion of the wrong connector or PCB.

12. Access for all maintenance shall be:

    a. From within the sign case and from the rear (i.e., the side opposite of the display surface) of the sign display for Walk-In DMS.

    b. From within the sign case and from the front of the sign display for Front Access DMS, TTMS, Over Lane DMS Array, and Over Shoulder DMS.

11.2.5 Pixels

Each pixel shall meet the following requirements:

1. Each pixel shall contain the quantity of discrete LEDs needed to output white colored light at a minimum of 12,400 Candelas/m2 (white).

2. The number of necessary LED's shall be determined by the Vendor and be provided to the Engineer for approval.

3. Pixel to pixel luminous intensity shall not vary by more than a 2:1 ratio.

4. The optical axis of all pixels shall be perpendicular to the face of the sign display.

5. Pixels shall be replaceable either individually or in groupings. Groupings with 3 or more pixels shall be permitted only if bench level repairs and replacements to individual pixels are possible.

6. The failure of an LED in 1 string within a pixel shall not affect the operation of any other string or pixel.

7. Pixel Pitch shall be 20 mm (0.81").

8. Pixel power shall not exceed 1.5W per pixel, including the driving circuitry.

11.2.6 LED Technology

LEDs used to form a display pixel shall meet the following minimum requirements:

1. The manufacturer shall be the same for all LEDs in all signs.

2. The LED manufacturer shall perform color and intensity sorting to the bins. Each color and intensity of the LED's shall be obtained from no more than 2 consecutive color 'bins' as defined by the LED manufacturer.

3. Each LED driver board shall be microprocessor controlled and shall communicate with the sign controller on a wire or fiber optic communications network using an addressable network protocol. The microprocessor shall process commands from the sign controller to display data, perform diagnostics, and report pixel status.

4. Red LEDs shall utilize AlInGaP (Aluminum Indium Gallium Phosphide) semiconductor technology and shall display a red color at a wavelength of 615 nm – 635 nm (± 5 nm).

5. Green LEDs shall utilize InGaN (Indium gallium nitride) semiconductor technology and shall display a green color at a wavelength of 520 nm – 540 nm (± 5 nm).

6. Blue LEDs shall utilize InGaN (Indium gallium nitride) semiconductor technology and shall display a blue color at a wavelength of 460 nm – 480 nm (± 5 nm).

7. The LED shall have a nominal viewing cone of 30° with a half-power angle of 15° measured from the longitudinal axis of the LED. Viewing tolerances shall be a specified in the LED manufacturer's product specifications and shall not exceed ± 5°. The LED display face shall have color uniformity and consistency within the 30° cone of vision, with no visible inconsistent color shifts or intensity.

8. The LED display matrix shall be clearly visible and legible from distances between 150 feet and 1,000 feet from the DMS front face under normal freeway operating conditions during daylight hours with direct sunlight on the face and behind the DMS.

9. The LED display matrix shall maintain a minimum of 12,000 candelas per square meter minimum (white) for full color displays when measured using a photometric meter through the DMS front face panel assembly.

10. The LED size shall be 0.20” maximum.

11. The luminous output shall be a minimum of 3,000 mcd luminous intensity at 20 mA forward current.

12. Current flow through any LED shall not exceed the following values under any light output level:

    a. RMS current of 25 mA.

    b. Peak current of 30 mA.

13. LED life shall be nominally rated for 100,000 hours of continuous operation under field conditions while maintaining a minimum of 70% of the LED’s initial light output.

14. To maximize LED service life, LED drive currents will not be allowed to exceed the manufacturer’s recommendations for the 100,000-hour life but shall be sufficient to supply the required intensity.

15. The LED pixels shall be directly driven using pulse width modulation (PWM) of the drive current to control the display intensity. This LED driver circuitry shall vary the current pulse width to achieve the proper display intensity levels for all ambient light conditions. The drive current pulse shall be modulated at a frequency high enough to provide flicker-free operation and a minimum of 200 brightness levels.

11.2.7 Sign Case

The DMS Sign Case shall meet the following requirements:

1. All steel components shall be stainless steel, unless otherwise noted in these specifications.

2. The sign case and structural connection shall be designed in accordance with the American Association of State Highway and Transportation Officials (AASHTO) standard “LRFD Specifications for Structural Supports for Highway Signs, Luminaries, and Traffic Signals,” current issue with interims. The Dynamic Message Signs shall conform with High Risk Category as defined by this standard. Design wind load shall be based on 120 mph wind with a 1.14 gust effect factor. Enclosure walkway shall support a load per AASHTO LRFD specifications for Highway Signs section 3.6, Live Loads. All sign case and structural drawings shall be stamped by a Professional Engineer registered in the State of Tennessee.

3. Be attached to and become an integral part of the support structure.

4. The sign case shall present a clean, unbroken, neat appearance.

5. The front of the sign case shall not have any visible text or logos on it.

6. The sign case shall be weatherproof and protect the interior from moisture, dust, dirt, and corrosion.

7. Positive corrosion protection shall be provided between dissimilar metals.

8. The sign case shall be constructed of aluminum sheeting to be 5052-H32 and structural members to be 6061-T6.

9. Aluminum sheeting shall be not less than 1/8” thick with all seams continuously welded by the inert gas process.

10. The front of the sign case shall have a flat black matte finish applied in accordance with American Architectural Manufacturers Association (AAMA 2605) with an expected outdoor service life of 10 to 15 years.

11. All other surfaces shall have a bare aluminum mill finish.

12. Weep holes shall be provided to allow moisture to escape.

11.2.7.1 Walk-In DMS

1. Sign case shall be a walk-in type, weatherproof enclosure that houses electrical, communication, and electronic control devices necessary for the operation of the sign.

2. The angular alignment of the sign case shall be adjusted in the vertical direction down by 3º and incorporated into the face of the display to leave the internal walkway as level as possible. If the sign can only be tilted using external brackets to the case, provisions shall be made to make the internal walkway level.

3. The sign case shall have an interior, non-skid walkway where the walkway shall extend the entire length of the sign case.

4. The unobstructed inside walkway shall be at least 24” wide and at least 6’-3” high.

5. Sign case shall have 2 lifting eyes for placement of sign on structure.

6. Complete sign, including casing, all peripherals and electronics shall weigh no more than 4200 lbs.

7. Total sign case dimensions shall not exceed:

    a. Width: 31’ (9.44 m).

    b. Height: 9’ (2.74 m).

    c. Depth: 4.5’ (1.4 m).

11.2.7.2 Front Access DMS

1. Sign case shall have 2 lifting eyes for placement of sign on structure.

2. Complete sign, including casing, all peripherals and electronics shall weigh no more than 1500 lbs.

3. Total sign case dimensions shall not exceed:

    a. Width: 19’ (5.79 m).

    b. Height: 7’ (2.13 m).

    c. Depth: 2’ (0.61 m).

11.2.7.3 TTMS

1. Complete sign, including casing, all peripherals and electronics shall weigh no more than 70 lbs.

2. Total sign case dimensions shall not exceed:

    a. Width: 4.5’ (1.37 m).

    b. Height: 2.5’ (0.76 m).

    c. Depth: 0.5’ (0.15 m).

11.2.7.4 Over Lane DMS Array

1. Sign case shall have 2 lifting eyes for placement of sign on structure.

2. Complete sign, including casing, all peripherals and electronics shall weigh no more than 250 lbs.

3. Total sign case dimensions shall not exceed:

    a. Width: 4’ (1.22 m).

    b. Height: 5’ (1.52 m).

    c. Depth: 0.5’ (0.15 m).

11.2.7.5 Over Shoulder DMS

1. Sign case shall have 2 lifting eyes for placement of sign on structure.

2. Complete sign, including casing, all peripherals and electronics shall weigh no more than 300 lbs.

3. Total sign case dimensions shall not exceed:

    a. Width: 6.5’ (1.98 m).

    b. Height: 5’ (1.52 m).

    c. Depth: 0.5’ (0.15 m).

11.2.8 Access Door

Walk-In DMS signs shall have at least one access door. Access doors shall meet the following requirements:

1. Access to the interior of the sign case shall be via a gasketed door that opens out. Door size should be no larger than 25”.

2. The door shall be in the side of the sign case nearest the right shoulder of the road and the catwalk when looking at the sign face. A door may also be required on the side of the sign case nearest the left shoulder of the road and catwalk when looking at the sign face as indicated on the Plans.

3. The door, latches, and locks shall be engineered in such a way that the door can always be opened from inside of the sign to prevent a technician from being locked in the sign case.

4. The door latching mechanism shall be a three-point roller type.

5. The door latching pushrods shall be turned edgewise at the outward supports and have a cross section of 0.25” thick by 0.75” wide, minimum.

6. Gasketing shall be provided on all door openings and shall meet the following requirements:

    a. Be dust tight.

    b. Meet NEMA 3R requirements.

    c. Permanently bonded to the door metal.

    d. Shall not stick to the mating metal surface.

7. A gasket top channel shall be provided to support the top gasket on the door (in order to prevent gasket gravitational fatigue).

8. When the door is closed and latched, the door shall be locked. The lock shall meet the following requirements:

    a. The lock and lock support shall be rigidly mounted on the door.

    b. In the locked position, the bolt throw shall extend a nominal 0.25” into the latch cam area.

    c. A lid or seal shall be provided to prevent dust or water entry through the lock opening.

    d. The locks shall be as specified in Section 8.2 of this SP725.

e. Two keys shall be supplied with each lock.

f. The keys shall be removable in the locked position only.

g. The locks shall have rectangular, spring-loaded bolts.

9. The door shall have catch mechanism that can hold the door open at 90° in 60 mph wind acting at an angle perpendicular to the plane of the door.

11.2.9 Sign Case Ventilation

The sign case shall include ventilation system that meets the following requirements:

1. Louvered vents or hoods shall be installed in the back or side walls of the sign case.

2. No vent(s) or hood(s) shall be installed in the door.

3. Ventilation openings shall be louvered or hooded.

4. Ventilation openings shall be covered with screens to prevent the entrance of birds or insects.

5. The number and size of louvered vents shall be determined by the DMS manufacturer to be of sufficient size to provide adequate ventilation.

6. Air filters shall be installed behind each vent and shall meet the following requirements:

   a. Replaceable industrial grade, Merv 6 rated.

   b. Shall completely cover the vent opening area.

   c. Shall be manufactured per ASHRAE Standard 52.2, latest version.

   d. Shall be of fire retardant and water-resistant construction, able to withstand temperatures up to 200ºF.

   e. Filter replacement is to be accomplished without tools with easy access.

7. The sign case shall be equipped with 1 or more fans that meet the following requirements:

   a. Positive pressure ventilation system.

   b. The continuous duty electric fans shall include ball or roller bearings.

   c. Sign case venting fan(s) shall have a minimum combined capacity to keep the signs housing internal temperature to a maximum of 30ºF above external ambient temperature.

   d. The sign shall be equipped with a minimum of 1 ambient temperature sensor, 1 internal temperature sensor, and 1 sensor that measures relative humidity of the air inside the housing. Mount the sensors such that they will never be in direct sunlight, and easy to maintain/replace. All sensors shall report data to the SCU.

e. Provide sign case ventilation calculations and LED cooling calculations to show sufficient air circulation is provided to meet this SP725 requirements under worse case air humidity, solar loading, internal heat generation with 50% of all sign pixel turned on at maximum light out level. All sign case temperatures shall be measured at ceiling level.

f. The fan(s) shall be mounted within the housing.

g. The fan(s) shall be downstream from the air filters.

h. The sign case venting fan(s) shall blow the air into the sign case.

i. The DMS manufacturer shall determine the number, placement, and size of the electric fans.

j. The fans shall be thermostatically controlled. The thermostat shall meet the following requirements:

    i. Shall be manually adjustable to turn off and on between 91º and 149ºF.

    ii. On and off hysteresis shall not exceed 3ºF.

    iii. The manual adjustment shall be graded in 5ºF increment scale.

    iv. Measure sign case temperature at ceiling level.

k. The fan circuit shall be protected at 125% of the fan motor capacity.

11.2.10 Redundant Power Supply

The DMS display power supply and driver electronics shall meet the following requirements:

1. Shall be auto-ranging regulated DC power source.

2. Operate from 90VAC, 60 Hz (or 240VAC, 60 Hz). Require NEMA TS 4 voltage input requirements.

3. Have an output of less than 24VDC.

4. Shall be wired in a redundant parallel configuration that uses multiple supplies to power a single load.

5. Shall be rated such that if 1 power supply fails, the remaining supplies will be able to operate 100% of the pixels in their display section at full brightness.

6. Shall incorporate short circuit protection.

7. Shall incorporate power failed alarm under the following conditions:

    a. Output voltage below 15% of normal.

    b. Internal temperature outside the design operational range.

8. Power supply failure alarm and power supply location or number shall be reported to the Sign Controller Unit.

11.2.11 Sign Electrical Requirements

1. The 120/240V electrical service panel shall be rated for 100A maximum.

2. The panel shall have an interrupt rating of not less than 10kA.

11.2.11.1 Walk-In DMS

1. Internal sign case illumination shall meet the following minimum requirement:

    a. Mounted near the DMS ceiling.

    b. Provide uniform light distribution in the sign case.

    c. The lighting shall be via compact fluorescent lamps with a life of at least 10,000 hours of operation and a minimum 30-watt rating, or LED equivalent.

    d. A minimum of 1 compact fluorescent light fixture (or LED equivalent) shall be installed every 8’ of DMS width. The lamps shall provide uniform light distribution throughout the inside of the assembly.

    e. The lamps shall be self-ballasted and be rated for temperatures as low as -15ºC (5ºF).

    f. The lamps shall be shielded with a protective wire cage.

    g. The lights are to be controllable with a manual timer having an adjustable maximum on-time of 4 hours.

    h. Two of the light fixtures shall be located approximately 2’ from each end of the sign case, and 1 fixture shall be located in the center of the sign case.

    i. The sign case shall be constructed to prohibit any interior light from being visible from the outside when the door is shut.

2. The sign case shall be equipped with three, 15A, 120VAC duplex GFCI (NEMA 15-R) AC receptacles.

3. Two AC receptacles shall be located approximately 4’ from each end, and 1 receptacle shall be located in the center of the sign case.

4. The AC receptacle shall be mounted on the back wall of the sign case.

5. The interior lighting circuits shall be protected by ground-fault circuit-interrupters.

6. The ground-fault circuit interruption shall occur on 6 mA of ground-fault current and shall not occur on less than 4 mA of ground-fault current.

7. All lighting and receptacle circuits shall use #12 AWG wiring enclosed in thin wall ¾” or ½” conduit or other measures.

11.2.12 Sign Controller Unit (SCU)

The Sign Controller Unit (SCU) shall control the operation of all DMS equipment housed at the Dynamic Message Sign site. The SCU shall meet the following requirements:

1. Shall include a front panel interface with graphical LCD and keypad for direct (local) operation and diagnostics.
2. Shall respond to the direct commands from the system computer and the portable, field-testing computer.
3. Shall be mounted in the road side DMS cabinet and not in the sign enclosure.
4. Shall receive and interpret commands sent by the system computer and cause the immediate message to be displayed on the sign and shall provide a return message to the computer that provides information concerning the status of the sign.
5. Shall continuously monitor command messages from the system computer.
6. Shall either blank the display, or continue to display a given message, depending on the option selected by the operator, when a computer system poll is not received within a user-definable threshold period.
7. Shall maintain a library of not less than 60 different display messages and related parameters. The SCU shall support uploading and downloading the message library.
8. Shall monitor and report internal sign case temperatures.
9. Shall be capable of detecting power failures. Power failure is defined when the power is out of limits for 3 or more cycles.
10. Shall perform the following function when power is restored after a power failure is detected:
    a. Display the same message prior to power failure if the outage is less than the user specified period.
    b. The sign display shall be blank if the power is restored after the user specified period.
11. Shall provide contact closure inputs alarms for the following functions:
    a. Sign case door switch.
    b. Road Side DMS cabinet door switch for each door.
12. Shall perform the following actions upon receiving a contact closure input alarm:
    a. For sign case and road side door open alarm, the SCU shall report a door open alarm.
    b. For over-height vehicle detection alarm, the SCU shall perform the following actions:
        i. Display a user programmable non-volatile message.

ii. The message shall overwrite any current message.

iii. The message shall be displayed for a user programmable time interval.

iv. The operator at the TDOT Regional TMC must be able to override the message if needed.

13. Shall incorporate memory with the following requirements:

    a. Permanent memory.

    b. Non-volatile memory capable of retaining the data in memory for a minimum of 30 calendar days without power.

14. Schedule and all configurable controller data shall be stored in non-volatile memory.

15. Shall have a user configurable IP address.

16. Shall have a user interface that allows resetting of the sign control unit.

17. Shall have a user interface that initiates a manual test of each pixel in the sign.

18. Shall have circuitry to perform the following functions:

    a. Drive the sign display.

    b. Determine ambient lighting levels.

    c. Control pixel luminance levels.

    d. Monitor the internal sign case temperature by mounting temperature sensors on the sign case.

19. Shall have a hardware watchdog timer that shall check its own operation. While the SCU program is running, the hardware watchdog timer shall be periodically reset. If the watchdog timer is not reset, the watchdog timer shall reset the SCU.

20. A slide-out notebook shelf, power, and connections to the Sign Controller Unit shall be provided at the road side DMS cabinet to allow for control of the sign from the road side cabinet with a laptop computer.

21. The presence of ambient radio signals, magnetic or electromagnetic interferences, including those from power lines, transformers, or motors within the proximity of any components of the system, shall not impair the performance of the system.

22. The system shall not radiate any electrical or electromagnetic signals that could adversely affect any other electrical or electronic device.

23. The sign controller as a function of the ambient light conditions shall automatically set the luminous intensity of the sign display pixels. Shall support brightness table with a minimum of 16 levels for automatic settings. Manually adjustable and may be set from 1% to 99% in 1% increments.

24. The controller shall monitor ambient light levels through a photo sensor assembly that senses the ambient illumination level using 3 photodiodes oriented as follows:

    a. Cell 1 – Monitors the change from "day" to "night".

    b. Cell 2 – Facing towards oncoming traffic; monitors prevailing ambient light levels in the upstream traffic.

    c. Cell 3 – Facing away from oncoming traffic; monitors prevailing ambient light levels in the downstream traffic.

25. In the event of communications failure, the sign shall blank and/or display a programmable stored message as determined by the Engineer at delivery time.

26. In the event of a controller lock-up due to any circumstance, the sign shall blank.

27. Shall be capable of auto line centering, left, and right justified in the specific line.

11.2.13 Communications

The DMS controller shall provide interfaces for local and remote communications meeting the following minimum requirements:

1. Communication interface shall be 10/100 Base TX Ethernet for all DMS devices. No serial to Ethernet converters (i.e., terminal servers) are permitted either internal or external to the controller.

2. Communication interface shall comply with NTCIP 1203 v03 or latest adopted version.

3. All DMS components shall follow FCC Part 15. All DMS components may not cause harmful wireless interference and must accept any interference received, including interference that may cause undesired operations. Manufacturer certification of compliance or declaration of conformity with FCC rules shall be provided to TDOT to ensure compliance.

11.2.14 NTCIP Requirements

This SP725 references standards through their NTCIP designated names and numbers. Each NTCIP Component covered by these project specifications shall implement the most recent adopted version of the standard that is available as of the project letting date, including all prepared Amendments to these standards as of the same date.

Profile Implementation conformance Specifications (PICS) for each NTCIP standard required shall be submitted for review and approval to TDOT.

1. **Ethernet Interface**: Communication interfaces using Ethernet shall conform at a minimum with all mandatory objects of all mandatory Conformance Groups of the following standards:

    a. 1101 – NTCIP Simple Transportation Management Framework (STMF)

    b. 1203 – NTCIP Object Definition for Dynamic Message Signs

    c. 2301 – NTCIP AP-STMF

    d. 2202 – NTCIP TP-Internet

    e. 2104 – NTCIP SP-Ethernet

2. **RS-232 Interface:** Communication interfaces using RS-232 shall conform at a minimum with all standards:

    a. 1101 – NTCIP Simple Transportation Management Framework (STMF)

    b. 1203 – NTCIP Object Definition for Dynamic Message Signs

    c. 2301 – NTCIP AP-STMF

    d. 2201 – NTCIP TP-Transportation Transport Profile

    e. 2104 – NTCIP SP-PMPP/RS232

3. **Subnet Level:** For each communication interface, the Subnet Level shall meet the following minimum requirements:

    a. NTCIP Components may support additional Subnet Profiles at the manufacturer's option.

    b. At any one time, only 1 Subnet Profile shall be active on a given communication interface.

    c. The NTCIP Component shall be configurable to allow the field technician to activate the desired Subnet Profile.

4. **Transport Level:** For each communication interface, the Transport Level shall meet the following minimum requirements:

    a. Communication interfaces may support additional Transport Profiles at the manufacturer's option.

    b. Response datagrams shall use the same Transport Profile used in the request.

    c. Each communication interface shall support the receipt of diagrams conforming to any of the identified Transport Profiles at any time.

5. **Application Level:** For each communication interface, the Application Level shall meet the following minimum requirements:

    a. All communication interfaces shall comply with NTCIP 1101 and shall meet the requirements for Conformance Level 1 (NOTE – See Amendment to standard).

    b. Optionally, the NTCIP Component may support SNMP traps.

    c. A communication interface may support additional Application Profiles at the manufacturer's option.

    d. Responses shall use the same Application Profile used by the request.

e. Each communication interface shall support the receipt of application data packets at any time allowed by the subject standards.

6. **Information Level:** All communication interfaces Information Level protocol shall meet the following minimum requirements:

a. All communication interfaces shall provide Full, Standardized Object Range Support of all objects required by these procurement specifications unless otherwise indicated below.

b. The maximum Response Time for any object or group of objects shall be 200 milliseconds.

c. All communication interfaces shall implement all mandatory objects of all mandatory Conformance Groups as defined in NTCIP 1203 and their respective Amendments.

d. The sign shall blank if a command to display a message contains an invalid Message CRC value for the desired message and shall provide a return message.

i. Shall also implement all mandatory objects of the following optional conformance groups of NTCIP 1201.

ii. Time Management Conformal Group

e. Report Conformal Group. Table 4 indicates the modified object requirements.

f. Implement all objects of the Font Configuration Conformance Group, as defined in NTCIP 1203.

g. Implement all objects of the DMS Configuration Conformance Group, as defined in NTCIP 1203.

h. Implement all objects of the Multi Configuration Conformance Group, as defined in NTCIP 1203.

i. Implement all objects of the Multi Error Configuration, as defined in NTCIP 1203.

j. Implement all objects of the Illumination/Brightness.

k. Sign Status, as defined in NTCIP 1203.

l. Status Error, as defined in NTCIP 1203.

m. Pixel Error Status, as defined in NTCIP 1203.

n. The display of any graphics shall follow the NTCIP Standards Version 03, Section 5.12.

11.2.15 NTCIP Compliance Documentation

Software shall be supplied with full documentation of the following Management Information Base (MIB) files in Abstract Syntax Notation 1 (ASN.1) format:

1. The relevant version of each official standard MIB Module referenced by the device functionality.

2. If the device does not support the full range of any given object within a Standard MIB Module, a manufacturer specific version of the official Standard MIB Module with the supported range indicated in ASN.1 format in the SYNTAX and/or DESCRIPTION fields of the associated OBJECT TYPE macro.

3. A MIB Module in ASN.1 format containing any and all manufacturer-specific objects supported by the device with accurate and meaningful DESCRIPTION fields and supported ranges indicated in the SYNTAX field of the OBJECT-TYPE macros.

4. A MIB containing any other objects supported by the device.

Additionally, the manufacturer shall provide a test procedure that demonstrates how the NTCIP compliance of both, the data dictionaries (NTCIP 1201, 1203, and their amendments) and the communications protocols have been tested.

The manufacturer shall allow the use of all this documentation by any party authorized by the Procuring Agency for systems integration purposes at any time initially or in the future, regardless of what parties engage in the systems integration effort.

11.2.16 Dynamic Message Sign Operation

The Dynamic Message Sign shall support 3 distinct modes.

1. System Control: System control is the normal mode of operation. The SCU responds to commands from the system computer.

2. Local Control: This is the mode of operation that is used to test the sign operation. In this mode, the SCU responds to commands from a portable computer that is interfaced to the SCU.

3. Failed Condition: This is the mode of operation that is used when the hardware watchdog timer or the communications watchdog timer is not reset, or a communications error is detected, or an error is detected by the SCU. In this mode, the sign face is blank (all LED pixels are off).

11.2.17 Sign Control Test Software

The Contractor shall provide Test Software that meets the following requirements:

1. The software shall operate on a laptop computer.

2. The software shall interface with the SCU using the SCU Ethernet port and crossover cable.

3. The software shall provide interface using Active Directory Service Interfaces (ADSI).

4. The software shall initiate a test pattern that energizes and verifies each individual pixel in the sign.

5. The test pattern shall be supported by a test report that documents the results of the test.

6. The software shall include a communication monitoring function that meet the following requirements:

   a. Display on the screen of the portable computer the commands received by the SCU from the system computer.

b. Display the response transmitted by the SCU to the system computer.

c. Display function shall be real-time and be functional when the SCU is operating in the system control mode.

11.2.18 Central Control Sign Software

The Contractor shall provide Test Software that meets the following requirements:

1. Shall operate on TDOT Regional TMC operator's workstation PCs. It shall be a client-server type architecture and be able to be installed on an existing server running Windows Server 2016. The relationship shall support multiple operator-client workstations that interface with the Server. 1 server license shall be required for multiple PC use.

2. Shall be able to view, group, and monitor multiple DMSs in real time.

3. Shall be able to communicate to any NTCIP-compliant sign communicating with the TDOT Regional TMC, including portable NTCIP-compliant signs.

4. Shall be able to support list view and map view of signs. The map shall be configured to show all applicable signs in the Region, as required by the Engineer.

5. Shall support full-color text, shape, and graphic message creation.

6. Shall be able to change messaging based on various input data, including time, temperature, date, and speed.

7. Shall be able to generate graphics, such as roadway signs and interstate shields, as well as clip art, shapes and free form creations. Standard MUTCD symbols shall be included in the graphics generator. The editing tool shall be able to move text and images on the editing area with graphical editing tools.

8. Shall be able to display multiple graphics, including shields and arrows for lane designation, or lane management.

9. Shall be able to schedule by date and time, up to one-minute increments via a calendar view, with options for schedule recurrence.

10. Shall be able to configure message flash rates, scrolling, beacons, templates and fonts to provide optimal DMS legibility.

11. Shall provide spell check and be able to create a list of prohibited words that can only be accessed for edit by an administrator.

12. Shall be able to log events and subsystem failures.

13. Shall be able to run diagnostics and alert for all system failures, including pixel tests and failures, power failures, environmental status, and other failure notifications.

14. Shall have built in security levels of access, including login/password access.

15. Shall be provided with the ability to install the client on Operator Workstations.

16. Shall include full software maintenance support for a duration of 3 years.

17. Shall also include the following functionality:

    a. Full diagnostic test of peripherals.

    b. Remote SCU reset and password override.

    c. Set/view brightness levels.

    d. View NTCIP conformance group values.

    e. Separate windows for multi-monitor display.

    f. Support the latest NTCIP 1203 font table changes and graphics objects.

    g. Display real time date/time/speed/temperature fields.

    h. Variable spacing between characters.

    i. View and Run Schedule Day Plans by week, month, year.

11.2.19 Road Side DMS Cabinet (Type C Cabinet)

The Contractor shall provide a ground-mounted cabinet for each Walk-In DMS, Front Access DMS, and Over Lane DMS Array/Over Shoulder DMS site. The ground-mounted DMS cabinet is labeled as a Type C cabinet on the Plans. The cabinet shall meet the following requirements:

1. Shall meet the applicable requirements of a Type C equipment cabinet in Section 8.2.4.

2. Shall be ground mounted.

3. A sliding storage drawer, power, and connections to the Sign Controller Unit (SCU) shall be provided at the road side DMS cabinet to allow for control of the sign from the road side cabinet with a laptop computer.

4. The cabinet should be of sufficient size to hold all the DMS support equipment (i.e., controller, power distribution panel, etc.), cabinet accessories (sliding storage drawer, etc.), and communication equipment as shown on the Plans.

5. Shall include a main circuit breaker, which shall turn off all power to components within the cabinet and the DMS sign case.

6. Shall include separate circuit breaker to power the sign case.

7. Shall include both serial and Ethernet communication cable surge protection devices with the following characteristics:

    a. Hybrid Multi-stage Suppression components, including gas tube and silicon avalanche diode.

    b. Response time to greater than 1 nanosecond.

    c. UL listed (UL 1449, UL 497, 497A, 497B, etc. as appropriate) and bonded to the same single-point ground point. Any DIN rail mounted SPDs shall be grounded via conductor and shall not rely solely upon the DIN rail's mechanical connection as a grounding point.

    d. Sides shall be clearly marked 'protected' and 'unprotected.'

11.2.20 Road Side TTMS Cabinet (Type B Cabinet)

The Contractor shall provide a pole-mounted cabinet for each TTMS site. The pole-mounted TTMS cabinet is labeled as a Type B cabinet on the Plans. The cabinet shall meet the following requirements:

1. Shall meet the applicable requirements of a Type B equipment cabinet in Section 8.2.3.

2. Shall be pole mounted.

3. A sliding storage drawer, power, and connections to the Sign Controller Unit (SCU) shall be provided at the road side TTMS cabinet to allow for control of the sign from the road side cabinet with a laptop computer.

4. The cabinet should be of sufficient size to hold all the TTMS support equipment (i.e., controller, power distribution panel, etc.), cabinet accessories (sliding storage drawer, etc.), and communication equipment as shown on the Plans.

5. Shall include a main circuit breaker, which shall turn off all power to components within the cabinet and the TTMS sign case.

6. Shall include separate circuit breaker to power the sign case.

7. Shall include both serial and Ethernet communication cable surge protection devices with the following characteristics:

    a. Hybrid Multi-stage Suppression components, including gas tube and silicon avalanche diode.

    b. Response time to greater than 1 nanosecond.

    c. UL listed (UL 1449, UL 497, 497A, 497B, etc. as appropriate) and bonded to the same single-point ground point. Any DIN rail mounted SPDs shall be grounded via conductor and shall not rely solely upon the DIN rail's mechanical connection as a grounding point.

    d. Sides shall be clearly marked 'protected' and 'unprotected.'

11.3 Installation Requirements

Contractor shall abide by the installation requirements in the following sections.

11.3.1 General Requirements

1. All equipment shall be installed according to the manufacturer's recommendations and the Plans. The Contractor shall have a DMS manufacturer representative commission the signs after installation.
2. DMS structures, sign cases, and cabinets shall be grounded in accordance with the DMS and the structure manufacturers' recommendations and the Standard Specifications.
3. Do not install the DMS sign case on the support structure until the structure grounding systems have been successfully completed and accepted, and the structure ground connection has been installed.
4. Do not install electrical service or electronic devices in the road side DMS cabinet or connect to the cabinet until the cabinet grounding systems have been successfully completed and accepted, and the cabinet ground connection has been installed.
5. Bundle all like cabling to minimize crosstalk and electrical interference. Route wiring to prevent conductors from being in contact with devices in the cabinet and metal edges. Arrange wiring so that any removable assembly may be removed without disturbing or unhooking conductors.
6. All power and communications wiring shall be 1 continuous run from cabinet to sign structure. No splicing of wiring will be permitted unless approved by the Engineer.
7. Do not install electronic devices in the cabinet until electrical service has been installed and activated, and the cabinet ventilation fan is operational.
8. A minimum of 2-2" spare conduits shall be installed in the base of all Type C DMS cabinets and shall terminate in the adjacent communications cable pull box. Spare conduits in the cabinet base and the pull box shall be sealed with blank duct plugs.
9. Prior to installation, all sign cases and cabinets must be stored in a location and manner approved by TDOT. The signs shall not be sitting directly on the ground or in a manner where standing water, mud, or debris will come in contact with the sign. The storage location should be free from excessive debris or other matter that may harm or deteriorate the sign. During storage, sign cases shall be structurally supported in accordance with the DMS manufacturer's recommendations.
10. The Contractor is responsible for coordinating with TDOT Regional TMC IT for IP addresses and integrating the DMS system into the manufacturer provided DMS central control software.
11. The Contractor shall provide any fonts, graphics, or messages to allow the sign to operate with the required functionality of the DMS. All fonts, graphics, and messages must be MUTCD-compliant and in accordance with the requirements in Section 11.2.3.

11.3.2 Beneficial Use of Dynamic Message Signs During Construction

Each DMS shall be road side controllable (by sign vendor software) within 30 calendar days of attachment to trusses over the roadway (visible to motorists). The Contractor's construction schedule shall clearly identify when installation of the signs over the roadway shall occur, and when road side control shall be established for each sign. The Contractor shall not install a DMS over the roadway until all ancillary and infrastructure elements, including cabinets, controllers, conduits, cabling, etc. necessary to operate the sign are in place and functional. Once road side controllable, the Contractor shall display emergency, special event, construction, safety or traveler information messages approved by TDOT, only when requested by TDOT, at no additional cost to TDOT. Normal diagnostic messaging for the purpose of installation and testing shall be determined by the Contractor but shall not be allowed to the extent that excessive power consumption or distraction to motorists occurs as determined by the Engineer. Any beneficial use of the signs to TDOT and the public prior to Final Acceptance does not constitute TDOT acceptance or waive any Contractor testing requirements. Failure to make signs road side controllable within 30 calendar days after installation over the roadway shall constitute failure to meet the Contractor's construction schedule and liquidated damages will be assessed as described in Special Provision 108B. The cost that may be incurred by the Contractor to display messages as described above during this construction contract shall be considered incidental and included in the cost of the Dynamic Message Sign.

11.3.3 Documentation

The documentation for the Dynamic Message Signs shall consist of the following: Communications Protocol, Operator's Manual, Maintenance Procedure Manual, Equipment Drawings, and Electrical Schematic Diagrams.

1. Communications Protocol

   This document shall fully describe the device support for NTCIP 1203 v03 along with the documentation requirements set forth in Section 11.2.15 of this SP725.

2. Operator's Manual

   This document shall fully describe the operation of the Dynamic Message Signs using the Windows based software that runs on a notebook computer. This document shall clearly define all functions that are supported by the software. The manual shall define the normal operation of the signs and the software including resetting and restarting the software package. A word-searchable electronic copy of this document shall be provided. The manual shall include the following:

   a. General Description

   b. General Characteristics

   c. Installation

   d. Adjustments

   e. Theory of Operation

   f. Maintenance

      i. Preventive Maintenance

      ii. Trouble Analysis

      iii. Trouble Shooting Sequence Chart

g. Wave Forms

h. Voltage Measurements

i. Alignment Procedures

j. Parts List

k. Communications Protocol

l. Schematic and Logic Diagrams

3. Maintenance Procedure Manual

   This manual shall document the preventive and corrective maintenance procedures that should be followed to maintain the Dynamic Message Signs at the highest level of operational efficiency. The manual shall include step-by-step field and bench trouble-shooting procedures to isolate and repair faults. The document shall include descriptions of normative waveforms and test voltages. A detailed parts list shall be included. For each part or assembly, a circuit diagram or pictorial shall be provided. A word-searchable electronic copy of this document shall be provided.

4. Equipment Drawings and Diagrams

   A pictorial drawing showing the physical location and identification of each component shall be provided for each different electronic assembly and each different subassembly. Wiring diagrams shall be provided for each sign case. These diagrams shall depict the location and interface of all components located within the sign case. An electronic copy of these drawings (using common drawing software such as MicroStation) shall be provided.

5. Electrical Schematic Diagrams

   An electrical schematic, wiring diagram, and a logic diagram shall be provided for each different type of equipment. A stage-by-stage explanation of the circuit theory shall be provided with the circuit wiring diagrams. Connection diagrams for each DMS subsystem including block diagrams, terminal numbers, and conductor color codes shall be provided. An electronic copy of these diagrams (using common drawing software such as MicroStation) shall be provided.

11.3.4 Training

If the DMS model and generation proposed by the Contractor is not identical to a DMS model and generation that is already deployed within the TDOT Region of the project, training will be required. Prior to the acceptance of the first DMS unit, training shall be provided for TDOT's engineering, maintenance, IT, and operations staff, at a facility provided by TDOT. The training shall include all material and manuals required for each participant.

The training shall be provided for 2, identical non-consecutive 1 day sessions for at least 10 engineering and operations personnel each. These hours of training are inclusive of those required in Section 2.4. The training shall include a complete demonstration of the operation and capabilities of the DMS equipment. This session shall include a complete review of any field adjustments or calibration that may be required for the LED's or any sign component. The training shall include operation instructions, theory of operation, circuit description, field adjustments, preventive maintenance procedures, troubleshooting, and repair of all components. Particular attention shall be given to the operation of the software packages to be provided including procedures for configuring the signs, displaying messages, developing and displaying graphics, and diagnosing faults.

11.4 Testing Requirements

11.4.1 General Requirements

1. The Contractor shall conduct a project testing program for all materials specified in this section and as required in Section 2.5 of this SP725.
2. All test results shall confirm physical and performance compliance with this SP725.
3. The Contractor shall submit all test results documentation to the Engineer within 7 calendar days of completion of the tests. The Engineer will review test documentation in accordance with the Submittal Review Process in Section 2.7.
4. Payment for all testing is included in the cost of the DMS.

11.4.2 Factory Acceptance Test

FAT may be performed in the presence of the Engineer. FAT shall include the following tests and inspections:

1. Test all completed and assembled DMS at the point of manufacture for performance and functionality required within this SP725 and the contract documents and provide an electronic copy of the manufacturer test documentation.

11.4.3 Bench Test Component

BTC shall be performed in the presence of the Engineer. The BTC shall include the following tests and inspections:

1. Verify the DMS has no internal or external damage.
2. Verify that all equipment is secured.
3. Verify that the sign is configured according to the requirements in this SP725 and as detailed on the Plans.
4. Test all DMS functionality including:
    a. Working communication between the sign case and SCU.
    b. All pixels are operational via cycling through the test patterns available in the vendor software.
    c. That text, colors, and graphics can be displayed on the sign using the vendor software.
    d. The ventilation and heater system works and can be both manually controlled and actuated by the thermostat.
    e. The ambient light sensors are producing accurate readings and are automatically controlling the brightness level of the pixels on the sign.
    f. Identification of any system faults via running a System Diagnostics check in the vendor software.

11.4.4 Bench Test System

BTS shall be performed in the presence of the Engineer. The BTS shall include the following tests and inspections:

1. Verify DMS attachment compatibility with the DMS Truss Structure.
2. Verify that the DMS is compatible and supports operational interoperability with the communication equipment, TDOT ATMS software, and any additional equipment at the DMS site including existing or proposed Overheight Vehicle Detection Systems.

11.4.5 Stand Alone Site Test

SAT shall be performed in the presence of the Engineer. The SAT shall include the following tests and inspections:

1. Verify all components have been installed per manufacturer requirements.
2. Verify all items have been attached properly (as per manufacturer recommendations and the Plans) to each other and to the DMS Truss or Sign Structure.
3. Verify the DMS has no internal or external damage.
4. Verify the SCU has been properly connected to the UPS for continuous, conditioned power.
5. Verify the DMS sign case has been properly connected to the power source in the Type C cabinet.
6. Verify the DMS sign case and cabinet equipment are protected by surge suppression.
7. Verify the DMS sign case is grounded to the DMS Truss or Sign Structure.
8. Verify local sign control using the vendor software.
9. Verify local sign control through the Type A Network Switch using the vendor software.
10. Test all DMS functionality including:
    a. Working communication between the sign case and SCU.
    b. All pixels are operational via cycling through the test patterns available in the vendor software.
    c. That text, colors, and graphics can be displayed on the sign using the vendor software.
    d. The ventilation and heater system works and can be both manually controlled and actuated by the thermostat.
    e. The ambient light sensors are producing accurate readings and are automatically controlling the brightness level of the pixels on the sign.
    f. Identification of any system faults via running a System Diagnostics check in the vendor software.

11.5 Warranty

All materials specified in this section shall carry a minimum one-year manufacturer’s warranty from the date of Final Acceptance against any imperfections in workmanship or materials. Warranties shall cover complete replacement at no charge for the equipment. Warranties shall be transferred to TDOT upon Final Acceptance of the project as per the requirements in Section 2.6 of this specification.

11.6 Method of Measurement

11.6.1 Dynamic Message Sign (Multi-Color)

The Walk-In Dynamic Message Sign (Multi-Color) will be measured in units of each and paid for at the contract unit price per each. The price shall include furnishing, installing, device integration, and testing of the complete Dynamic Message Sign including the sign case, light sources, display apparatus, wiring, controller, communications interface, structure mounted conduit, fittings, and junction boxes, sign case support connections to the sign support structure, satisfactory completion of testing requirements, wireless communication platform (identified remote locations only), and all work, equipment, and appurtenances as required to effect the full operation including remote and local control of the sign complete in place and ready for use. Note this item does not include the sign support structure. The bid price shall also include all system documentation including shop drawings, operations and maintenance manuals, wiring diagrams, block diagrams, and other material necessary to document the operation of the Dynamic Message Sign. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

11.6.2 Dynamic Message Sign (Front Access)

The Multi-Color Front Access DMS will be measured in units of each and paid for at the contract unit price per each. The price shall include furnishing, installing, device integration, and testing of the complete Front Access DMS including the sign case, light sources, display apparatus, wiring, controller, communications interface, structure mounted conduit, fittings, and junction boxes, sign case support connections to the sign support structure, satisfactory completion of testing requirements, and all work, equipment, and appurtenances as required to effect the full operation including remote and local control of the sign complete in place and ready for use. Note this item does not include the sign support structure. The bid price shall also include all system documentation including shop drawings, operations and maintenance manuals, wiring diagrams, block diagrams, and other material necessary to document the operation of the Front Access DMS. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

11.6.3 Dynamic Message Sign (TTMS)

The Multi-Color TTMS will be measured in units of each and paid for at the contract unit price per each. The price shall include furnishing, installing, device integration, and testing of the complete TTMS including the sign case, light sources, display apparatus, wiring, controller, communications interface, above-ground conduit, fittings, and junction boxes, sign case support connections to the sign support structure, satisfactory completion of testing requirements, wireless communication platform (identified remote locations only), and all work, equipment, and appurtenances as required to effect the full operation including remote and local control of the sign complete in place and ready for use. Note this item does not include the sign support structure or accompanying static sign. The bid price shall also include all system documentation including shop drawings, operations and maintenance manuals, wiring diagrams, block diagrams, and other material necessary to document the operation of the TTMS. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

11.6.4 Dynamic Message Sign (Over Lane DMS Array)

The Multi-Color Over Lane DMS Array will be measured in units of each and paid for at the contract unit price per each. The price shall include furnishing, installing, device integration, and testing of the complete Over Lane DMS Array including the sign case, light sources, display apparatus, wiring, controller, communications interface, structure mounted conduit, fittings, and junction boxes, sign case support connections to the sign support structure, satisfactory completion of testing requirements, and all work, equipment, and appurtenances as required to effect the full operation including remote and local control of the sign complete in place and ready for use. Note this item does not include the sign support structure. The bid price shall also include all system documentation including shop drawings, operations and maintenance manuals, wiring diagrams, block diagrams, and other material necessary to document the operation of the Over Lane DMS Array. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

11.6.5 Dynamic Message Sign (Over Shoulder DMS)

The Multi-Color Over Shoulder DMS will be measured in units of each and paid for at the contract unit price per each. The price shall include furnishing, installing, device integration, and testing of the complete Over Shoulder DMS including the sign case, light sources, display apparatus, wiring, controller, communications interface, structure mounted conduit, fittings, and junction boxes, sign case support connections to the sign support structure, satisfactory completion of testing requirements, and all work, equipment, and appurtenances as required to effect the full operation including remote and local control of the sign complete in place and ready for use. Note this item does not include the sign support structure. The bid price shall also include all system documentation including shop drawings, operations and maintenance manuals, wiring diagrams, block diagrams, and other material necessary to document the operation of the Over Shoulder DMS. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

11.6.6 DMS Comm Cable

The DMS Comm Cable will be incidental to the DMS. The bid price for the DMS shall include furnishing, installing, device integration, and testing of a complete DMS Comm Cable installation with operational DMS and shall include cable labels and all ancillary and incidental materials, testing, documents, and all labor and equipment necessary to complete the work. No measurement for payment will be made for cable storage amounts in excess of that required in this SP725 or the Plans.

11.6.7 DMS Power Cable

The DMS Power Cable will be incidental to the DMS. The bid price for the DMS shall include furnishing, installing, and testing of a complete DMS Power Cable installation between the sign case and the Type C cabinet with operational DMS and shall include all ancillary and incidental materials, testing, documentation, and all labor and equipment necessary to complete the work. No measurement for payment will be made for cable storage amounts in excess of that required in this SP725 or the Plans.

11.7 Payment

The contract unit price shall be full compensation for all work specified in this section. Payment will be made under:

Item No.	Description	Unit
725-21.02	DYNAMIC MESSAGE SIGN (MULTI-COLOR)	EA
725-21.25	DYNAMIC MESSAGE SIGN (OVER LANE DMS ARRAY)	EA

Item No.	Description	Unit
725-21.26	DYNAMIC MESSAGE SIGN (OVER SHOULDER DMS)	EA
725-21.28	DYNAMIC MESSAGE SIGN (FRONT ACCESS)	EA
725-21.29	DYNAMIC MESSAGE SIGN (TTMS)	EA

Dynamic Message Signs will be paid per each as follows:

1. 50% of the contract unit price upon satisfactory Factory Acceptance Test results, delivery to the site, and Bench Test Component results. For those signs not going through Factory Acceptance Testing, 50% of the contract unit price upon delivery to the site and satisfactory Bench Test Component results.

2. Additional 20% of the contract unit price upon satisfactory Stand Alone Site Test results.

3. Additional 20% of the contract unit price upon satisfactory Conditional System Acceptance Test results.

4. Final 10% of the contract unit price upon Final System Acceptance.

12 RADAR DETECTION EQUIPMENT

12.1 Description

12.1.1 General Description

This section specifies the minimum requirements for Radar Detection Systems (RDS) furnished and installed on this project. The work shall consist of providing all labor, materials, equipment, and incidentals necessary to furnish, install, test, and operate a working RDS System for TDOT.

The RDS will provide roadway monitoring capabilities via microwave radar detectors transmitting data over wireline network equipment specified in this SP725. The data provided includes but is not limited to lane occupancy, speeds, classification, and volume. The RDS device shall support high-definition radar consisting of multiple radar beams. 2 receive antennas shall be positioned side-by-side with enough space between to create two, separate high-definition beams.

It shall be the Contractors responsibility to ensure that the submitted RDS is compatible with the travel time module within the TDOT ATMS software and can operate as designed on the Plans. It shall be the Contractor's responsibility to submit a product that is in compliance with this specification and the locations on the Plans. The Contractor shall notify the Engineer of any deviation or issue with the Plans or specifications prior to submitting, furnishing, and installing the RDS.

12.2 Materials

Contractor shall provide all materials according to the requirements in the following sections.

All equipment shall be new and constructed using the highest quality, commercially available components and techniques to assure high reliability and minimum maintenance. Prior to installation, the Contractor shall submit and receive approval from the Engineer on a complete set of shop drawings of all the equipment and components listed within this Special Provision and included as part of the installation.

All functionality of the RDS data communications shall be ethernet-based and integral to the Device and Data Processor housings. Terminal servers shall not be used to facilitate data communications between the Device and Data Processor.

The firmware pre-installed on the device shall meet the minimum version listed in APPENDIX D at the time of device installation in the field.

12.2.1 Microwave Transmission

1. The microwave radar detector shall transmit on a frequency band of 24.0-24.25 GHz, or another spectral band approved by the Engineer. It shall comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC rules or the appropriate Spectrum Management Authority. The RDS shall not interfere with any known equipment.

12.2.2 Area of Coverage

The RDS's field of view shall cover an area defined by a beam its maximum detection range shall be as follows:

1. Elevation Beam Width 40º or more

2. Azimuth Beam Width 15º or less

3. Range 6' to 250', minimum

12.2.3 Detection Zones

1. The minimum number of detection zones defined shall be no less than 12 lanes simultaneously.

12.2.4 Capabilities

The RDS shall be a true presence detector. It shall be suitable for mounting on road side poles or on overhead structures and provide the following:

1. Presence indication of moving or stopped vehicles in either direction in its detection zones, provided by contact closure.
2. The RDS shall have TCP/IP connection.
3. Traffic data, periodically accumulated over user defined time intervals in a 20 to 600 sec range, shall be transmitted via ethernet communications over Category 6 (minimum) cable to the local ethernet switch.
4. Traffic data shall be available simultaneously with detection zone contact closures and ethernet communications.
5. Side-fired configuration data shall include the following in each of up to 12 detection zones (lanes):
   a. Volume
   b. Lane occupancy
   c. Average speed
   d. Vehicle classification by length in a minimum of 8 user defined classes
6. RDS shall allow the user to define the contents of transmitted data.
7. Furnish the unit with the required software for data collection, processing, configuration and set-up, and data logging and retrieval. An operator shall be able to use the software to set detector count periods, sensitivities, and other operational features and parameters. The software must be capable of providing both manual and automatic setup and calibration.

12.2.5 Measurement Accuracy

1. The following error levels shall be achievable and demonstrated during testing:

Parameter	Error Percentage
Presence	5%
Volume	8%
Lane Occupancy	10%
Average Speed	10%
Length Classification Limits	10%

Parameter	Error Percentage
Time Event	10 ms
Input Voltage	2%

12.2.6 Environmental Conditions and Protection

Except as stated otherwise herein, the equipment shall meet all its specified requirements during and after installation subjecting to any combination of the following:

1. Ambient temperature range of -37°C to +74°C.
2. Relative humidity from 5% to 95%, non-condensing.
3. Winds up to 90 mph (sustained) with a 30% gust factor.
4. Rain and other precipitation up to 2” per hour rate.
5. Power surge of ± 1kV (rise time = 1.2 μsec, hold = 50μsec) applied in differential mode to all lines, power and output, as defined by IEC 1000-4-5 and EN 61000-4-5 standards.
6. Printed circuit boards shall be conformal coated for protection against humidity.
7. Except as may be otherwise stated herein for a particular item, no item, component, or subassembly shall emit a noise level exceeding the peak level of 55db when measured at a distance of 3’ away from its surface.
8. The microwave radar detector shall be resistant to vibration in accordance with IEC 60068-2-30 (test Fc), NEMA TS2 (latest edition), or approved equivalent.
9. The microwave detector shall be resistant to shock in accordance with IEC 60068-2-27 – Test Ea and guidance: Shock, NEMA TS2 (latest edition), or approved equivalent.

12.2.7 Mechanical

1. The microwave radar detector shall be enclosed in a rugged weatherproof box and sealed to protect the unit from wind up to 90 mph, dust and airborne particles, and exposure to moisture (IP 66 or greater compliant enclosure).
2. Maximum weight of the microwave radar detector assembly: 10 lbs.
3. The mounting assembly shall have all coated steel, stainless steel, or aluminum construction, and shall support a load of 20 lbs. or more. The mounting assembly shall incorporate a ball-joint, or other approved mechanism that can be tilted in both axes and then locked into place, to provide the optimum area of coverage.

12.2.8 Electrical

1. The RDS unit shall be operable from 12 – 24VDC and shall include necessary power supply to derive this voltage from a 120VAC nominal source.

12.2.9 Electrical Isolation and Surge Protection

1. All power lines, contact closures and the data port shall be surge protected within the unit. Contact closures and the data ports shall be isolated.

12.2.10 Data Processor

Data communications shall be full duplex asynchronous, configurable as:

1. RJ-45 port for ethernet communications.
2. Both point-to-point and multi-dropped configurations shall be supported.

12.2.11 RDS Comm Cable

1. The RDS comm cable shall be outdoor wet/dry rated cable with UV-resistant PVC or polyethylene outer jacket in accordance with UL 444 and wiring that supports a temperature rating of 105°C.
2. The RDS comm cable shall support Power over Ethernet to supply both data and power over the same cable.
3. Cable connectorization and termination pin-out on all cables shall be in accordance with TIA 568B and the manufacturer's recommendations.
4. Connection between the RDS and the cabinet equipment shall be provided by a single RDS comm cable that is terminated with an IP67-rated shielded RJ-45 8P8C male push-pull connector with eight-position non-keyed and eight gold anodized pins or other Ethernet-compatible locking weathertight connector at the RDS and terminated to a surge suppressor prior to the RDS Data Processor in the equipment cabinet. No splices are permitted in the RDS comm cable.
5. Provide cable labels that meet the following requirements:
    a. Self-coiling wrap-around type.
    b. PVC or equivalent plastic material with UV and fungus inhibitors.
    c. Base materials and graphics/printing inks/materials designed for underground outside plant use including solvent resistance, abrasion resistance, and water absorption.
    d. Minimum size of 2.5" wide by 2.5" long
    e. Minimum thickness of 0.01".
    f. Orange label body with pre-printed text in bold black block-style font with minimum text height of 0.375".
    g. Pre-print the following text legibly on RDS Cable labels:
        i. RDS CABLE
        ii. TDOT ITS
    h. On all cable labels, print the text specified above twice on the label with the text of the second image reversed. The result shall be text which "reads right" when the label is coiled onto a cable.

12.2.12 Programmable Logic Controller (PLC)

If required as indicated on the Plans, the PLC shall process select data from the RDS unit and drive various field devices for turnkey applications.

1. Core requirements:

   a. Minimum of 58 MHZ microprocessor
   b. Minimum of 1024K of SRAM
   c. Minimum of 512K of non-volatile flash memory
   d. Real-time clock with battery backup
   e. Watchdog timers to prevent device lockup
2. Physical requirements:
   a. Weight less than 0.5 lb.
   b. Din rail mounting
   c. Hot-swappable
3. Power requirements:
   a. Power supply 9-28 VDC
   b. Power consumption: less than 10 W
4. Environmental requirements:
   a. Ambient operating temperature: -34°C to +74° C
   b. Relative humidity: 95%
5. Connectivity requirements:
   a. Four (4) independent physical serial ports (two RS-232 and two RS-485)
   b. Two (2) multi-functional digital input ports
   c. Two (2) solid state contact closure output ports
6. Communication requirements:
   a. Converts RS-232 to RS-485 and vice versa
   b. Support the following baud rates: 1200, 2400, 4800, 9600, 19200, 38400, 57600, and 115200 bps
7. Contact closure to Ethernet device:
   a. Provide a contact closure device that will input contact closure relay signals from the RDS and output onto the 10/100Base-T Ethernet network to local Ethernet Switch.
   b. Device shall be rack, DIN rail, or wall mountable.

12.3 Installation Requirements

Contractor shall abide by the installation requirements in the following sections.

12.3.1 Radar Detection System

1. The RDS shall be mounted in side-fired configuration on poles as shown on the Plans, using mounting brackets. The brackets shall be attached with approved ¾" wide stainless-steel bands. The various mounting configurations include attaching to new light standard poles where the

wiring shall be installed inside the pole; attaching to new CCTV poles where the wiring shall be installed inside the pole; and attaching to existing overhead truss structures where conduit risers may be required on the outside of the truss structure.

2. The Contractor shall install the detector unit on a pole at the manufacturer's recommended height above the road surface so that the masking of vehicles is minimized and that all detection zones are contained within the specified elevation angle as suggested by the manufacturer.

3. When installing a detector near metal structures, such as buildings, bridges, or sign supports, the sensor shall be mounted and aimed so that the detection zone is not under and does not pass through any structure to avoid distortion and reflection.

4. The RDS mode of operation, detection zones, and other calibration and set up will be performed using a Microsoft Windows-based software and a Notebook PC. The software shall allow verification of correct setup and diagnostics. It shall include facilities for saving verification data and collected data as well as saving and retrieving sensor setup from a non-volatile memory device.

5. Unused conductors in the RDS unit harness cable shall be grounded or un-terminated in the cabinet in accordance with the manufacturer's recommendations. Un-terminated conductors shall be individually doubled back and taped, then loosely bundled and secured.

6. Contractor shall install a local / remote disconnect switch or a RDS communications wiring module in accordance with Section 8.2.2, 8.2.3, or 8.2.4 and as shown on the Plans.

7. The RDS power supply shall be connected to the UPS within the cabinet.

12.3.1.1 Device Configuration

The RDS shall be configured within the ATMS software as part of the setup process. The following configuration parameters shall be followed.

1. Use field verification to determine proper link/lane configuration at the detector site.

2. Create links for each portion of the main line roadway and each auxiliary portion of the roadway. Split existing links into multiple if necessary.
    a. Main line roadway is named like the detectors; for example: "R3G-00I24-43.6E (143)" and "R3G-00I24-43.6W (143)". Note the difference in roadway direction for each link.
    b. Auxiliary roadway links are named like the main line, but with an additional suffix. Add "Off Ramp", "On Ramp", or "Auxiliary" to the name after the mile marker and direction; for example: "R3G-00I24-56.7E Off Ramp (267)"
    c. Length of the link can be estimated by using roadway satellite imagery or a map of the detector locations. The length is defined as half the distance from a detector to its upstream neighbor, plus half the distance from the detector to its downstream neighbor.
3. Create expected lanes within each link.
    a. Lane number is not the same as the sensor detection zone number. In fact, they will typically be reversed.
        i. Sensor detection zones start at zero and increase moving away from the sensor (e.g., 0-7 for an eight-lane highway).
        ii. Lane numbers start at one (1) in the center of the roadway (left-most when facing in the direction of travel) and increase moving outwards (to the right when facing

in the direction of travel). Lane numbering is the same for each travel direction of the roadway, so there is expected to be overlap in numbers.

iii. Lane numbers for auxiliary lanes re-start at one (1) for the center-most auxiliary lane and increase moving outwards. Again, these are numbered for each auxiliary line independently.

b. In the ATMS configuration, each lane belongs to a given link. Each link, therefore, must have at least one lane created.

c. Lane names for main line links will use a suffix in the format "-Lane#"; for example, "R3G-00I24-43.6E (143)-Lane1".

d. Auxiliary lanes will use the auxiliary classification from the link as a suffix in the format "-OffRamp#"; for example, "R3G-00I24-56.7E (267)-OffRamp1". Note that the auxiliary classification is used only once in the lane suffix, not carried over from the link portion of the name. The name has a limited number of characters, so it cannot have both.

e. Assign the expected detection zone to the lane based on what the sensor is seeing. Recall the detection zones start at zero and increase moving outwards from the sensor location.

4. Detector software configuration:
   a. Each detector make/model may have different configuration software. The following are general guidelines for setting up the sensor and should be supplemented with the installation manual for the device for manufacturer recommendations.
   b. The sensor shall be set up to report US/Imperial units for speed and vehicle length.
   c. Calibration of the device for detection zones and speeds shall be performed during a moderate- or high-traffic period since vehicles must be readily present within the detection zones to properly identify them.
      i. The number of detection zones on the sensor shall match the number of lanes configured in the ATMS software.
   d. Update length bin classifications to the values in the following Table.

RDS Length Classification Bins		
Bin #	**Description**	**Length Range**
1	Motorcycle/small vehicle	0.0-8.9
2	Most passenger vehicles	9.0-18.9
3	Large pickup/van	19.0-23.9
4	Bus	24.0-25.9
5	Small/single unit truck (SU)	26.0-40.9
6	5-axle semitrailer | WB-40 intermediate semitrailer	41.0-50.9
7	6-axle single / 5-axle multi semitrailer | WB-50/WB-62 large/"full" semitrailer	51.0-70.9
8	6+-axle multi semitrailer | WB-65/67 Interstate semitrailer	71.0+

12.3.2 RDS Comm Cable

12.3.2.1 RDS Cable Shipping and Delivery

1. Package the cable for shipment on reels. Each package shall contain only 1 continuous length of cable. Construct the packaging to prevent damage to the cable during shipping and handling.
2. Seal both ends of the cable to prevent the ingress of moisture.
3. Include with each reel a weatherproof reel tag attached identifying the reel and cable that can be used by the manufacturer to trace the manufacturing history of the cable. Include with each cable a cable data sheet containing the following information:
    a. Manufacturer name
    b. Cable part number
    c. Factory order number
    d. Cable length
    e. Factory measured continuity and attenuation of each conductor and shield

12.3.2.2 RDS Cable Installation

1. Do not exceed the maximum recommended pulling tension during installation as specified by the cable manufacturer. Continuously monitor pulling tensions with calibrated measuring devices, such as a strain dynamometer.
2. Before cable installation, carefully inspect the cable reels and reel stands for imperfections or faults such as nails that might cause damage to the cable as it is unreeled.
3. Take all necessary precautions to protect reeled cable from vandals or other sources of damage while unattended. Any damage to reeled cable or the reel itself shall necessitate replacement of the entire cable section.
4. Whenever unreeled cable is placed on the pavement or surface above a pull box, provide means of preventing vehicular or pedestrian traffic through the area in accordance with the approved Maintenance of Traffic provisions.
5. Keep the cable continuous throughout the pull. Terminate the cable only in equipment cabinets on terminal blocks. Cable splices are not permitted.

12.3.2.3 RDS Cable Storage and Labeling

1. Safely store all cable to minimize susceptibility to damage. Maintain proper bend radius, both short and long term, during cable storage. Storage coils shall be neat in even length coils, with no cross over or tangling. Storage coils of different cables shall be kept separate. Storage coils shall be secured to cable racking hardware with tie wraps, Velcro straps, or non-metallic cable straps with locking/buckling mechanism. Do not use adhesive or self-adhering tapes, metal wires and straps, or rope/cord.
2. Unless otherwise noted on the Plans, the following are the requirements for cable storage for underground applications:
    a. Cable in Type C pull box – 20’.
    b. Cable in Type D pull box – 20’.

c. Cable in Type E pull box – 20’.

3. Install cable labels on all RDS Cables. Clean the installed cable of all dirt and grease before applying any label.

4. Label all cables in or at every location where the cable is exposed outside of a conduit, inner-duct, or pole. As a minimum, install cable labels in the following locations:

   a. Within 12” of every cable entry to a pull box or equipment cabinet.

   b. Every 10’ for the entire length of cable in any storage coil in pull boxes.

12.4 Testing Requirements

12.4.1 General Requirements

1. The Contractor shall conduct a project testing program for all materials specified in this section and as required in Section 2.5 of this SP725.

2. All test results shall confirm physical and performance compliance with this SP725.

3. Payment for all testing is included in the cost of the Radar Detection Equipment.

4. All RDS Cables under test shall be removed from all wiring termination devices until testing is completed. All RDS Cable conductors shall be connected to ground immediately after testing to ensure elimination of all capacitive charges and potentials.

5. The Contractor shall submit all test results documentation to the Engineer within 7 calendar days of completion of the tests. The Engineer will review test documentation in accordance with the Submittal Review Process in Section 2.7. Test documentation shall include:

   a. RDS Cable Identification:

      i. Cable ID and Location – physical location (device ID and station number of equipment cabinet) and conductor/pair/shield ID for both the beginning and ending point

      ii. Operator Name

      iii. Engineer’s Representative

      iv. Date & Time

   b. Setup and Test Conditions Parameters:

      i. Battery charge and proper operation of ohmmeter

      ii. Battery charge and proper operation of insulation resistance tester

      iii. Ambient Temperature

   c. Test Results for Continuity Test:

      i. Conductor continuity

      ii. Resistance (ohms)

      iii. Measured Length (Cable Marking)

d. Test Results for Insulation Resistance Test:

   i. Measured Cable Length

   ii. Insulation resistance (exceeds manufacturer's specifications for at least 60 seconds.)

12.4.2 Factory Acceptance Test

FAT is not required for Radar Detection Equipment.

12.4.3 Bench Test Component

BTC shall be performed in the presence of the Engineer. The BTC shall include the following tests and inspections:

1. Verify the Radar Detection Equipment has no internal or external damage.
2. Test all Radar Detection Equipment functionality using vendor software.
3. Perform continuity test on all conductors and shield in the RDS Cable.

12.4.4 Bench Test System

BTS shall be performed in the presence of the Engineer. The BTS must be performed utilizing the maximum total length of the RDS Cable required in this project. The BTS shall include the following tests and inspections:

1. Verify Radar Detection Equipment attachment compatibility with the mounting bracket.
2. Verify that the Radar Detection Equipment is compatible and supports operational interoperability with the communication equipment, TDOT ATMS software, and any existing equipment at the Radar Detection Equipment site.
3. Verify that the RDS can be configured and calibrated using the vendor software.
4. Verify that the required operational characteristics of the device are valid including the counting of volume and speed.

12.4.5 Stand Alone Site Test

SAT shall be performed in the presence of the Engineer. The SAT shall include the following tests and inspections:

1. Verify all components have been installed per manufacturer requirements.
2. Verify all items have been attached properly (as per manufacturer recommendations and the Plans) to each other and to the Pole Structure.
3. Verify the Radar Detection Equipment has no internal or external damage.
4. Verify the Radar Detection Equipment has been properly connected to the UPS for continuous, conditioned power.
5. Verify the RDS and cabinet equipment are protected by surge suppression.
6. Verify volume and speed data can be observed through the direct local connection.
7. Verify volume and speed data can be observed through the Network Ethernet Switch.

8. Test and document the accuracy of the RDS in accordance with the accuracy requirements specified in Section 12.2.5. A portion of this test requires the contractor to use a calibrated radar gun to compare observed speeds on a per lane basis between the calibrated radar gun and RDS data over a 5-minute period. All data collected during the test shall be documented and submitted to the Engineer for approval.
9. Perform continuity test and insulation resistance test on all conductors and shield in the RDS Cable.

12.5 Warranty

All materials specified in this section shall carry a minimum three-year manufacturer's warranty from the date of Final Acceptance against any imperfections in workmanship or materials. Warranties shall cover complete replacement at no charge for the equipment. Warranties shall be transferred to TDOT upon Final Acceptance of the project as per the requirements in Section 2.6 of this specification.

12.6 Method of Measurement

12.6.1 Radar Detection System

The Radar Detection System (RDS) will be measured in units of each and paid for at the contract price per each. The bid price shall include furnishing and installing of the RDS including the unit, power supply, all conduit, risers, and weather head between the RDS and the cabinet, interconnection wiring to the ethernet switch, connections to support structures (includes all incidental components, attachment hardware, mounting brackets, mounting arms, bolts, or any other items to mount the RDS as intended), and all work, equipment, and appurtenances as required to effect the full operation including remote and local control of the RDS site complete in place and ready for use. Furnishing and installing of RDS harness cabling to be bid under the RDS Comm Cable pay Item. The bid price shall include satisfactory completion of device integration and testing of a complete RDS, including the unit, the RDS harness cabling, and interconnection wiring. The bid price shall also include all documentation including shop drawings, operations and maintenance manuals, wiring diagrams, block diagrams, and other material necessary to document the operation of the RDS. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

In locations where an RDS is connected to an existing cabinet via RDS Cable, the bid price for the RDS shall include furnishing, installing, and testing of a RDS communication subsystem inside the existing cabinet. This RDS communications subsystem shall meet the specifications in Section 12.2.

12.6.2 RDS Comm Cable

RDS Comm Cable will be measured in units of linear feet and paid for at the contract price per linear feet of actual cable installed as measured from the cable sequential length markings. The bid price shall include furnishing, installing, device integration, and testing of a complete RDS Comm Cable installation with operational RDS units and shall include cable labels and all ancillary and incidental materials, testing, documentation, and all labor and equipment necessary to complete the work. No measurement for payment will be made for cable storage amounts in excess of that required in this SP725 or the Plans.

12.7 Payment

The contract unit price shall be full compensation for all work specified in this section.

Payment will be made under:

Item No.	Description	Unit
725-21.91	RADAR DETECTION SYSTEM	EA
725-21.96	RDS COMM CABLE	LF

Radar Detection System (RDS) will be paid per each as follows:

1. 50% of the contract unit price upon approval of Bench Test Component and Bench Test System test results.
2. Additional 20% of the contract unit price upon approval of Stand Alone Site Test results.
3. Additional 20% of the contract unit price upon approval of Conditional System Acceptance Test results.
4. Final 10% of the contract unit price upon Final System Acceptance.

RDS Cable will be paid per linear foot as follows:

1. 25% of the contract unit price upon delivery and reel test.
2. Additional 35% of the contract unit price for complete installation of cables.
3. Additional 30% of the contract unit price for successful completion of Stand Alone Site Test results of the complete cable in any lineal foot between terminations in equipment cabinets and Stand Alone Site Testing of all RDS units communicating through this section of cable.
4. Final 10% of the contract unit price upon Final System Acceptance.

13 ENVIRONMENTAL SENSOR SYSTEM (ESS)

13.1 Description

This Section specifies the minimum requirements for the Environmental Sensor System (ESS) furnished and installed on this project as shown on the Plans. The ESS will provide environmental information as specified on the Plans, including but not limited to pavement temperature, pavement precipitation, and visibility sensors, for the purpose of evaluating environmental conditions for hazards. It is the Contractor's responsibility to furnish, program, install, and integrate environmental sensors in the field and at the TDOT Regional TMC.

The Contractor shall provide a complete sensor package including all cabling, conduits, sensors, mounts, electrical service, surge suppression, and all hardware associated with a complete installation as required by this SP725.

13.2 Materials

Contractor shall provide all materials according to the requirements in the following sections.

All equipment shall be new and constructed using the highest quality, commercially available components and techniques to assure high reliability and minimum maintenance. Prior to installation, the Contractor shall submit and receive approval from the Engineer on a complete set of shop drawings of all the equipment and components listed within this Special Provision and included as part of the installation.

The firmware pre-installed on the device shall meet the minimum version listed in APPENDIX D at the time of device installation in the field.

13.2.1 General

1. Communications:
    a. The environmental sensor, whether an individual sensor or working as a system, must be capable of transmitting all collected data via IP communications.
2. Calibration Device
    a. Each sensor shall be provided with an applicable calibration device and associated user's manual.
3. Software:
    a. All software required to configure and operate the Sensor shall be provided.
4. ATMS Compatibility:
    a. The environmental sensor, whether an individual sensor or working as a system, must be compatible with the TDOT ATMS software. The devices must be able to be integrated into the software such that the data processed by the sensors is available for monitoring within the TDOT ATMS software.

13.2.2 Pavement Temperature Sensors

1. Remote Pavement Temperature:

a. A remote pavement temperature sensor uses a non-intrusive remote sensor to determine the temperature of the roadway.

b. The remote pavement temperature sensor shall provide temperature information of the pavement at which the sensor is directed, without delay.

c. The remote pavement temperature sensor shall meet the physical characteristics in the following table:

Description	Specification
Temperature Operating Range	-40°C to 60°C
Temperature Observation Range	-40°C to 60°C
Accuracy	±1.11°C
Housing	Weatherproof IP 66 rated
Power	12 or 24VDC

13.2.3 Pavement Precipitation Sensors

1. Pavement Precipitation Depth:

a. A pavement precipitation depth sensor determines the thickness of ice, water, or snow currently on the roadway.

b. The pavement precipitation depth sensor shall provide information on the depth of precipitation on the roadway in all weather conditions, without delay.

c. The pavement precipitation depth sensor shall meet the physical characteristics in the following table:

Description	Specification
Temperature Operating Range	-40°C to 60°C
Water Depth Observation Range	0.01 – 0.07 in {0.3 – 2 mm}
Snow and Ice Depth Observation Range	0.01 – 0.39 in {0.3 – 10 mm}
Housing	Weatherproof IP 66 rated
Power	12 or 24VDC
Water Depth Accuracy	±0.1 mm
Surface Conditions	Dry, Damp, Wet, Snow, Ice

13.2.4 Visibility Sensors

1. Visibility:

a. A visibility sensor determines the distance a driver can see (sight distance) through adverse conditions via the measure of meteorological optical range.

b. The visibility sensor shall provide information on the distance of visibility near the roadway in all weather conditions, without delay.

c. The visibility sensor shall meet the physical characteristics in the following table:

Description	Specification
Temperature Operating Range	-40°C to 60°C
Visibility Observation Range	10-2000 m
Weather Type Identification	Clear, Haze, Fog, and Precipitation
Housing	Weatherproof IP 66 rated
Power	12 or 24VDC
Visibility Distance Accuracy	±10% or less

13.2.5 Data Processing Unit

The data processing unit shall meet the following requirements:

1. The data processing unit shall be from the same manufacturer as the environmental sensors.
2. The sensor data provided from the unit shall comply with NTCIP 1204 v04, or latest.
3. The sensor data provided from the unit shall be sent to and capable of being ingested by the TDOT ATMS software.
4. The data processing unit shall be able to support at least 3 environmental sensors simultaneously including pavement temperature, pavement precipitation, and visibility.
5. The data processing unit shall utilize ethernet communications with at least 1 RJ45 port.
6. The data processing unit shall perform any data processing and storage required on the data received from the sensors.
7. The data processing unit shall be capable of transmitting an alarm in the event of a low power supply, complete power loss, or return to normal operation.
8. The data processing unit shall be able to transmit alarms for user-defined thresholds for sensor parameters.
9. The data processing unit shall be rated to operate within the following parameters:
   a. Temperatures between -40°C and 60°C
   b. Relative humidity between 5% and 95%

13.2.6 Power Supply

The power supply shall meet the following requirements:

1. The power supply shall be from the same manufacturer as the environmental sensors.
2. The power supply shall provide power to all sensors and the data processing unit.

3. The power supply shall be rated to operate within the following parameters:
   a. Temperatures between -40°C and 60°C
   b. Relative humidity between 5% and 95%

13.2.7 ESS Comm Cable

1. The ESS harness cable shall be outdoor wet/dry rated cable with UV-resistant PVC or polyethylene outer jacket with conductors that have a temperature rating of 105ºC.
2. Cable shall be provided by the same manufacturer as the sensors and data processing unit.
3. Connection between the ESS and the cabinet equipment shall be provided by a single ESS harness cable. No splices are permitted in the harness cable.
4. Provide cable with outer jacket marking using the following template:

   Manufacturer's Name – "ESS Cable" – Month/Year of Manufacture – Telephone Handset Symbol – "TDOT ITS"
5. Provide cable labels that meet the following requirements:
   a. Self-coiling wrap-around type.
   b. PVC or equivalent plastic material with UV and fungus inhibitors.
   c. Base materials and graphics/printing inks/materials designed for underground outside plant use including solvent resistance, abrasion resistance, and water absorption.
   d. Minimum size of 2.5" wide by 2.5" long
   e. Minimum thickness of 0.01".
   f. Orange label body with pre-printed text in bold black block-style font with minimum text height of 0.375".
   g. Pre-print the following text legibly on ESS Cable labels:
      i. ESS CABLE
      ii. TDOT ITS
   h. On all cable labels, print the text specified above twice on the label with the text of the second image reversed. The result shall be text which "reads right" when the label is coiled onto a cable.

13.3 Installation Requirements

Contractor shall abide by the installation requirements in the following sections.

13.3.1 General Requirements

All equipment shall be installed according to the manufacturer's recommendations, the Plans and as follows:

1. Materials and associated accessories/adapters shall not be applied contrary to the manufacturer's recommendations and standard practices.

2. All components shall be grounded in accordance with manufacturers' recommendations and the Standard Specifications.
3. Surge protection shall be provided between the sensors and cabinet components.
4. All like cabling shall be bundled to minimize crosstalk and electrical interference. Wiring shall be routed to prevent conductors from being in contact with devices in the cabinet and metal edges. Wiring shall also be arranged so that any removable assembly may be removed without disturbing or unhooking conductors.
5. All power and communications wiring shall be 1 continuous run from cabinet to Sensor. No splicing of wiring will be permitted unless approved by the Engineer.
6. Electronic devices in the sensor cabinet shall not be installed until electrical service has been installed and activated, and the cabinet ventilation fan is operational.
7. The ESS power supply shall be connected to the UPS within the cabinet.
8. Prior to installation, all equipment must be stored in a location and manner approved by TDOT.
9. The Contractor is responsible for coordinating with TDOT Regional TMC IT for IP addresses and integrating the new sensors into the TDOT ATMS software.

13.3.2 Documentation

The documentation for the ESS shall consist of the following: Communications Protocol, Operator's Manual, Maintenance Procedure Manual, Equipment Drawings, and Electrical Schematic Diagrams.

1. Operator's Manual:

   This document shall fully describe the operation of the ESS using the Windows based software that runs on a notebook computer. This document shall clearly define all functions that are supported by the sensors/software. The manual shall define the normal operation of the sensors and the software including resetting and restarting the software package. A word-searchable electronic copy of this document shall be provided.

2. Maintenance Procedure Manual:

   This manual shall document the preventive and corrective maintenance procedures that should be followed to maintain the ESS at the highest level of operational efficiency. The manual shall include step-by-step field and bench trouble-shooting procedures to isolate and repair faults. The document shall include descriptions of normative waveforms and test voltages. A detailed parts list shall be included. For each part or assembly, a circuit diagram or pictorial shall be provided. A word-searchable electronic copy shall be provided.

3. Equipment Drawings and Diagrams:

   A pictorial drawing showing the physical location and identification of each component shall be provided for each different electronic assembly and each different subassembly. An electronic copy of these drawings shall be provided in either PDF or CAD file type.

4. Electrical Schematic Diagrams:

   An electrical schematic, wiring diagram, and a logic diagram shall be provided for each different type of equipment. A stage-by-stage explanation of the circuit theory shall be provided with the circuit wiring diagrams. Connection diagrams for each sensor including block diagrams, terminal numbers, and conductor color codes shall be provided. An electronic copy of these diagrams shall be provided in either PDF or CAD file type.

13.3.3 Training

If the ESS model and generation proposed by the Contractor is not identical to an ESS model and generation that is already deployed within the TDOT Region of the project, training will be required. Prior to the acceptance of the first ESS, training shall be provided for TDOT's engineering, maintenance, and operations staff, at a facility provided by TDOT. The training shall include all material and manuals required for each participant.

The training shall be provided for 2 identical non-consecutive 1 day sessions for at least 10 engineering and operations personnel each. These hours of training are inclusive of those required in Section 2.4. The training shall include a complete demonstration of the operation and capabilities of the ESS. This session shall include a complete review of any field adjustments or calibration that may be required for any component. The training shall include operation instructions, theory of operation, circuit description, field adjustments, preventive maintenance procedures, troubleshooting, and repair of all components. Particular attention shall be given to the operation of the software packages to be provided.

13.4 Testing Requirements

13.4.1 General Requirements

1. The Contractor shall conduct a project testing program for all materials specified in this section and as required in Section 2.5 of this SP725.
2. All test results shall confirm physical and performance compliance with this SP725.
3. Payment for all testing is included in the cost of the ESS.
4. All ESS Cables under test shall be removed from all wiring termination devices until testing is completed. All ESS Cable conductors shall be connected to ground immediately after testing to ensure elimination of all capacitive charges and potentials.
5. Submit all test results documentation to the Engineer within 7 days of completion of the tests. The Engineer will review test documentation in accordance with the Project Submittal Program Requirements in Section 2.7. Test documentation shall include:
    a. ESS Cable Identification:
        i. Cable ID and Location – physical location (device ID and station number of equipment cabinet) and conductor/pair/shield ID for both the beginning and ending point
        ii. Operator Name
        iii. Engineer's Representative
        iv. Date & Time
    b. Setup and Test Conditions Parameters:
        i. Battery charge and proper operation of ohmmeter
        ii. Battery charge and proper operation of insulation resistance tester

    iii. Ambient Temperature

c. Test Results for Continuity Test:

    i. Conductor continuity

    ii. Resistance (ohms)

    iii. Measured Length (Cable Marking)

d. Test Results for Insulation Resistance Test:

    i. Measured Cable Length

    ii. Insulation resistance (exceeds manufacturer's specifications for at least 60 seconds.)

13.4.2 Factory Acceptance Test

FAT is not required for ESS.

13.4.3 Bench Test Component

BTC shall be performed in the presence of the Engineer. The BTC shall include the following tests and inspections:

1. Verify the ESS has no internal or external damage.
2. Test all ESS functionality using vendor software.
3. Perform continuity test on all conductors and shield in the ESS Cable.

13.4.4 Bench Test System

BTS shall be performed in the presence of the Engineer. The BTS must be performed utilizing the maximum total length of the ESS Cable required in this project. The BTS shall include the following tests and inspections:

1. Verify ESS attachment compatibility with the mounting brackets.
2. Verify that the ESS is compatible and supports operational interoperability with the communication equipment, TDOT ATMS software, and any existing equipment at the ESS site.
3. Verify that the ESS can be configured and calibrated using the vendor software.
4. Verify that the required operational characteristics of the device are valid including the measurement of environmental conditions required in Section 13.2.

13.4.5 Stand Alone Site Test

SAT shall be performed in the presence of the Engineer. The SAT shall include the following tests and inspections:

1. Verify all components have been installed per manufacturer requirements.
2. Verify all items have been attached properly (as per manufacturer recommendations and the Plans) to each other and to the Pole Structure.
3. Verify the ESS has no internal or external damage.

4. Verify the ESS has been properly connected to the UPS for continuous, conditioned power.
5. Verify the ESS and cabinet equipment are protected by surge suppression.
6. Verify the measurement of environmental conditions required in Section 13.2 can be observed through the direct local connection.
7. Verify the measurement of environmental conditions required in Section 13.2 can be observed through the Type A Network Switch.
8. Test the accuracy of the ESS in accordance with the accuracy requirements specified in Section 13.2.
9. Perform continuity test and insulation resistance test on all conductors and shield in the ESS Cable.

13.5 Warranty

All materials specified in this section shall carry a minimum three-year manufacturer's warranty from the date of Final Acceptance against any imperfections in workmanship or materials. Warranties shall cover complete replacement at no charge for the equipment. Warranties shall be transferred to TDOT upon Final Acceptance of the project as per the requirements in Section 2.6 of this specification.

13.6 Method of Measurement

13.6.1 Environmental Sensor (Pavement Temperature)

The ESS shall be measured in units of each and paid for at the contract unit price per each. The price shall include furnishing, installing, device integration, and testing of the complete ESS including the data processor, power supply, pavement temperature sensor, wiring, controller, communications interface, fittings, and junction boxes, satisfactory completion of testing requirements, and all work, equipment, and appurtenances as required to effect the full operation of the sensors, complete in place and ready for use. The bid price shall also include all system documentation including shop drawings, operations and maintenance manuals, wiring diagrams, block diagrams, and other material necessary to document the operation of the ESS. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

13.6.2 Environmental Sensor (Precipitation)

The ESS shall be measured in units of each and paid for at the contract unit price per each. The price shall include furnishing, installing, device integration, and testing of the complete ESS including the data processor, power supply, pavement precipitation sensor, wiring, controller, communications interface, fittings, and junction boxes, satisfactory completion of testing requirements, and all work, equipment, and appurtenances as required to effect the full operation of the sensors, complete in place and ready for use. The bid price shall also include all system documentation including shop drawings, operations and maintenance manuals, wiring diagrams, block diagrams, and other material necessary to document the operation of the ESS. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

13.6.3 Environmental Sensor (Visibility)

The ESS shall be measured in units of each and paid for at the contract unit price per each. The price shall include furnishing, installing, device integration, and testing of the complete ESS including the data processor, power supply, visibility sensor, wiring, controller, communications interface, fittings, and junction boxes, satisfactory completion of testing requirements, and all work, equipment, and appurtenances as required to effect the full operation of the sensors, complete in place and ready for use. The bid price shall also include all system documentation including shop drawings, operations and maintenance manuals, wiring diagrams, block diagrams, and other material necessary to document the operation of the ESS. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

13.6.4 Environmental Sensor (Pavement Temperature and Precipitation)

The ESS shall be measured in units of each and paid for at the contract unit price per each. The price shall include furnishing, installing, device integration, and testing of the complete ESS including the data processor, power supply, pavement temperature sensor, pavement precipitation sensor, wiring, controller, communications interface, fittings, and junction boxes, satisfactory completion of testing requirements, and all work, equipment, and appurtenances as required to effect the full operation of the sensors, complete in place and ready for use. The bid price shall also include all system documentation including shop drawings, operations and maintenance manuals, wiring diagrams, block diagrams, and other material necessary to document the operation of the ESS. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

13.6.5 Environmental Sensor (Pavement Temperature and Visibility)

The ESS shall be measured in units of each and paid for at the contract unit price per each. The price shall include furnishing, installing, device integration, and testing of the complete ESS including the data processor, power supply, pavement temperature sensor, visibility sensor, wiring, controller, communications interface, fittings, and junction boxes, satisfactory completion of testing requirements, and all work, equipment, and appurtenances as required to effect the full operation of the sensors, complete in place and ready for use. The bid price shall also include all system documentation including shop drawings, operations and maintenance manuals, wiring diagrams, block diagrams, and other material necessary to document the operation of the ESS. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

13.6.6 Environmental Sensor (Precipitation and Visibility)

The ESS shall be measured in units of each and paid for at the contract unit price per each. The price shall include furnishing, installing, device integration, and testing of the complete ESS including the data processor, power supply, pavement precipitation sensor, visibility sensor, wiring, controller, communications interface, fittings, and junction boxes, satisfactory completion of testing requirements, and all work, equipment, and appurtenances as required to effect the full operation of the sensors, complete in place and ready for use. The bid price shall also include all system documentation including shop drawings, operations and maintenance manuals, wiring diagrams, block diagrams, and other material necessary to document the operation of the ESS. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

13.6.7 Environmental Sensor (Pavement Temperature, Precipitation, and Visibility)

The ESS shall be measured in units of each and paid for at the contract unit price per each. The price shall include furnishing, installing, device integration, and testing of the complete ESS including the data processor, power supply, pavement temperature sensor, pavement precipitation sensor, visibility sensor, wiring, controller, communications interface, fittings, and junction boxes, satisfactory completion of testing requirements, and all work, equipment, and appurtenances as required to effect the full operation of the sensors, complete in place and ready for use. The bid price shall also include all system documentation including shop drawings, operations and maintenance manuals, wiring diagrams, block diagrams, and other material necessary to document the operation of the ESS. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

13.6.8 Environmental Sensor Comm Cable

The communications cable between the environmental sensors and the device cabinet shall be measured in units of linear feet and paid for at the contract unit price per linear foot. The price shall include furnishing and installing the communication cable between each environmental sensor and the device cabinet. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

13.6.9 Environmental Sensor (Calibration Device)

Each project that includes ESS shall include a calibration device that can calibrate all provided sensors. Each project shall include only a single calibration device per sensor type, and the cost of the calibration device(s) shall be incidental to the cost of the ESS.

13.7 Payment

The contract unit price shall be full compensation for all work specified in this section. Payment will be made under:

Item No.	Description	Unit
725-21.87	ENVIRONMENTAL SENSOR COMM CABLE	LF
725-22.10	ENVIRONMENTAL SENSOR (PAVEMENT TEMPERATURE)	EA
725-22.11	ENVIRONMENTAL SENSOR (PRECIPITATION)	EA
725-22.12	ENVIRONMENTAL SENSOR (VISIBILITY)	EA
725-22.13	ENVIRONMENTAL SENSOR (PAVEMENT TEMPERATURE AND PRECIPITATION)	EA
725-22.14	ENVIRONMENTAL SENSOR (PAVEMENT TEMPERATURE AND VISIBILITY)	EA
725-22.15	ENVIRONMENTAL SENSOR (PRECIPITATION AND VISIBILITY)	EA
725-22.16	ENVIRONMENTAL SENSOR (PAVEMENT TEMPERATURE, PRECIPITATION, AND VISIBILITY)	EA

ESS will be paid per each as follows:

1. 50% of the contract unit price upon approval of Bench Test Component and Bench Test System test results.
2. Additional 20% of the contract unit price upon approval of Stand Alone Site Test results.
3. Additional 20% of the contract unit price upon approval of Conditional System Acceptance Test results.
4. Final 10% of the contract unit price upon Final System Acceptance.

ESS Cable will be paid per linear foot as follows:

1. 25% of the contract unit price upon delivery and reel test.
2. Additional 35% of the contract unit price for complete installation of cables.
3. Additional 30% of the contract unit price for successful completion of Stand Alone Site Test results of the complete cable in any lineal foot between terminations in equipment cabinets and Stand Alone Site Testing of all ESS units communicating through this section of cable.
4. Final 10% of the contract unit price upon Final System Acceptance.

14 ROAD SIDE UNIT (RSU)

14.1 Description

14.1.1 *General Requirements*

This section specifies the minimum requirements for DSRC/C-V2X/Bluetooth Road Side Unit (RSU) furnished and installed on this project as shown on the Plans. The following general requirements apply:

1. The devices described in this document are deployment grade electronic instruments that must be capable of both transmitting and receiving 5.x GHz RF paths for facilitating connected vehicle applications as well as receiving Discoverable and Non-Discoverable Bluetooth signals. Each unit shall include all components necessary for complete functionality of the unit. Types of proposed devices include RSU, and handheld units or referred to as Multi Channel Test Tool (MCTT).

2. If Vendors have multiple generations of hardware available, they shall offer only the latest certified and commercially available version of their equipment for this bid with the latest firmware pre-installed.

14.1.2 Contractor Prequalification

This section identifies the required minimum qualifications for the Contractor for the installation and integration of the RSU. Written proof of the Contractor's ability to meet these requirements shall be submitted to TDOT for review and approval prior to any procurement of related materials and work related to the RSUs.

1. Experience providing equipment for and working on similar vehicle to everything (V2X) tests or projects.

2. Staff availability and resumes showing experience in similar V2X installation projects.

3. Experience working with Basic Safety Message standard SAE J2735_201603 and SAE J2945/1 latest version.

4. Ability to perform training and oversight for the installers and other staff.

14.1.3 Qualitative Standards and Criteria

The Vendor shall ensure the following standards and criteria are followed:

1. DSRC Message Set Dictionary – the SAE J2735_201603 Library for Basic Safety Message (BSM), Signal Phasing and Timing (SPaT), Map Data (MAP), and Traveler Information Message (TIM): https://www.sae.org/standardsdev/dsrc/

2. V2X Message Set Dictionary – the SAE J2735_202007 Library: https://www.sae.org/standards/content/j2735_202007/

3. Object Definitions for RSUs – NTCIP 1218 v01

4. Best Practices for Surveying and Mapping Roadway and Intersections for Connected Vehicles; Connected Vehicle Pooled Fund Study; May 15, 2016:http://escholarship.org/uc/item/4f88m75k#page-1

5. USDOT SPaT Documentation:www.itsforge.net

6. USDOT SCMS: http://www.its.dot.gov/pilots/pdf/SCMS_POC_EE_Requirements.pdf or later
7. USDOT Intersection MAP and SPaT Tool: https://webapp2.connectedvcs.com/
8. TDOT's Dedicated Short Range Communication (DSRC) Statewide Guidance: https://www.tn.gov/content/dam/tn/tdot/traffic-engineering/TDOTDSRC_Final%20Report_version%201.0_Nov%202018.pdf

14.1.4 Minimum Technical Requirements

This section identifies the minimum equipment requirements for the project.

1. All devices offered shall be new and available for purchase from the awarded Vendor.
2. DSRC/C-V2X RSU shall be carrier grade.
3. DSRC two-way communication protocol shall employ and integrate the Institute of Electrical and Electronics Engineers (IEEE) 802.11p, 1609.0 through 1609.12 standards (latest edition) and the Society of Automotive Engineers (SAE) J2735_201603 message set dictionary. Simple Network Management Protocol (SNMP) shall be supported to interface with the TDOT ATMS software.
4. C-V2X two-way communication protocol shall employ and integrate the IEEE 1609.2 (latest edition), ETSI EN 302 571 (latest edition) and 3GPP, latest Release standards and the SAE J2735_201603 message set dictionary. Simple Network Management Protocol (SNMP) shall be supported to interface with the TDOT ATMS software.
5. The RSU C-V2X radio shall be upgradable to 5G.
6. The Bluetooth Radio shall be adjustable and support the communication with both Discoverable and Non-Discoverable signals.
7. The RSU shall support the capability to hook up a remote antenna that can be run a distance of at least 60' away from the base unit.
8. The RSU shall support an Internet Protocol (IP) iPv4 and iPv6 connection to the USDOT Security Credential Management System (SCMS).
9. The RSU shall support NIST and Brainpool Elliptic Curve Cryptography. The RSU shall also support the storage of at least 500 security keys through a V2X-embedded Hardware Security Module.
10. The RSU shall transmit the Signal Phasing and Timing (SPaT), Traveler Information Messages (TIMs), and intersection geometry (or MAP) messages as defined in SAE J2735_201603.
11. The RSU shall forward Basic Safety Messages (BSMs) received from passing vehicles to a configurable remote network host.
12. The RSU shall support Global Positioning System (GPS) as specified in the latest adopted USDOT RSU Specification.
13. The RSU devices shall connect to an existing IP network via Ethernet. The RSU shall have at least 1 RJ-45 Ethernet port for network connection and support iPv4 and iPv6 address configuration dual stacked.
14. The RSU devices shall have software applications installed which will accept information from signal controllers to broadcast SPaT messages.
15. The RSU hardware shall be powered via Power over Ethernet (PoE) of at least PoE 802.3af.

16. Any additional enclosures required to accommodate supporting equipment shall be National Electrical Manufacturers Association (NEMA) rated with surge protection.

17. The RSU must include a Security Credential Management System (SCMS).

14.2 Materials

Contractor shall provide all materials according to the requirements in the following sections.

All equipment shall be new and constructed using the highest quality, commercially available components and techniques to assure high reliability and minimum maintenance. Prior to installation, the Contractor shall submit and receive approval from the Engineer on a complete set of shop drawings of all the equipment and components listed within this Special Provision and included as part of the installation.

The firmware pre-installed on the device shall meet the minimum version listed in APPENDIX D at the time of device installation in the field.

1. RSUs shall be compatible with the Iteris BlueARGUS platform to work cohesively with existing RSUs.

2. The RSU shall include 2 Omni-Directional Antennas for Bluetooth detection. The RSU shall also include a minimum of 2 external antenna mounting ports with antennas for DSRC/C-V2X broadcast with at least 1 additional mounting port for GPS antenna if external antenna is required for GPS support.

3. A NEMA TS2 AC/DC power supply for powering PoE unit shall be included.

4. Mounting brackets, mounting plates, and stainless-steel straps shall be included as needed for mounting.

5. Category 6, minimum, ethernet cable that is long enough to run between the RSU and ethernet switch shall be included.

6. UL 497B Listed, Series-connected surge protector with POE support for Ethernet Cable.

14.3 Installation Requirements

Contractor shall abide by the installation requirements in the following sections. Prior to installation, verify required locations are filed and accepted with the FAA per CFR Title 14 Part 77.9.

14.3.1 General Requirements

1. The RSU must be installed in accordance with TDOT Dedicated Short Range Communication (DSRC) Statewide Guidance (latest version). As noted in this document:

    a. DSRC/C-V2X radio and components shall be installed per latest FCC standards and regulations.

    b. All conduits and ducts shall be sealed with a rubber fitting or a weather head.

    c. All mounting hardware shall be stainless steel.

    d. Bracket arm to be include as part of RSU pay item.

    e. The maximum height for mounting the RSU shall be 26’ above the roadway surface.

f. RSU shall be mounted in such a manner to achieve clear line of sight to the roadway for all intersection approaches.

g. The final mounting location shall be approved by the Engineer prior to installation.

h. The method and materials used to mount the RSU shall be submitted by the Contractor and approved by the Engineer prior to installation.

i. Connect RSU to ethernet switch in signal cabinet using PoE cable as approved by the Engineer.

j. RSU manufacturer representative shall be present during RSU equipment installation and set-up.

2. Per the FCC regulations the DSRC/C-V2X radio shall be mounted at a maximum height of 26’ above the roadway surface before a maximum Equivalent Isotropically Radiated Power (EIRP) limitation occurs.

3. The RSU mounting offset from the desired structure should be such to maximize range of the device. For example: pole locations set further back from the roadway, should consider using a bracket arm (ex: 6’-18’) for mounting the RSU. Pole locations that are behind guardrail near to the roadway, may use a standard L bracket arm for securing the RSU to the pole.

4. RSU mounting location shall be optimized to achieve clear line of sight to the roadway, free of radio frequency (RF) signal path interference from trees, bridges, overpasses and other structures.

5. The Contractor shall perform a site survey to confirm the most appropriate field location for each RSU.

6. DSRC/C-V2X spectrum coordination must be completed to assure all FCC regulatory requirements are met and to ensure no interference with other existing radio frequency (RF) signals is present.

7. An Ethernet signal booster shall be provided and installed if the length of the Ethernet cable connecting the RSU and the Equipment Cabinet is greater than 328’.

8. The Contractor shall install and configure the SCMS.

14.3.2 Documentation

The documentation for the RSU shall consist of the following: Communications Protocol, Operator’s Manual, Maintenance Procedure Manual, Equipment Drawings, and Electrical Schematic Diagrams.

14.3.2.1 Operator’s Manual:

This document shall fully describe the operation of the RSU using the Windows based software that runs on a notebook computer. This document shall clearly define all functions that are supported by the software. The manual shall define the normal operation of the RSUs and the software including resetting and restarting the software package. A word-searchable electronic copy of this document shall be provided. The manual shall include the following:

a. General Description

b. General Characteristics

c. Installation

d. Adjustments

e. Theory of Operation

f. Maintenance

    i. Preventive Maintenance

    ii. Trouble Analysis

    iii. Trouble Shooting Sequence Chart

g. Wave Forms

    i. Voltage Measurements

    ii. Alignment Procedures

    iii. Parts List

    iv. Communications Protocol

    v. Schematic and Logic Diagrams

14.3.2.2 Maintenance Procedure Manual:

This manual shall document the preventive and corrective maintenance procedures that should be followed to maintain the RSU at the highest level of operational efficiency. The manual shall include step-by-step field and bench trouble-shooting procedures to isolate and repair faults. The document shall include descriptions of normative waveforms and test voltages. A detailed parts list shall be included. For each part or assembly, a circuit diagram or pictorial shall be provided. A word-searchable electronic copy of this document shall be provided.

14.3.2.3 Equipment Drawings and Diagrams:

A pictorial drawing showing the physical location and identification of each component shall be provided for each different electronic assembly and each different subassembly. Wiring diagrams shall be provided for each sign case. These diagrams shall depict the location and interface of all components located within the sign case. An electronic copy of these drawings (using common drawing software such as MicroStation) shall be provided.

14.3.2.4 Electrical Schematic Diagrams:

An electrical schematic, wiring diagram, and a logic diagram shall be provided for each different type of equipment. A stage-by-stage explanation of the circuit theory shall be provided with the circuit wiring diagrams. Connection diagrams for each RSU subsystem including block diagrams, terminal numbers, and conductor color codes shall be provided. An electronic copy of these diagrams (using common drawing software such as MicroStation) shall be provided.

14.3.3 T*raining*

Prior to the Stand Alone Site Test of the first RSU, training shall be provided for TDOT's engineering, maintenance, and operations staff, at a facility provided by TDOT. The training shall include all material and manuals required for each participant.

The training shall be provided for 2 identical non-consecutive 1 day sessions for at least 10 engineering and operations personnel. These hours of training are inclusive of those required in Section 2.4. The training shall include a complete demonstration of the operation and capabilities of the RSU. This session shall include a complete review of any field adjustments or calibration that may be required. The training shall include operation instructions, theory of operation, circuit description, field adjustments, preventive maintenance procedures, troubleshooting and repair of all components. Particular attention shall be given to the operation of the software packages to be provided including procedures for configuring the signs, displaying messages and diagnosing faults.

14.4 Testing Requirements

14.4.1 General Requirements

1. The Contractor shall conduct a project testing program for all materials specified in this section and as required in Section 2.5 of this SP725.
2. All test results shall confirm physical and performance compliance with this SP725.
3. The Contractor shall submit all test results documentation to the Engineer within 7 calendar days of completion of the tests. The Engineer will review test documentation in accordance with the Submittal Review Process in Section 2.7.
4. Payment for all testing is included in the cost of the RSU.

14.4.2 Factory Acceptance Test

FAT is not required for RSU.

14.4.3 Bench Test Component

BTC shall be performed in the presence of the Engineer. The BTC shall include the following tests and inspections:

1. Verify the RSU has no internal or external damage.
2. Verify there are no missing antennas.
3. Test all RSU functionality including sending and receiving J2735 messages using vendor software.

14.4.4 Bench Test System

BTS shall be performed in the presence of the Engineer. The BTS shall include the following tests and inspections:

1. Verify RSU attachment compatibility with the mounting brackets.
2. Verify that the RSU is compatible and supports operational interoperability with the communication equipment, TDOT ATMS software, and any existing equipment at the RSU site.

3. Verify that the RSU can be configured and calibrated using the vendor software.
4. Verify that the required operational characteristics of the device are valid including the sending and receiving J2735 messages and detection of Bluetooth, DSRC, and C-V2X signatures.

14.4.5 Stand Alone Site Test

SAT shall be performed in the presence of the Engineer. The SAT shall include the following tests and inspections:

1. Verify all components have been installed per manufacturer requirements.
2. Verify all items have been attached properly (as per manufacturer recommendations and the Plans) to each other and to the Pole Structure.
3. Verify the RSU has no internal or external damage.
4. Verify there are no missing antennas.
5. Verify the RSU has been properly connected to the UPS for continuous, conditioned power.
6. Verify the RSU and cabinet equipment are protected by surge suppression.
7. Verify the required operational characteristics of the device including the sending and receiving J2735 messages and detection of Bluetooth, DSRC, and C-V2X signatures can be observed through the direct local connection. This testing requires the Contractor provide an OBU installed in a vehicle with an HMI.
8. Verify the required operational characteristics of the device including the sending and receiving J2735 messages and detection of Bluetooth, DSRC, and C-V2X signatures can be observed through the Type A Network Switch. This testing requires the Contractor provide an OBU installed in a vehicle with an HMI.

14.5 Warranty

All materials specified in this section shall carry a minimum one-year manufacturer's warranty from the date of Final Acceptance against any imperfections in workmanship or materials. Warranties shall cover complete replacement at no charge for the equipment. Warranties shall be transferred to TDOT upon Final Acceptance of the project as per the requirements in Section 2.6 of this specification.

14.6 Method of Measurement

14.6.1 Road Side Unit (RSU)

The RSU shall be measured in units of each and paid for at the contract price per each after the complete installation. The bid price shall include furnishing, configuring the device, developing and installing the device MAP, installing and configuring the SCMS, and integrating and installing the RSU including all mounting hardware, cabling, PoE injector, site surveys, and other incidentals required for proper installation.

14.7 Payment

Payment for all cabling, wall outlets, and other hardware required for proper installation shall be considered incidental and no separate payment will be made. Payment will be made under:

Item No.	Description	Unit
725-28.01	ROAD SIDE UNIT (RSU)	EA

RSU will be paid per each as follows:

1. 50% of the contract unit price upon approval of Bench Test Component and Bench Test System test results.
2. Additional 20% of the contract unit price upon approval of Stand Alone Site Test results.
3. Additional 20% of the contract unit price upon approval of Conditional System Acceptance Test results.
4. Final 10% of the contract unit price upon Final System Acceptance.

15 OVERHEIGHT VEHICLE DETECTION SYSTEMS

15.1 Description

Furnish and install Overheight Vehicle Detection Systems (OVDS) as shown on the Plans or as directed by the Engineer.

The system will detect any overheight components of the vehicle and any load hauled by the vehicle. Overheight components of the vehicle or hauled load must be detected despite material type, density, size, or shape. The system shall include warning devices that direct the operators of overheight vehicles to take appropriate action to avoid a collision with any conflicting structures. Any necessary connections with the system must be integrated as part of this Item. The system must communicate operational information with a communication network as specified by the Engineer and shown on the Plans.

Ensure the system is comprised of all items of hardware, software, interconnect cabling, and cabinets and enclosures required to provide an operational system to detect and warn overheight vehicles upstream of a potential clearance violation. To ensure the function of the system, equipment furnished and installed under this section must include the following:

1. Infrared transmitters and receivers, or approved equal,
2. Local controller,
3. Wireless I/O, where specified,
4. Controller enclosure and ancillary equipment,
5. Mounting hardware, and
6. Cabling as required.

Furnish, assemble, fabricate, or install materials referenced under this SP725 are new, corrosion resistant, and in strict accordance with the details shown on the Plans or as directed.

15.2 Materials

Contractor shall provide all materials according to the requirements in the following sections.

All equipment shall be new and constructed using the highest quality, commercially available components and techniques to assure high reliability and minimum maintenance. Prior to installation, the Contractor shall submit and receive approval from the Engineer on a complete set of shop drawings of all the equipment and components listed within this Special Provision and included as part of the installation.

The firmware pre-installed on the device shall meet the minimum version listed in APPENDIX D at the time of device installation in the field.

15.2.1 Overheight Detection

To support the installation of a fully functional system, the Contractor shall:

1. Provide a complete system that will detect objects that dynamically cross a user-created horizontal elevated plane at a user-determined height above the roadway surface. The detection system will be positioned so that it only detects objects moving in 1 travel direction. The detection system will utilize infrared or red source technology or approved equal and spectrally

matching detectors mounted on poles positioned on opposite sides of the approach at locations shown on the Plans. Alternate detection technology may be used with the approval of the Engineer. Furnish units with an effective detection range of 10’ to 200’ with a reaction speed range of 1 mph to 75 mph for a 2.5” diameter object that extends 1” above the height of the detectors. Provide detection system that negates the effect of ambient light and an internal environmental control that reduces operational failure from fog condensation and insects.

2. Furnish units that are solid state with printed circuit boards and regulated power. Furnish units that do not exceed a maximum overall size of 18” (W) x 19” (L) x 10” (D), or as approved by the Engineer. Provide a communication system as shown on the Plans that meets the OVDS manufacturer’s recommendations and specifications that provides the interface needed between the 2 detection units.

3. Provide medium duty anodized aluminum, fiberglass, or equivalent housing not less than 1/8” thick, rated National Electrical Manufacturer’s Association (NEMA) 3R or better.

4. Provide transmitter, remote, receiver, and master units required to operate the equipment. The enclosure will maintain its structural integrity for the operational life of the equipment and allow access for control adjustment and electrical interconnection without the use of any special tools.

5. Provide a local controller unit that controls the system at the design location shown on the Plans. The local controller unit will continuously monitor detector inputs for a positive overheight detection reading. When the detectors sense an overheight vehicle, the controller will activate the warning components of the system. Circuit breaker protection must be incorporated into the controller. Provide user-configurable settings on the controller for adjusting the duration of the activation of the warning components to accommodate anticipated travel conditions. The controller unit may be in the detection unit housing or in a separate enclosure.

6. New OVDS shall be equipped with a monitoring system accessible to the TDOT ATMS software. This may require the implementation of an API or other means for the OVDS to be managed by the TDOT ATMS software. The system shall be able to communicate the following information to the TDOT Regional TMC:

    a. When the system is activated
    b. When an overheight vehicle is detected
    c. When a Fault Condition is detected in the system

7. All power lines, contact closures and the serial port shall be surge protected within the unit. Contact closures and the serial and ethernet ports shall be isolated.

15.2.2 Mounting Poles

1. Mounting structure shall be existing or furnished and installed per Section 9 and as shown on the Plans.

2. Furnish mounting hardware that will securely attach the detection equipment to a vertical cylindrical pole that does not require any machining operation. The attachment will not stress or deform the unit and will prevent the movement of the unit in any direction by the force of developed wind. Furnish mounting hardware that has the capability of adjustment to the angular orientation of the optical axis in both the horizontal and vertical plane over an angular range of ± 5°.

3. Install all poles and foundations outside of the clear zone or behind barrier protection as shown on the Plans.

15.2.3 Warning Components

1. Integrate (a) static or dynamic sign(s) as shown on the Plans that directs detected overheight vehicles to take appropriate action. Provide 4 flashing beacons with each static sign, as shown on the Plans. Flashing beacons will conform to Road Side Flashing Beacon Assembly. The static sign assembly will conform all essential elements of the sign to MUTCD standards. If dynamic signs are required, refer to Section 11 for additional requirements.

2. Provide a communication system between the OVDS controller and the flashing beacons, as shown on the Plans, that is supported by the OVDS system.

15.2.4 Environmental Requirements

1. Provide equipment that operates and meets all of the requirements of this specification under the following atmospheric conditions:

    a. Temperature: 40°C to 57°C,
    b. Relative Humidity: 0 to 100%,
    c. Rain: 2" per hour rate,
    d. Snow: 5" per hour rate,
    e. Fog: 200 ft. visibility, and
    f. Wind Velocity: Design wind load shall be based on 120 mph wind with a 1.14 gust effect factor per AASHTO LRFD specifications for Highway Signs.

2. Furnish equipment that operates properly when the sun is outside 10° axis of the receiver/master unit in its installed configuration. If the above requirements cannot be met, the equipment will be deemed satisfactory if explicit installation information is provided by the manufacturer such that the rays of the sun will not interfere with the proper operation of the equipment. This provision includes reflections from vehicles.

    Shadow Effect. Furnish equipment that ensures that light intensity caused by the shadow of passing clouds will not interfere with the proper operation of the equipment.

15.2.5 System Communication Requirements

A communications links shall be provided between the OVDS controller, the flashing beacon assembly (if present), and the DMS (if present) as shown on the Plans.

1. Wireless

    Provide an Industrial grade wireless I/O radio communications link where shown on the Plans. The wireless I/O device must be compatible with the manufacturer of the OVDS system. The wireless I/O radio unit must meet the following:

    a. Outdoor rating of IP 67, or better,
    b. Utilize the 900 MHz or 2.4 GHz frequency,
    c. Support Type C outputs (normally open and normally closed),
    d. Support 3 terminals per relay (common, NO, NC),
    e. Support multiple user-programmable channels,
    f. Support High Gain antenna, and
    g. Require a maximum of 7W power supply.

2. Hard-Wired

    Provide hard-wired communication using twisted-wire pair or fiber optic cable where shown on the Plans.

3. Alternative communication mediums may be approved by the Engineer.

A remote connection between the OVDS controller and TDOT network shall also be provided where shown on the Plans. Network components shall be furnished and installed in accordance with Section 19 and as shown on the Plans.

15.2.6 Interface with Third Party Software

1. The OVDS must be compatible with the TDOT ATMS software. The devices must be able to be integrated into the software such that the data processed by the sensors is available for monitoring within the TDOT ATMS software. All events, including alarms, faults, and status, will be transmitted from the OVDS controller to the TDOT ATMS software.
2. In addition, there are state operated programs within the state of Tennessee that manage vehicle permits. These systems are collecting data for overheight vehicle detections.

15.3 Installation Requirements

It is the Contractor's responsibility to furnish, program, install, and integrate the OVDS devices in the field and into the TDOT ATMS software. The cost of coordination and integration efforts shall be the sole responsibility of the Contractor and no payment will be made directly or indirectly by TDOT.

All equipment shall be installed according to the manufacturer's recommendations and as follows:

1. Install OVDS system in accordance with the manufacturer's specifications to achieve specified accuracy and reliability.
2. Install OVDS system so that proper operation of the equipment will commence within 15 seconds after restoration of power.
3. Install all system components at the locations shown on the Plans or as directed by the Engineer.
4. Install pole, breakaway base, local control cabinet, connectors, wiring, signal beacons, sign, and foundation as shown on the Plans, or as directed by the Engineer.
5. Install the flasher controller assembly in the ITS cabinet.
6. Install watertight breakaway electrical fuse holders in all line and neutral conductors at the breakaway base.
7. Install foundations, poles, and associated cabinets outside of the clear zone or behind barrier protection.
8. Use established industry and utility safety practices to erect assemblies near overhead or underground utilities. Contractor to coordinate with local utility companies. Consult with the appropriate utility company before beginning such work.
9. Allow for directional adjustment and aiming after initial installation. Perform basic alignment of the detectors either manually or electronically. Perform this step on both the transmitter/remote and receiver/master unit locations as per the manufacturer's guidelines and recommendations.
10. Construct all foundations for detecting units, and other system support structures.
11. Mount the transmitter/remote and receiver/master unit to detect the presence of vehicles that exceed the specified vertical height.

15.4 Testing Requirements

15.4.1 General Requirements

1. The Contractor shall conduct a project testing program for all materials specified in this section and as required in Section 2.5 of this SP725.
2. All test results shall confirm physical and performance compliance with this SP725.
3. The Contractor shall submit all test results documentation to the Engineer within 7 calendar days of completion of the tests. The Engineer will review test documentation in accordance with the Submittal Review Process in Section 2.7.
4. Payment for all testing is included in the cost of the OVDS.

15.4.2 Factory Acceptance Test

FAT is not required for OVDS.

15.4.3 Bench Test Component

BTC shall be performed in the presence of the Engineer. The BTC shall include the following tests and inspections:

1. Verify the overheight detection equipment has no internal or external damage.
2. Verify beacons and flasher controller has no internal or external damage.
3. Test all OVDS Equipment functionality using vendor software and/or external inputs.

15.4.4 Bench Test System

BTS shall be performed in the presence of the Engineer. The BTS shall include the following tests and inspections:

1. Verify OVDS Equipment attachment compatibility with the mounting bracket.
2. Verify that the OVDS Equipment is compatible and supports operational interoperability with the communication equipment, TDOT ATMS software, and any existing equipment at the OVDS site.

15.4.5 Stand Alone Site Test

SAT shall be performed in the presence of the Engineer. The SAT shall include the following tests and inspections:

1. Verify all components have been installed per manufacturer requirements.
2. Verify all items have been attached properly (as per manufacturer recommendations and the Plans) to each other.
3. Verify the OVDS has no internal or external damage.
4. Verify the OVDS has been properly connected to the UPS for continuous, conditioned power.
5. Verify the OVDS is protected by surge suppression including all copper communication cables entering and leaving the cabinet.

15.5 Warranty

All materials specified in this section shall carry a minimum one-year manufacturer's warranty from the date of Final Acceptance against any imperfections in workmanship or materials. Warranties shall cover complete replacement at no charge for the equipment. Warranties shall be transferred to TDOT upon Final Acceptance of the project as per the requirements in Section 2.6 of this specification.

15.6 Method of Measurement

15.6.1 Overheight Vehicle Detection System

The Overheight Vehicle Detection System will be measured in units of each and paid for at the contract price per each for each system furnished, installed, made fully operational, and tested in accordance with this SP725. The bid price shall include furnishing, installing, device integration, documentation, and testing of a complete OVDS. The bid price shall also include all local configuration and control manufacturer software, system documentation including: shop drawings, operations and maintenance manuals, wiring diagrams, block diagrams and other materials necessary to document the operation of the OVDS. This price shall be full compensation for all labor, tools, materials, equipment and incidentals necessary to complete the work.

15.7 Payment

The contract unit price shall be full compensation for all work specified in this section.

Payment will be made under:

Item No.	Description	Unit
725-23.41	OVERHEIGHT VEHICLE DETECTION SYSTEM	EA

The OVDS will be paid per each as follows:

1. 50% of the contract unit price upon approval of Bench Test Component and Bench Test System test results.
2. Additional 20% of the contract unit price upon approval of Stand Alone Site Test results.
3. Additional 20% of the contract unit price upon approval of Conditional System Acceptance Test results.
4. Final 10% of the contract unit price upon Final System Acceptance.

16 HIGHWAY ADVISORY RADIO (HAR)

16.1 Description

This section specifies the minimum requirements for Highway Advisory Radio (HAR) furnished and installed on this project as shown on the Plans. The following general requirements apply:

1. The HAR system shall include one AM/FM transmitter, one CB transmitter, coupler, audio processor, ethernet interface, required antennas for all transmitters, power supply, GPS synchronizer, communication and audio module, flashing beacon controller, sign, associated software, grounding system, and transient lightning suppression.
2. If Vendors have multiple generations of hardware available, they shall offer only the latest certified and commercially available version of their equipment for this bid.

16.2 Materials

Contractor shall provide all materials according to the requirements in the following sections.

All equipment shall be new and constructed using the highest quality, commercially available components and techniques to assure high reliability and minimum maintenance. Prior to installation, the Contractor shall submit and receive approval from the Engineer on a complete set of shop drawings of all the equipment and components listed within this Special Provision and included as part of the installation.

The firmware pre-installed on the device shall meet the minimum version listed in APPENDIX D at the time of device installation in the field.

The components required in the subsections below shall all be provided from the same manufacturer.

16.2.1 General

1. Furnish and configure HAR to be installed at locations as shown on the Plans. Furnish and configure all equipment and materials for each specific location as shown on the Plans.
2. Provide electrical system and components with UL-listings for the appropriate application.
3. Unless otherwise specified, provide wire and cable with stranded copper conductors, 75°C/90°C wet/dry rated insulation, and sized for the maximum voltage and current in the circuit.
4. Transmitters shall be the type certified and accepted by the FCC for traveler information station (TIS) service.
    a. AM transmitters shall operate in a range from 530 kHz to 1700 kHz.
    b. FM transmitters shall operate in a range from 88.1 MHz and 107.9 MHz
    c. Each transmitter shall have the capability of remote and local control. The ability to broadcast live messages from the transmitter site and the ability to record and broadcast from the TDOT Regional TMC shall be provided.
5. One radio frequency (RF) power/VSWR meter shall be included with the transmitter. The power/VSWR meter shall measure output power between the required antennas and the RF output of the transmitter coupler.

6. One coupler unit shall be included. The coupling unit shall:
    a. Isolate the transmitter from high voltage through the use of high-pass capacitors and fuses.
    b. Compensate for antenna system impedance mismatch through the use of multi-tap toroidal transformers.
    c. Compensate for antenna stray reactance through the use of a decade system of capacitor combinations.
    d. Include an internal VSWR meter and include controls for correcting load impedance and reactance.
7. HAR shall provide the ability to broadcast via AM, FM, and CB Radios.
8. HAR shall support FCC 15-37 filtering requirement of 5kHz.
9. Surge protective devices shall be provided on each end of cables entering/leaving an enclosure.
10. All HAR Equipment shall be capable of operating within the following environmental parameters:
    a. Temperatures of -40°C to 80°C
    b. Relative Humidity of 20%-95% non-condensing

16.2.2 Power Supply

Power Supply shall:

1. Automatically switch to DC power when AC power loss occurs.
2. Condition power and charge battery backup system.
3. Output at 13.6 VDC@5A.
4. Be rack-mountable.
5. Be capable of powering HAR Transmitter, GPS Synchronizer, and Communication and Audio Module at a minimum.

16.2.3 HAR Transmitter

HAR Transmitter shall:

1. Provide AM Radio Output from 0 to 10 Watts in accordance with FCC requirements.
2. Provide FM Radio Output from 0 to 100 Watts in accordance with FCC requirements.
3. Provide 100% Modulation.

16.2.4 GPS Synchronizer

GPS Synchronizer shall:

1. Provide connection to GPS Antenna.

2. Include GPS Antenna and coaxial connection to GPS Synchronizer.

16.2.5 Communication and Audio Module

Communication and Audio Module shall:

1. Support 1 Gbps ethernet communications including at least 2 RJ45 ports supporting Category 5E, minimum.

2. Provide support for simultaneous broadcast of AM/FM Radio and CB Radio transmission.

3. Provide 4-pin connector for CB radio transmission.

4. Provide connection to HAR Transmitter for AM/FM radio transmission.

5. Support a minimum of 10 hours of audio.

16.2.6 Flashing Beacon Controller

Flashing Beacon Controller shall:

1. Support 1 Gbps ethernet communications including at least 1 RJ45 port supporting Category 5E, minimum.

2. Support the connection of at least 2 flashing beacons.

3. Provide the ability for simultaneous or alternating flashing of beacons.

16.2.7 Transmission Antenna

All required Transmission Antennas shall be:

1. Made of continuous glass fabric epoxy.

2. Mounted to the pole utilizing insulated antenna mounts.

3. Designed and manufactured to withstand wind loads of at least 120 mph.

4. Capable of transmitting AM/FM or CB radio broadcasts.

16.3 Installation Requirements

Contractor shall abide by the installation requirements in the following subsections.

16.3.1 General Requirements

1. All conduits and ducts shall be sealed with a rubber fitting or a weather head.
2. All mounting hardware shall be stainless steel.
3. The HAR components shall be housed in a Type A Cabinet, or approved equal, in accordance with the requirements in Section 8.

4. The HAR Transmitter Antennas shall be mounted on a direct-bury wood pole at a minimum height of 30 feet above ground level. The maximum height for mounting the HAR Transmitter Antennas shall be no more than 47 feet above ground level in accordance with FCC Rules and Regulations §90.242.
5. The final mounting location shall be approved by the Engineer prior to installation.
6. Connect HAR Transmitter Antenna to HAR Transmitter in Cabinet.
7. Connect GPS Antenna to GPS Synchronizer.
8. Connect GPS Synchronizer to Communication and Audio Module.
9. Connect Communication and Audio Module to local Ethernet Switch using Category 6 cable.
10. Connect Flashing Beacon Controller to flashing beacons.
11. Connect Flashing Beacon Controller to local Ethernet Switch using Category 6 cable.
12. Connect all cabinet components to the Power Supply. Power Supply shall be connected to the site power source and grounded in accordance with NEC requirements.
13. Once all HAR devices have been installed, the Contractor shall configure all components of the HAR system.

16.3.2 Documentation

The documentation for the HAR shall consist of the following: Operator's Manual, Maintenance Procedure Manual, Equipment Drawings, and Electrical Schematic Diagrams.

1. Operator's Manual:

   This document shall fully describe the operation of the HAR using the Windows based software that runs on a notebook computer. This document shall clearly define all functions that are supported by the software including proper calibration procedures. The manual shall define the normal operation of the signs and the software including resetting and restarting the software package. A word-searchable electronic copy of this document shall be provided.

2. Maintenance Procedure Manual:

   This manual shall document the preventive and corrective maintenance procedures that should be followed to maintain the HAR at the highest level of operational efficiency. The manual shall include step-by-step field and bench trouble-shooting procedures to isolate and repair faults. The document shall include descriptions of normative waveforms and test voltages. A detailed parts list shall be included. For each part or assembly, a circuit diagram or pictorial shall be provided. A word-searchable electronic copy of this document shall be provided.

3. Equipment Drawings and Diagrams:

   A pictorial drawing showing the physical location and identification of each component shall be provided for each different electronic assembly and each different subassembly. An electronic copy of these drawings shall be provided in either PDF or CAD file type.

4. Electrical Schematic Diagrams:

An electrical schematic, wiring diagram, and a logic diagram shall be provided for each different type of equipment. A stage-by-stage explanation of the circuit theory shall be provided with the circuit wiring diagrams. Connection diagrams for each sensor including block diagrams, terminal numbers, and conductor color codes shall be provided. An electronic copy of these diagrams shall be provided in either PDF or CAD file type.

16.3.3 T*raining*

If the HAR model and generation proposed by the Contractor is not identical to HAR model and generation that is already deployed within the TDOT Region of the project, training will be required. Prior to the acceptance of the first HAR, training shall be provided for TDOT's engineering, maintenance, and operations staff, at a facility provided by TDOT. The training shall include all material and manuals required for each participant.

The training shall be provided for 2 identical non-consecutive 1 day sessions for at least 10 engineering and operations personnel. These hours of training are inclusive of those required in Section 2.4. The training shall include a complete demonstration of the operation and capabilities of the HAR. This session shall include a complete review of any field adjustments or calibration that may be required for any component. The training shall include operation instructions, theory of operation, circuit description, field adjustments, preventive maintenance procedures, troubleshooting, and repair of all components. Particular attention shall be given to the operation of the software packages to be provided.

16.4 Testing Requirements

16.4.1 General Requirements

1. The Contractor shall conduct a project testing program for all materials specified in this section and as required in Section 2.5 of this SP725.
2. All test results shall confirm physical and performance compliance with this SP725.
3. The Contractor shall submit all test results documentation to the Engineer within 7 calendar days of completion of the tests. The Engineer will review test documentation in accordance with the Submittal Review Process in Section 2.7.
4. Payment for all testing is included in the cost of the HAR.

16.4.2 Factory Acceptance Test

FAT is not required for HAR.

16.4.3 Bench Test Component

BTC shall be performed in the presence of the Engineer. The BTC shall include the following tests and inspections:

1. Verify the HAR has no internal or external damage.
2. Verify there are no missing antennas.
3. Test all HAR functionality including broadcast transmission over AM/FM and CB radios as well as activation of flashing beacons.

16.4.4 Bench Test System

BTS shall be performed in the presence of the Engineer. The BTS shall include the following tests and inspections:

1. Verify HAR attachment compatibility with the mounting brackets.
2. Verify that the HAR is compatible and supports operational interoperability with the communication equipment, TDOT ATMS software, and any existing equipment at the HAR site.
3. Verify that the HAR can be configured and calibrated using the vendor software.

16.4.5 Stand Alone Site Test

SAT shall be performed in the presence of the Engineer. The SAT shall include the following tests and inspections:

1. Verify all components have been installed per manufacturer requirements.
2. Verify all items have been attached properly (as per manufacturer recommendations and the Plans) to each other and to the Pole Structures.
3. Verify the HAR has no internal or external damage.
4. Verify there are no missing antennas.
5. Verify the HAR and cabinet equipment are protected by surge suppression.
6. After all HAR equipment has been installed and configured, the Contractor shall test the HAR transmission. Minimum test equipment required for testing the HAR shall consist of:

    a. Dummy load, 50 ohms
    b. Power meter
    c. Communications monitor
    d. Field strength meter

7. The Contractor shall tune the HAR with the impedance matching network of the coupling unit by adjusting the stainless steel tip of the antenna. The HAR shall be considered tuned when the system's voltage standing-wave ratio (vswr) is at the lowest possible value (1.2:1 or better) as directed by the Engineer.

8. After the HAR has been tuned, the Contractor shall record and transmit a test message with the output power level of the transmitter set at approximate 10 watts or lower. Modulation shall be adjusted between 85 to 95 percent as specified by the FCC for the standard AM/FM and CB broadcast bands.

16.5 Warranty

All materials specified in this section shall carry a minimum one-year manufacturer's warranty from the date of Final Acceptance against any imperfections in workmanship or materials. Warranties shall cover complete replacement at no charge for the equipment. Warranties shall be transferred to TDOT upon Final Acceptance of the project as per the requirements in Section 2.6 of this specification.

16.6 Method of Measurement

16.6.1 Highway Advisory Radio (HAR)

The Highway Advisory Radio shall be measured in units of each and paid for at the contract unit price per each. The price shall include furnishing, installing, device integration, and testing of the complete Highway Advisory Radio including the mounting hardware, cabling, power supplies, controllers, above-ground conduit, antennas, satisfactory completion of testing requirements, and all work, equipment, and appurtenances as required to effect the full operation of the Highway Advisory Radio, complete in place and ready for use. The bid price shall also include all system documentation including shop drawings, operations and maintenance manuals, wiring diagrams, block diagrams, and other material necessary to document the operation of the Highway Advisory Radio. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work. Pole for mounting Transmission Antenna, cabinet, pull boxes, and conduit between Transmission Antenna Pole and cabinet to be paid for separately.

16.6.2 HAR Flashing Beacon Sign

The HAR Flashing Beacon Sign shall be measured in units of each and paid for at the contract unit price per each. The price shall include furnishing, installing, device integration, and testing of the complete HAR Flashing Beacon Sign including the mounting hardware, cabling, power supplies, flashing beacon controller, above-ground conduit, satisfactory completion of testing requirements, and all work, equipment, and appurtenances as required to effect the full operation of the HAR Flashing Beacon Sign, complete in place and ready for use. The bid price shall also include all system documentation including shop drawings, operations and maintenance manuals, wiring diagrams, block diagrams, and other material necessary to document the operation of the HAR Flashing Beacon Sign. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work. Cabinet, static sign and sign supports, pull boxes, and conduit between Flashing Beacon Sign and cabinet to be paid for separately.

16.7 Payment

The contract unit price shall be full compensation for all work specified in this section. Payment will be made under:

Item No.	Description	Unit
725-22.01	HIGHWAY ADVISORY RADIO	EA
725-22.04	HAR FLASHING BEACON SIGN	EA

HAR Sites will be paid per each as follows:

1. 50% of the contract unit price upon approval of Bench Test Component and Bench Test System test results.
2. Additional 20% of the contract unit price upon approval of Stand Alone Site Test results.
3. Additional 20% of the contract unit price upon approval of Conditional System Acceptance Test results.

4. Final 10% of the contract unit price upon Final System Acceptance.

17 WEIGH IN MOTION (WIM) SYSTEM

17.1 Description

This section specifies the minimum requirements for Weigh in Motion (WIM) System furnished and installed meeting ASTM E1318 Type III functional performance requirements. The work shall consist of providing all labor, materials, equipment, and incidentals necessary to furnish, install, test, and operate a working WIM System for TDOT.

The WIM System will provide automated traffic monitoring wheel load, axle load, axle group load, gross vehicle weight, speed, and axle – spacing and wheelbase. It is the Contractor's responsibility to furnish, program, install, calibrate and integrate WIM system in the field and into TDOT MS2 network.

The Contractor shall provide a complete sensor package including all cabling, conduits, sensors, mounts, electrical service, surge suppression, and all hardware associated with a complete installation as required by this SP725.

17.2 Materials

Contractor shall provide all materials according to the requirements in the following sections.

All equipment shall be new and constructed using the highest quality, commercially available components, and techniques to assure high reliability and minimum maintenance. Prior to installation, the Contractor shall submit and receive approval from the Engineer on a complete set of shop drawings of all the equipment and components listed within this Special Provision and included as part of the installation.

1. Furnish WIM and integral materials recommended by the manufacturers for outside plant use and the intended application. This requirement includes wiring, electrical materials and configurations (including connector pin-outs) that are wholly or partially related to the field device applications.

2. Furnish and configure WIM to be installed at locations as shown on the Plans. Furnish and configure all equipment and materials for each specific location as shown on the Plans.

3. Provide electrical system and components with UL-listings for the appropriate application.

4. Unless otherwise specified, provide wire and cable with stranded copper conductors, 75°C/90°C wet/dry rated insulation, and sized for the maximum voltage and current in the circuit.

17.2.1 Quartz Sensor

Quartz Sensor shall meet or exceed the following requirements.

1. The quartz sensor shall be a force base sensor with the ability to measure wheel and axle loads of road vehicles.

2. The number of supplied quartz sensors shown on the plans shall be the number required to make the required lane system ASTM E1318 Type III compliant.

3. Sensor shall operate at -40°C to 80°C.

4. Loop sealant shall be used for sensors leading sealant.

17.2.2 Data Logger

WIM System data logger shall meet or exceed the following requirements.

1. The WIM data logger shall work in combination with the supplied quartz sensor to provide ASTM E1318 Type III functional performance.
2. WIM data logger shall provide real time and stored vehicle data.
3. WIM data logger shall provide 4 traffic lane monitoring.
4. Monitor stop and go traffic ranging from 6 mph to 155 mph.
5. Ability to detect single or dual tire with the ability for system enhancement to provide flat tire detection.
6. The number of required data logger per system shall be based on the required number of quartz sensors required to provide ASTM E1318 Type III functionality.
7. WIM data logger shall have the capability to provide gross vehicle weight. Wheel and axle load, axle distance, number of axles, vehicle speed, vehicle length, driving direction, imbalance of weight, traffic density, classification.
8. The WIM data logger be equipped with DIN rail adapter, cap protection, sealing inserts for unused channels.
9. Loop card for up to 8 inductive loops.
10. All require equipment shall be installed in the controller cabinet. The controller cabinet must include all of hardware and software to store and transmit data. The system shall operate on AC power with UPS backup.

17.2.3 Inductive (WIM) Loop

Inductive loops shall meet or exceed the following requirements.

1. One-conductor #14 AWG cable 19 stranded annealed bare copper ASTM B3 and B8 rated. Insulated in cross linked polyethylene containing high strength rip cord with an outside tubing of loose polyvinyl chloride or high molecular weight polyethylene meeting IMSA 51-7, rated for 600 volts.
2. Two-conductor #14 AWG conforming to IMSA 50-2 shielded lead-in cable rated at 600 volts.
3. Cable temperature tolerance range of -20°C to 73°C.
4. Flexible embedding sealer – a two component polyester loop sealant that is highly durable and remains permanently flexible. Use a loop sealant capable of withstanding corrosive effects of road salts, automotive fluids, fuel, and extreme weather conditions. Use a loop sealant that features rapid chemical curing and has extreme adhesion to concrete and asphalt. A sealer accelerant or retarder may be added per the manufacture's recommendations.
5. Vinyl electrical tape that has a PVC base with rubber-based pressure sensitive adhesive, a minimum of 7 mils thick, UL listed, and marked per UL standard 510 as flame retardant and cold resistant.

Use a tape compatible with synthetic cable insulation, jackets, and splicing compounds and rated for wire and cable splices up to 600-volts.

6. Dual wall heat shrinking tubing in accordance with ANSI C119.1, for extruded insulated tubing 600 volts that is heavy wall thickness irradiated polyolefin tubing containing an adhesive mastic inner wall. Minimum wall thickness before contraction of 40 mils.

7. Splicing kit with in-line barrel design, resin encapsulating compound kit with UL486D rating. Suitable for use in wet or direct buried locations. Use only resin encapsulating compounds acceptable for use at 16°C.

8. Joint sealing backup material of a stitched cotton piping cord, polyethylene backer rod, or approved equal material compatible with the sealant and capable of withstanding the required sealant application temperature without melting meeting stitched cotton piping cord ASTM D5249 backer rod and ASTM D5249

9. The number of loop cards required will be determined on the number required of required loops to provide the overall WIM system per lane to provide ASTM E1318 Type III functionality.

17.2.4 Grouting Compound

Grouting compound shall meet or exceed the following requirements.

1. Grouting compound shall be a 3-component epoxy resin design for installation for grouting of quartz sensors in road bituminous, asphalt, or concrete surfaces.

2. Grouting compound shall have rapid shrink free curing, site ready use packaging, high tensile strength, chemical resistance, and rapid strength agents.

3. Grouting compound shall allow installation without heating equipment with pavement temperature and air temperature between 20°C and 50°C. Heating equipment may be utilized for lower temperatures but must adhere to manufacturers requirements.

17.3 Installation Requirements

Contractor shall abide by the installation requirements in the following sections.

17.3.1 General Requirements

It is the Contractor's responsibility to furnish, program, install, calibrate, and integrate the WIM System in the field and into the TDOT MS2 network. The cost of coordination and integration efforts shall be the sole responsibility of the Contractor and no payment will be made directly or indirectly by TDOT.

All equipment shall be installed according to the manufacturer's recommendations and as follows:

1. Installation of quartz sensors shall be completed by a manufacturer certified installer as well as the integration of the entire system.

2. Installation of WIM system shall be in accordance with the manufacturer's specifications to achieve specified accuracy and reliability.

3. All quartz sensors, loops, and lead-in cables shall be marked out in lane prior to installation. Ensure saw cuts do not deviate more than 0.5 inches from chalk line.

4. Saw cut for quartz sensor shall meet manufacture installation requirements. Saw cut for WIM loops shall be a minimum of 5/8-inch wide and at least 3 ½-inchs deep. Remove all sharp edges within the saw cut and round corners. Blow out saw cut with compressed air or vacuum to remove loose materials prior to sensor and cable installation.

5. Slot must be dry, clean, and free from dust, oil, or grease.

6. Install quartz sensor in accordance with manufactures recommendations. Installation of wires should use blunt tools to prevent damage.

7. Loop slots shall be cut to allow unforced placement of wire into bottom of cut. Four turns of #14 AWG place the IMSA 51-7 copper wire in the slot. Place short pieces of backer rod 2 inches to 3 inches in length every 18 inches to 24 inches to hold the loop wire in the bottom of the slot.

8. Twist loop leads at the rate of 8 to 12 twist per foot. Loops within 150 feet of the cabinet, extend the twisted pair loop wire directly to the cabinet. For distances over 150 feet, #14 IMSA 50-2 shielded lead-in cable must be spliced to the loop wire twisted pair at the first pull box to which the loop wire is pulled.

9. Quartz sensor grouting compound shall be prepared, placed, and finished in accordance with sensors manufactures requirements. Loop sealer, and sealer accelerant or retarder, if necessary, shall be placed in accordance with the manufacturer's requirements. Protection of the area from traffic until grouting and sealer has set.

10. Place backer rod on top of loop wire in the saw cut as needed to secure the wire within the saw cut.

11. Before installation of joint backup material, provide back-up material/bond breaker so that when placed in the joint will support the sealant at its design depth, allow the sealant to achieve the design shape, prevent the sealant from leaking around and underneath it, and allow the sealant to deform freely when the joint expands and contracts.

12. When heated, the inner wall melts and fills all crevices and interstices of the object being covered while the outer wall shrinks to form a waterproof insulation. An overlap of the conductor insulation of a minimum of 1 ½ inches should be provided at each end of the heat-shrink tube, or open end of the end cap of the heat-shrink tubing after contraction.

13. All splices will be performed using splice kits designated for direct burial. Splice kits will include screw-on wire connectors and housings with enough sealant to encapsulate the spliced connection fully. Taped splices are not permitted.

14. Install all system components at the locations shown on the Plans or as directed by the Engineer.

15. Install pole, breakaway base, local control cabinet, connectors, wiring, and foundation as shown on the Plans, or as directed by the Engineer.

16. Install watertight breakaway electrical fuse holders in all line and neutral conductors at the breakaway base.

17. Install foundations, poles, and associated cabinets outside of the clear zone or behind barrier protection.

18. Use established industry and utility safety practices to erect assemblies near overhead or underground utilities. Contractor to coordinate with local utility companies. Consult with the appropriate utility company before beginning such work.

19. Contractor shall calibrate equipment in accordance with manufacturer's recommendations to be able to accurately and reliably collect data on wheel load, axle load, axle group load, gross vehicle weight, speed, and axle – spacing and wheelbase.

17.3.2 Documentation

The documentation for the WIM shall consist of the following: Communications Protocol, Operator's Manual, Maintenance Procedure Manual, Equipment Drawings, and Electrical Schematic Diagrams.

17.3.2.1 Operator's Manual:

This document shall fully describe the configuration and operation of the WIM using the Windows based software. This document shall clearly define all functions that are supported by the software. The manual shall define the normal operation of the WIM and the software including resetting and restarting the software package. A word-searchable electronic copy of this document shall be provided. The manual shall include the following:

a. General Description

b. General Characteristics

c. Installation

d. Configuration

e. Adjustments

f. Theory of Operation

g. Maintenance

    i. Preventive Maintenance

    ii. Trouble Analysis

    iii. Trouble Shooting Sequence Chart

h. Wave Forms

    i. Voltage Measurements

    ii. Alignment Procedures

    iii. Parts List

    iv. Communications Protocol

    v. Schematic and Logic Diagrams

17.3.2.2 Maintenance Procedure Manual:

This manual shall document the preventive and corrective maintenance procedures that should be followed to maintain the WIM at the highest level of operational efficiency. The manual shall include step-by-step field and bench trouble-shooting procedures to isolate and repair faults. The document shall include descriptions of normative waveforms and test voltages. A detailed parts list shall be included. For each part or assembly, a circuit diagram or pictorial shall be provided. A word-searchable electronic copy of this document shall be provided.

17.3.2.3 Equipment Drawings and Diagrams:

A pictorial drawing showing the physical location and identification of each component shall be provided for each different electronic assembly and each different subassembly. Wiring diagrams shall be provided for each sign case. These diagrams shall depict the location and interface of all components located within the sign case. An electronic copy of these drawings (using common drawing software such as MicroStation) shall be provided.

17.3.2.4 Electrical Schematic Diagrams:

An electrical schematic, wiring diagram, and a logic diagram shall be provided for each different type of equipment. A stage-by-stage explanation of the circuit theory shall be provided with the circuit wiring diagrams. Connection diagrams for each HAR subsystem including block diagrams, terminal numbers, and conductor color codes shall be provided. An electronic copy of these diagrams (using common drawing software such as MicroStation) shall be provided.

17.3.3 Training

Prior to the Stand Alone Site Test of the first WIM, training shall be provided for TDOT's engineering, maintenance, and operations staff, at a facility provided by TDOT. The training shall include all material and manuals required for each participant.

The training shall be provided for 2 identical non-consecutive 1 day sessions for at least 10 engineering and operations personnel. These hours of training are inclusive of those required in Section 2.4. The training shall include a complete demonstration of the operation and capabilities of the WIM. This session shall include a complete review of any field adjustments or calibration that may be required. The training shall include operation instructions, theory of operation, circuit description, field adjustments, preventive maintenance procedures, troubleshooting and repair of all components. Particular attention shall be given to the operation of the software packages to be provided including procedures for configuring the signs, displaying messages and diagnosing faults.

17.4 Testing Requirements

17.4.1 General Requirements

1. The Contractor shall conduct a project testing program for all material specified in this section and as required in Section 2.5 of this SP725.

2. All test results shall confirm physical and performance compliance with this SP725.

3. The Contractor shall submit all test result documentation to the Engineer within 7 calendar days of completion of tests. The Engineer will review test documentation in accordance with the Submittal Review Process in Section 2.7.

4. Payment for all testing is included in the cost of the WIM.

17.4.2 Factory Acceptance Test

FAT is not required for WIM.

17.4.3 Bench Test Component

BTC shall be performed in the presence of the Engineer. The BTC shall include the following test and inspections:

1. Verify WIM quartz sensors have no internal or external damage.
2. Verify cables and wire has no internal or external damage.
3. Test WIM Equipment functionality using vendor software and/or external inputs.

17.4.4 Bench Test System

BTS shall be performed in the presence of the Engineer. The BTS shall include the following tests and inspections:

1. Verify WIM equipment.
2. Verify that the WIM equipment is compatible and supports operational interoperability with the communication equipment and TDOT MS2 Network.
3. Verify that the WIM can be configured and calibrated using the vendor software.

17.4.5 Stand Alone Site Test

SAT shall be performed in the presence of the Engineer. The SAT shall include the following test and inspections:

1. Verify all components have been installed per manufacture requirements.
2. Verify all items have been attached properly as per manufacturer recommendations and the plans.
3. Verify the WIM has no internal or external damage.
4. Verify the WIM is properly connected to the UPS.
5. Verify the WIM is protected by surge suppression including all copper cables entering and leaving the cabinet.
6. Verify the WIM equipment has been properly calibrated to collect accurate and reliable data on wheel load, axle load, axle group load, gross vehicle weight, speed, and axle – spacing and wheelbase. Accuracy shall +/-5% over 20 passes using a truck with known characteristics.

17.5 Warranty

All materials specified in this section shall carry a minimum one-year manufacturer’s warranty from the date of Final Acceptance against any imperfections in workmanship or materials. Warranties shall cover complete replacement at no charge for the equipment. Warranties shall be transferred to TDOT upon Final Acceptance of the project as per the requirements in Section 2.6 of this specification.

17.6 Method of Measurement

17.6.1 Weigh- In-Motion (WIM) Loop Detector

The WIM Loop Detector will be measured in units of each and paid at the contractor price per each loop furnished, installed, made fully operational, and tested in accordance with this SP725. The bid price shall include furnishing, installing, integrating, documentation, and testing of a complete WIM loop installed in lane. The bid price shall also include all local configuration and control manufacturer software, system documentation including shop drawings, operations, maintenance manuals, wiring diagrams, block diagrams, and other materials necessary to document the operation of the WIM loop. This price shall be fully compensation for all labor, materials, equipment, and incidental needed.

17.6.2 Weigh- In-Motion (WIM) System Two Lane

The WIM system will be measured in units of each and paid at the contractor price per each system furnished, installed, made fully operational, and tested in accordance with this SP725. The bid price shall include furnishing, installing, integrating, documentation, and testing of a complete WIM system based on the number of lanes. The bid price shall also include all local configuration and control manufacturer software, system documentation including shop drawings, operations, maintenance manuals, wiring diagrams, block diagrams, and other materials necessary to document the operation of the WIM systems. This price shall be fully compensation for all labor, materials, equipment, and incidental needed to complete the system.

17.6.3 Weigh- In-Motion (WIM) System Three Lane

The WIM system will be measured in units of each and paid at the contractor price per each system furnished, installed, made fully operational, and tested in accordance with this SP725. The bid price shall include furnishing, installing, integrating, documentation, and testing of a complete WIM system based on the number of lanes. The bid price shall also include all local configuration and control manufacturer software, system documentation including shop drawings, operations, maintenance manuals, wiring diagrams, block diagrams, and other materials necessary to document the operation of the WIM systems. This price shall be fully compensation for all labor, materials, equipment, and incidental needed to complete the system.

17.6.4 Weigh- In-Motion (WIM) System Four Lane

The WIM system will be measured in units of each and paid at the contractor price per each system furnished, installed, made fully operational, and tested in accordance with this SP725. The bid price shall include furnishing, installing, integrating, documentation, and testing of a complete WIM system based on the number of lanes. The bid price shall also include all local configuration and control manufacturer software, system documentation including shop drawings, operations, maintenance manuals, wiring diagrams, block diagrams, and other materials necessary to document the operation of the WIM systems. This price shall be fully compensation for all labor, materials, equipment, and incidental needed to complete the system.

17.7 Payment

The contract unit price shall be full compensation for all work specified in this section. Payment will be made under:

Item No.	Description	Unit
725-16.01	WEIGH-IN-MOTION (WIM), LOOP DETECTOR	EA
725-16.02	WEIGH-IN-MOTION (WIM) SYSTEM, TWO LANE	EA
725-16.03	WEIGH-IN-MOTION (WIM) SYSTEM, THREE LANE	EA
725-16.04	WEIGH-IN-MOTION (WIM) SYSTEM, FOUR LANE	EA

WIM will be paid per each as follows:

1. 50% of the contract unit price upon approval of Bench Test Component and Bench Test System test results.
2. Additional 20% of the contract unit price upon approval of Stand Alone Site Test results.
3. Additional 20% of the contract unit price upon approval of Conditional System Acceptance Test results.
4. Final 10% of the contract unit price upon Final System Acceptance.

18 PERMANENT SPEED FEEDBACK SIGN

18.1 Description

This Section specifies the minimum requirements for the Permanent Speed Feedback Sign furnished and installed on this project as shown on the Plans. The Permanent Speed Feedback Sign will provide speed information immediately to motorists for the purpose of notification of excessive speed to promote the reduction of speed to ultimately reduce high-speed accidents in the area of deployment. It is the Contractor's responsibility to furnish, install, configure and calibrate the Permanent Speed Feedback sign in the field.

The Contractor shall provide a complete device site including all cabling, conduits, cabinets, batteries, solar panel, sign, supports, foundation, sensors, software and all hardware associated with a complete functioning installation as required by this Special Provision.

18.2 Materials

Contractor shall provide all materials according to the requirements in the following sections.

All equipment shall be new and constructed using the highest quality, commercially available components and techniques to assure high reliability and minimum maintenance. Prior to installation, the Contractor shall submit and receive approval from the Engineer on a complete set of shop drawings of all the equipment and components listed within this Special Provision and included as part of the installation.

18.2.1 *General Requirements*

The Permanent Speed Feedback Sign Assembly shall conform to the following general characteristics.

1. All equipment shall be permanently marked with manufacturer name or trademark, part number, and date of manufacture or serial number. All parts shall be constructed of corrosion-resistant materials, such as plastic, stainless steel, anodized aluminum, brass, or gold-plated metal. All fasteners exposed to the elements must be Type 304 or 316 passivated stainless steel.

2. Sign assembly and LED display must meet MUTCD legibility standards for color, character and height

3. If the assembly includes a cabinet, the cabinet must meet the applicable TDOT cabinet material requirements found in Section 8 of this SP725 and NEMA 3R standards.

4. Detectors shall meet the environmental requirements of NEMA TS2 (latest edition).

5. All software required to configure and operate the Sensor shall be provided to TDOT.

6. The assembly must conform to the physical characteristics of the following:

    a. Temperature operating range: -30°C to 60°C

    b. Housing: Field hardened, weatherproof, gasketed, NEMA 3R

    c. Power: 12 VDC

    d. Accuracy:

i. Volume: 97% typical

ii. Speed: 95% typical

e. Sensor Calibration: Traffic counts shall be calibrated on-site and per-lane. RDS shall measure within 5% of measured traffic volume, counted in 5-minute intervals. Average vehicle speed shall be verified using a radar gun and RDS shall measure within 5 mph of measured speed.

18.2.2 *Solar Power Unit*

Provide solar power unit consisting of the following components: solar panel(s) and mounting hardware; 12 V storage battery; and voltage regulator with wiring and associated mounting hardware. Power unit shall provide for 4 days of autonomy with limited solar input. Power unit shall be configured to recharge solar batteries within 4 hours of direct solar exposure.

1. Solar Panel Configured for Nominal 12 VDC

    a. Solar panels cannot have internal voltage regulators and must be capable of multiple arrays and series or parallel wiring configurations.

    b. Manufacturer shall provide documentation to determine the correct solar panel sizing for the specific project location(s) and need.

    c. Components shall meet the following physical characteristics:

        i. Peak Power Range: 50 to 170 watts

        ii. Voltage: Maximum power greater than 16.5 V at 25°C

        iii. Photovoltaic modules construction: Mono or poly-crystalline cells

        iv. AppFrame Construction: Anodized aluminum

        v. Mounting hardware construction: anodized, galvanized or stainless steel

2. Battery 12 V

    a. Battery shall be rechargeable for photovoltaic applications.

    b. Battery shall be valve regulated, lead-calcium gelled electrolyte or absorbed glass mat.

    c. Manufacturer shall provide documentation to determine the correct battery sizing for the specific project locations and need.

    d. The Battery shall meet the following physical characteristics:

        i. Case construction: ABS plastic or polypropylene

        ii. Current discharge rate: minimum of 100 hours at .9 amperes

        iii. Dimensions: Approximately 12 inches by 7 inches by 9 inches

3. Voltage Regulator Configured for Nominal 12 VDC

    a. The voltage regulator shall meet the following characteristics:

        i. Voltage for battery charging: Minimum of 13.5 VDC. Begin charging when battery voltage is 13.3 V or less. Discontinue charging when battery voltage is 14.5 V.

        ii. Quiescent Current: Maximum 15 mA

        iii. Operating Temperature Range: -30°C to 60°C

        iv. Dimensions: Approximately 2 inches by 5 inches by 1 inch

18.3 Installation Requirements

18.3.1 General Requirements

All equipment shall be installed according to the manufacturer's recommendations, the Plans, and as follows:

1. Materials and associated accessories/adapters shall not be applied contrary to the manufacturer's recommendations and standard practices.
2. All components shall be grounded in accordance with manufacturers' recommendations and NEC Requirements for Grounding.
3. Bundle all like cabling to minimize crosstalk and electrical interference. Route wiring to prevent conductors from being in contact with devices in the cabinet and metal edges. Arrange wiring so that any removable assembly may be removed without disturbing or unhooking conductors.
4. All power and communications wiring shall be one continuous run controller to sensor/sign. No splicing of wiring will be permitted unless approved by the Engineer.
5. Prior to installation, all equipment must be stored in a location and manner approved by the Engineer.
6. The Permanent Speed Feedback radar sensor shall be calibrated prior to acceptance by TDOT. Calibration results shall be provided to the Engineer for confirmation.

18.3.2 Documentation

The documentation for the Permanent Speed Feedback Sign shall consist of the following: Operator's Manual, Maintenance Procedure Manual, Equipment Drawings, and Electrical Schematic Diagrams.

1. Operator's Manual:

    This document shall fully describe the operation of the Permanent Speed Feedback Sign using the Windows based software that runs on a notebook computer. This document shall clearly define all functions that are supported by the software including proper calibration procedures. The manual shall define the normal operation of the signs and the software including resetting and restarting the software package. A word-searchable electronic copy of this document shall be provided.

2. Maintenance Procedure Manual:

   This manual shall document the preventive and corrective maintenance procedures that should be followed to maintain the Permanent Speed Feedback Sign at the highest level of operational efficiency. The manual shall include step-by-step field and bench trouble-shooting procedures to isolate and repair faults. The document shall include descriptions of normative waveforms and test voltages. A detailed parts list shall be included. For each part or assembly, a circuit diagram or pictorial shall be provided. A word-searchable electronic copy of this document shall be provided.

3. Equipment Drawings and Diagrams:

   A pictorial drawing showing the physical location and identification of each component shall be provided for each different electronic assembly and each different subassembly. An electronic copy of these drawings shall be provided in either PDF or CAD file type.

4. Electrical Schematic Diagrams:

   An electrical schematic, wiring diagram, and a logic diagram shall be provided for each different type of equipment. A stage-by-stage explanation of the circuit theory shall be provided with the circuit wiring diagrams. Connection diagrams for each sensor including block diagrams, terminal numbers, and conductor color codes shall be provided. An electronic copy of these diagrams shall be provided in either PDF or CAD file type.

18.3.3 Training

If the Permeant Speed Feedback Sign model and generation proposed by the Contractor is not identical to a Permanent Speed Feedback Sign model and generation that is already deployed within the TDOT Region of the project, training will be required. Prior to the acceptance of the first Permanent Speed Feedback Sign, training shall be provided for TDOT's engineering, maintenance, and operations staff, at a facility provided by TDOT. The training shall include all material and manuals required for each participant.

The training shall be provided for 2 identical non-consecutive 1 day sessions for at least 10 engineering and operations personnel each. These hours of training are inclusive of those required in Section 2.4. The training shall include a complete demonstration of the operation and capabilities of the Permanent Speed Feedback Sign. This session shall include a complete review of any field adjustments or calibration that may be required for any component. The training shall include operation instructions, theory of operation, circuit description, field adjustments, preventive maintenance procedures, troubleshooting, and repair of all components. Particular attention shall be given to the operation of the software packages to be provided.

18.4 Testing Requirements

18.4.1 General Requirements

1. The Contractor shall conduct a project testing program for all materials specified in this section and as required in Section 2.5 of this SP725.
2. All test results shall confirm physical and performance compliance with this SP725.
3. Payment for all testing is included in the cost of the Permanent Speed Feedback Sign.

4. The Contractor shall submit all test results documentation to the Engineer within 7 calendar days of completion of the tests. The Engineer will review test documentation in accordance with the Submittal Review Process in Section 2.7. Test documentation shall include:
    a. Setup and Test Conditions Parameters:
        i. Ambient Temperature
        ii. Humidity
        iii. Precipitation
    b. Test Results for Calibration Accuracy:
        i. Volume
        ii. Speed

18.4.2 Factory Acceptance Test

FAT is not required for Permanent Speed Feedback Sign.

18.4.3 Bench Test Component

BTC shall be performed in the presence of the Engineer. The BTC shall include the following tests and inspections:

1. Verify the Permanent Speed Feedback Sign has no internal or external damage.
2. Test all Radar Detection Equipment functionality using vendor software.

18.4.4 Bench Test System

BTS shall be performed in the presence of the Engineer. The BTS shall include the following tests and inspections:

1. Verify Permanent Speed Feedback Sign attachment compatibility with the mounting brackets, sign support, and metal sign.
2. Verify that the Permanent Speed Feedback Sign can be configured and calibrated using the vendor software.
3. Verify that the required operational characteristics of the device are valid including the counting of volume and speed.

18.4.5 Stand Alone Site Test

SAT shall be performed in the presence of the Engineer. The SAT shall include the following tests and inspections:

1. Verify all components have been installed per manufacturer requirements.
2. Verify all items have been attached properly (as per manufacturer recommendations and the Plans) to each other and to the Post Structure.
3. Verify the Permanent Speed Feedback Sign has no internal or external damage.
4. Verify the Permanent Speed Feedback Sign has been properly connected to the solar power unit for continuous power.

5. Verify the Permanent Speed Feedback Sign and cabinet equipment are protected by surge suppression.
6. Verify volume and speed data can be observed through the direct local connection.
7. Test and document the accuracy of the Permanent Speed Feedback Sign in accordance with the accuracy requirements specified in Section 18.2.1. A portion of this test requires the contractor to use a calibrated radar gun to compare observed speeds on a per lane basis between the calibrated radar gun and RDS data over a 5-minute period. All data collected during the test shall be documented and submitted to the Engineer for approval.

18.5 Warranty

All materials specified in this section shall carry a minimum one-year manufacturer's warranty from the date of Final Acceptance against any imperfections in workmanship or materials. Warranties shall cover complete replacement at no charge for the equipment. Warranties shall be transferred to TDOT upon Final Acceptance of the project as per the requirements in Section 2.6 of this specification.

18.6 Method of Measurement

The Permanent Speed Feedback Sign shall be measured in units of each and paid for at the contract unit price per each. The price shall include furnishing, installing, configuration, calibration, training, and testing of the complete Permanent Speed Feedback Sign including the cabling, conduits, solar power, sign, supports, foundation, sensors, satisfactory completion of testing and training requirements, and all work, equipment, and appurtenances as required to affect the full operation of the sign, complete in place and ready for use. The price bid shall also include all system documentation including: shop drawings, operations and maintenance manuals, wiring diagrams, block diagrams, and other material necessary to document the operation and maintenance of the Permanent Speed Feedback Sign. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

18.7 Payment

The contract unit price shall be full compensation for all work specified in this section. Payment will be made under:

Item No.	Description	Unit
725-05.90	SPEED FEEDBACK ASSEMBLY (PERMANENT)	EA

Permanent Speed Feedback Sign shall be paid per each as follows:

1. 50% of the contract unit price upon approval of Bench Test Component test results.
2. Additional 30% of the contract unit price upon approval of Stand Alone Site Test results.
3. Final 20% of the contract unit price upon Final System Acceptance.

19 NETWORK SWITCH

19.1 Description

19.1.1 Overview

1. The Contractor shall furnish Network Ethernet Switch and Ethernet Bridge models indicated on the Plans and specified on the certification published on the TDOT Traffic Design Division website for proprietary items regarding Local Area Network devices:

   https://www.tn.gov/content/dam/tn/tdot/traffic-operations/its/qualified-products-list/Proprietary%20Item_Statewide_Exp%2009-23-2025_ITS%20SmartWay%20LAN.pdf

2. The Contractor shall furnish and install new Layer 2 (L2) Field Ethernet Switches at the locations identified on the Plans. Upon successful completion of Bench Testing, the Contractor shall deliver the L2 Field Ethernet Switches to TDOT Regional TMC IT for TDOT to configure and provision the switches. TDOT Regional TMC will notify the Contractor when the configuration and provisioning of the L2 Field Ethernet Switches is complete and the switches are ready for pickup by the Contractor. Upon notice to the Contractor, the Contractor shall then collect the L2 Field Ethernet Switches and install them in the field. The Contractor shall then integrate the L2 Field Ethernet Switches into the TDOT communications network.

3. The Contractor shall furnish and install Layer 3 (L3) Aggregation Ethernet Switches and L3 Field Aggregation Ethernet Switches at locations identified on the Plans. Upon successful completion of Bench Testing, the Contractor shall deliver the L3 Aggregation Ethernet Switches to TDOT Regional TMC IT for TDOT to configure and provision the switches. TDOT Regional TMC will notify the Contractor when the configuration and provisioning of the L3 Aggregation Ethernet Switches is complete and the switches are ready for pickup by the Contractor. Upon notice to the Contractor, the Contractor shall then collect the L3 Aggregation Ethernet Switches and install them in the field. The Contractor shall then integrate the L3 Aggregation Ethernet Switches into the TDOT communications network.

4. The Contractor shall furnish and install new Ethernet Bridges at the locations identified on the Plans. The Contractor shall integrate the Ethernet Bridges into the TDOT communications network.

19.1.2 Virtual Local Area Network (VLANs)

1. For the L2 Field Ethernet Switches installed in the field, VLANs shall be developed to group devices by type. Where utilized, the management VLAN will be logically separate from all other VLANs to ensure manageability during network events and to provide additional security.

2. Common/consistent ports shall be used for the edge devices at each L2 Field Ethernet Switch. 2 ports shall be reserved for future edge devices. 1 port shall be reserved for network connection by a laptop computer at the equipment cabinet, which shall be the only port configured with access to the management VLAN.

19.1.3 Systems Design Report

1. See Section 22.2.4 for Systems Design Report requirements.

19.2 Materials

Contractor shall provide all materials according to the requirements in the following sections.

All equipment shall be new and constructed using the highest quality, commercially available components and techniques to assure high reliability and minimum maintenance. Prior to installation, the Contractor shall submit and receive approval from the Engineer on a complete set of shop drawings of all the equipment and components listed within this Special Provision and included as part of the installation.

The firmware pre-installed on the device shall meet the minimum version listed in APPENDIX D at the time of device installation in the field.

19.2.1 General

1. Furnish equipment for the LAN that complies with applicable IEEE 802 standards. Furnish Network Ethernet Switches and Ethernet Bridges that are fully compatible and interoperable with the network monitoring software, the existing network architecture and configuration, and the existing firewall and Layer 3 switch at the TDOT Regional TMC.

2. Furnish Network Ethernet Switches and Ethernet Bridges that comply with the following electrical safety requirements: UL60950-1 or CAN/CSA-C22.2 No. 60950-1 (safety requirements for IT equipment) and FCC Part 15 Class A for EMI emissions.

3. All expansion modules, SFP modules, and power supplies furnished shall be from the same manufacturer as the Network Ethernet Switch or Ethernet Bridge furnished.

19.2.2 Network Switch (Type A) (L2 Field Ethernet Switch)

1. Furnish L2 Field Ethernet Switches that are indicated on the Plans.

2. L2 Field Ethernet Switches shall be DIN rail mounted.

3. Furnish L2 Field Ethernet Switches with a Power Supply meeting the following requirements:
   a. Shall be manufactured by the same vendor as the L2 Ethernet Switch.
   b. Shall be DIN rail mounted.
   c. Power supply shall have 2-stage isolation accomplished via 2 transformers: the first steps down from primary AC/DC to 48VDC; the second steps down from 48VDC to the final DC voltage required by the switch.
   d. Shall be sized to power the L2 Ethernet Switch.
   e. A power cord of not less than 5' in length shall be supplied.

4. Furnish industrial SFP modules rated to service the Field Ethernet to Field Ethernet optical uplinks and Field Ethernet to Gig-E Hub Uplink rated for optical attenuation required to service the link. Use SFP modules that are LX or ZX and are matched and compatible with the SFP module it is mated with. LX SFP modules should be used for link lengths less than 10 km, EX SFP modules should be used for link lengths between 10 km and 40 km, and ZX SFP modules should be used for link lengths between 40 km and 80 km. Furnish attenuators, if required, to service link without saturating receiving optics.

5. If Cellular Communications are required for a specific L2 Field Ethernet Switch at a specific location as indicated on the Plans, the L2 Field Ethernet Switch shall also include dual active LTE-capable modules that support LTE and LTE-Advanced with carrier aggregation. The L2

Field Ethernet Switch shall be capable of concurrent connectivity to two separate cellular networks.

6. Furnish industrial SFP modules rated for use with the optical cable furnished under this project.

7. Furnish industrial SFP modules with LC connector or as indicated on the Plans and approved by the Engineer.

8. Furnish industrial SFP modules that are hardened to operate in temperatures from -40°C to 60°C.

9. Furnish single mode fiber jumper cables with appropriate connectors to connect with switch and adjacent fiber optic drop panel connectors and/or other switches. Single mode fiber jumper cables shall meet the requirements in Section 5 of this SP725.

19.2.3 Network Switch (Type B) (L3 Aggregation Ethernet Switch)

1. Furnish L3 Aggregation Ethernet Switches that are indicated on the Plans.

2. L3 Aggregation Ethernet Switches shall only be installed in environmentally-controlled ITS Communications Hub Buildings or TDOT Regional TMC.

3. L3 Aggregation Ethernet Switches shall be rack mounted.

4. Furnish L3 Aggregation Ethernet Switches with a Power Supply meeting the following requirements:
   a. Shall be manufactured by the same manufacturer as the L3 Aggregation Ethernet Switch.
   b. Shall have dual redundant Power Supplies installed in the Ethernet Switch power supply bays.
   c. Shall be sized to power the L3 Aggregation Ethernet Switch.

5. L3 Aggregation Ethernet Switches shall have a minimum of forty-eight 1G SFP fiber ports.

6. Furnish SFP modules for a minimum of twenty-four 1G SFP fiber ports with LC connector or as indicated on the Plans and approved by the Engineer. 1G SFP module shall support a link length of 25 miles or greater.

7. Furnish SFP+ modules for a minimum of 8 10G SFP+ fiber ports with LC connector or as indicated on the Plans and approved by the Engineer. 10G SFP+ module shall support a long-haul link length of 50 miles or greater.

8. Furnish industrial SFP modules rated for use with the optical cable furnished under this project.

9. Furnish industrial SFP modules with LC connector or as indicated on the Plans and approved by the Engineer.

10. Furnish industrial SFP modules that are hardened to operate in temperatures from -40°C to 60°C.

11. Furnish single mode fiber jumper cables with appropriate connectors to connect with switch and adjacent fiber optic termination cabinet and/or other switches. Single mode fiber jumper cables shall meet the requirements in Section 5 of this SP725.

19.2.4 Network Switch (Type C) (L3 Field Aggregation Ethernet Switch)

1. Furnish L3 Field Aggregation Ethernet Switches that are indicated on the Plans.

2. L3 Field Aggregation Ethernet Switches shall be hardened for use in ITS Communications Hub Cabinets.

3. L3 Field Aggregation Ethernet Switches shall be rack mounted.

4. Furnish L3 Field Aggregation Ethernet Switches with a Power Supply meeting the following requirements:
   a. Shall be manufactured by the same manufacturer as the L3 Aggregation Ethernet Switch.
   b. Shall have dual redundant Power Supplies installed in the Ethernet Switch power supply bays.
   c. Shall be sized to power the L3 Field Aggregation Ethernet Switch.

5. L3 Field Aggregation Ethernet Switches shall have a minimum of forty-eight 1G SFP fiber ports.

6. Furnish SFP modules for a minimum of twenty-four 1G SFP fiber ports with LC connector or as indicated on the Plans and approved by the Engineer. 1G SFP module shall support a link length of 25 miles or greater.

7. Furnish SFP+ modules for a minimum of 8 10G SFP+ fiber ports with LC connector or as indicated on the Plans and approved by the Engineer. 10G SFP+ module shall support a long-haul link length of 50 miles or greater.

8. Furnish industrial SFP modules rated for use with the optical cable furnished under this project.

9. Furnish industrial SFP modules with LC connector or as indicated on the Plans and approved by the Engineer.

10. Furnish industrial SFP modules that are hardened to operate in temperatures from -40°C to 60°C.

11. Furnish single mode fiber jumper cables with appropriate connectors to connect with switch and adjacent fiber optic termination cabinet and/or other switches. Single mode fiber jumper cables shall meet the requirements in Section 5 of this SP725.

19.2.5 Ethernet Bridge

1. Furnish Ethernet Bridges that are indicated on the Plans.

2. Ethernet Bridges shall be DIN rail mounted.

3. Furnish Ethernet Bridges with a Power Supply meeting the following requirements:
   a. Shall be manufactured by the same manufacturer as the Ethernet Bridge.
   b. Shall be DIN rail mounted.
   c. Power supply shall have 2-stage isolation accomplished via 2 transformers: the first steps down from primary AC/DC to 48VDC; the second steps down from 48VDC to the final DC voltage required by the switch.
   d. Shall be sized to power the Ethernet Bridge.
   e. A power cord of not less than 5' in length shall be supplied.

19.2.6 Software Requirements & Licensing

1. The manufacturer for the Network Ethernet Switches shall also supply the configuration and management software for the corresponding switch hardware. This software shall be provided at no additional cost and shall be included in the unit price of each Network Ethernet Switch pay item.

2. Necessary firmware updates shall be communicated to TDOT Regional TMC IT and performed by the Contractor during the life of the project. Prior to Final Project Acceptance, the Contractor shall notify their Network Ethernet Switch vendor representatives that TDOT Regional TMC IT will assume maintenance responsibilities on the switches themselves as well as any needed firmware updates after Final Acceptance. The vendor shall then communicate directly with TDOT Regional TMC IT or their ITS Maintenance Contractor representatives of any needed firmware updates.

19.3 Installation Requirements

Contractor shall abide by the following installation requirements:

1. Install L2 Field Ethernet Switches, L3 Aggregation Ethernet Switches, L3 Field Aggregation Ethernet Switches, Ethernet Bridges and all associated hardware for each component.

2. Install Power Supply and plug into UPS for continuous, conditioned power.

3. Coordinate all work at, near, or inside buildings with the Engineer. Do not work on buildings or enter buildings without prior, written authorization from the Engineer. Coordinate and obtain approval from Engineer regarding allowable working time in buildings. Obtain necessary permits and inspections. Work shall not commence until the necessary permits are issued, posted on site, and approved Plans are available on site. The Contractor shall coordinate installation with TDOT staff at least 2 weeks in advance of needing access to the installed cable(s)/network equipment.

4. Furnish MAC addresses in a spreadsheet for all equipment utilized as part of this project, in addition to the equipment models, serial numbers, and firmware revisions. Equipment shall be registered in the name of TDOT. Affix a MAC Address label to each device utilized. Furnish IP addresses for all equipment utilized as part of this project. Affix final IP address to each device utilized. Use labels that do not smear or fade.

5. In field equipment cabinets, fully integrate new Network Ethernet Switches with the fiber optic termination patch panels. Integrate all field equipment as shown on the Plans.

6. No Ethernet switch configuration or deployment can occur until the Contractor's Systems Design Report has been approved in final form by the TDOT Regional TMC IT.

19.4 Testing Requirements

19.4.1 General Requirements

1. The Contractor shall conduct a project testing program for all materials specified in this section and as required in Section 2.5 of this SP725.
2. All test results shall confirm physical and performance compliance with this SP725.
3. The Contractor shall submit all test results documentation to the Engineer within 7 calendar days of completion of the tests. The Engineer will review test documentation in accordance with the Submittal Review Process in Section 2.7.
4. Payment for all testing is included in the cost of the Network Switch.

19.4.2 Factory Acceptance Test

FAT is not required for Network Switches.

19.4.3 Bench Test Component

BTC shall be performed in the presence of the Engineer. The BTC shall include the following tests and inspections:

1. Verify the Network Switch has no internal or external damage.
2. Test all Network Switch functionality using Cisco DNA Center software.

19.4.4 Bench Test System

BTS shall be performed in the presence of the Engineer. BTS of Network Switch will be performed in conjunction with other components in this SP725 that are reliant upon the Network Switch for communications.

19.4.5 Stand Alone Site Test

SAT shall be performed in the presence of the Engineer. The SAT shall include the following tests and inspections:

1. Verify all components have been installed per manufacturer requirements.
2. Verify all items have been attached properly (as per manufacturer recommendations and the Plans) to each other and within the Equipment Cabinet or Equipment Rack.
3. Verify the Network Switch has no internal or external damage.
4. Verify the Network Switch has been properly connected to the UPS for continuous, conditioned power.

19.5 Warranty

All materials specified in this section shall carry a minimum one-year manufacturer's warranty from the date of Final Acceptance against any imperfections in workmanship or materials. Warranties shall cover complete replacement at no charge for the equipment. Warranties shall be transferred to TDOT upon Final Acceptance of the project as per the requirements in Section 2.6 of this specification.

19.6 Method of Measurement

19.6.1 Network Switch (Type A)

Network Switch (Type A) L2 Field Ethernet Switch will be measured in units of each and paid for at the contract price per each unit furnished, installed, and accepted. All SFP modules, optics, cabling, jumper cables, patch cables, attenuators, power supplies, applicable configuration, and testing or other labor or materials required to install and integrate the Field Ethernet Switch will be considered incidental and not be paid for separately. If an L2 Field Ethernet Switch is required to provide cellular connectivity as indicated on the Plans, TDOT will provide the provisioned SIM card to achieve connectivity via coordination with the Contractor. Contractor shall coordinate with TDOT at the preconstruction meeting to ensure the SIM cards have been requested from Strategic Technology Solutions (STS) to avoid construction delays.

19.6.2 Network Switch (Type B)

Network Switch (Type B) L3 Aggregation Ethernet Switch will be measured in units of each and paid for at the contract price per each unit furnished, installed, and accepted. All SFP modules, optics, cabling, jumper cables, patch cables, attenuators, power supplies, applicable configuration, and testing or other labor or materials required to install and integrate the Aggregation Ethernet Switch will be considered incidental and not be paid for separately.

19.6.3 Network Switch (Type C)

Network Switch (Type C) L3 Field Aggregation Ethernet Switch will be measured in units of each and paid for at the contract price per each unit furnished, installed, and accepted. All SFP modules, optics, cabling, jumper cables, patch cables, attenuators, power supplies, applicable configuration, and testing or other labor or materials required to install and integrate the Field Aggregation Ethernet Switch will be considered incidental and not be paid for separately.

19.6.4 Ethernet Bridge

Ethernet Bridge will be measured in units of each and paid for at the contract price per each unit furnished, installed, and accepted. All cabling, jumper cables, patch cables, power supply, configuration, and testing or other labor or materials required to install and integrate the Ethernet Bridge will be considered incidental and not be paid for separately.

19.7 Payment

Payment will be made under:

Item No.	Description	Unit
725-21.11	NETWORK SWITCH (TYPE A)	EA
725-21.12	NETWORK SWITCH (TYPE B)	EA
725-21.13	NETWORK SWITCH (TYPE C)	EA
725-21.16	ETHERNET BRIDGE	EA

L2 Field Ethernet Network Switch (Type A) will be paid per each as follows:

1. 50% of the contract unit price upon completion Bench Test Component and Bench Test System test results.
2. 20% of the contract unit price upon completion of Stand Alone Site Testing at the field cabinet.
3. 20% of the contract unit price upon Conditional System Acceptance test results.
4. Final 10% of the contract unit price upon Final System Acceptance.

L3 Aggregation Ethernet Network Switches (Type B and Type C) will be paid per each as follows:

1. 50% of the contract unit price upon completion Bench Test Component and Bench Test System test results.
2. 20% of the contract unit price upon completion of Stand Alone Site Testing at the ITS Communications Hub.
3. 20% of the contract unit price upon Conditional System Acceptance test results.
4. Final 10% of the contract unit price upon Final System Acceptance.

Ethernet Bridge will be paid per each as follows:

1. 50% of the contract unit price upon completion Bench Test Component and Bench Test System test results.
2. 20% of the contract unit price upon completion of Stand Alone Site Testing at the Equipment Cabinet or Building housing the Ethernet Bridge.
3. 20% of the contract unit price upon Conditional System Acceptance test results.
4. Final 10% of the contract unit price upon Final System Acceptance.

20 ITS COMMUNICATIONS HUB BUILDING

20.1 Description

This Item shall consist of the Contractor furnishing and installing a pre-cast ITS communications hub building as shown on the Plans. This work includes site preparation, procurement, transportation, and installation of an ITS communications hub building with conduit connections as specified on the Plans. Major elements of the ITS communications hub include the building enclosure and interior finish components, building foundation, heating, ventilation and air conditioning (HVAC) system, interior electrical distribution system, lighting, fire extinguisher, hub camera, lightning protection system, interior and exterior grounding, equipment racks, cable management trays, electrical utility/service connections, standby generator power system, site preparation and driveways, and paving and fencing around the hub building. The work shall be in accordance with the Plans and this SP725.

20.2 Materials

Contractor shall provide all materials according to the requirements in the following sections.

All equipment shall be new and constructed using high quality, commercially available components and techniques to assure high reliability and minimum maintenance. Prior to installation, the Contractor shall submit and receive approval from the Engineer on a complete set of shop drawings of all the equipment and components listed within this Special Provision and included as part of the installation.

The components of the ITS Communications Hub Building described by this specification shall consist of the following:

1. Site Grading and Earthwork
2. Communication Hub Building with appurtenances and concrete foundation
3. Three adjacent four-post 19” communication equipment racks
4. Overhead wireway
5. Conduit, cabling, and connections
6. Lightning protection system
7. Side-mounted heating and air conditioning unit
8. Mounting brackets and hardware
9. Electrical power system
10. Uninterruptible Power Supply
11. Standby generator power system
12. Hub monitoring system
13. Fencing system with double gate
14. Signs and signposts
15. Drainage structures per Section 710 of the TDOT Standard Specifications.

20.3 Construction Requirements

The Contractor shall be required to assemble and install all necessary material and equipment and to furnish a working ITS Communications Hub Building in accordance with the Plans and this SP725 and compatible with the requirements of the overall intelligent transportation system. All items that are required to complete the installation and ensure an operational ITS shall be supplied by the Contractor whether listed above or not. Items required but not listed above shall be at no direct pay. All components supplied by the Contractor are the responsibility of the Contractor.

The Contractor shall field verify final site layout, Hub Building, and equipment locations with the Engineer. Plans are diagrammatic and indicate the general arrangement of devices and work included in these documents. Final placement and arrangement are the responsibility of the Contractor.

Upon request by TDOT, the Contractor shall arrange for the manufacturer to grant access to the manufacturing and assembly facilities for the Hub Building and Standby Generator specified herein.

20.3.1 Precast Concrete Hub Building

All equipment shall be new and constructed using high quality, commercially available components and techniques to assure high reliability and minimum maintenance. The Contractor shall submit, prior to manufacturing, a complete set of shop drawings and product data of all the equipment and components previously listed and included as part of the installation. Shop drawings showing the details for each precast concrete Hub Building shall be included in the submittal for review and acceptance. Shop Drawings shall list structural design criteria as well as building envelope energy design criteria. Information on the foundation required to support the Hub Building shall be included in shop drawings. Precast concrete Hub building shall be designed and certified by a registered Professional Engineer in the State of Tennessee. Stamped engineering drawings shall be submitted with the shop drawing package.

20.3.2 Technical Specifications

The supplied precast concrete Hub Building shall conform to the following technical specifications:

1. ACI-318, Building Code Requirements for Reinforced Concrete, latest edition.
2. ASCE/SEI 7, Building Code Requirements for Minimum Design Loads in Buildings and Other Structures, latest edition.
3. Tennessee Building Code, latest edition, incorporating the corresponding year of International Building Code (IBC).
4. Walls shall be UL-752 Test Method Level 4 for bullet resistance, certified by an independent structural engineer.
5. Concrete Reinforcing Institute, Manual of Standard Practice.
6. The precast concrete Hub Building producer shall be a plant-certified member of either the National Precast Concrete Association (NPCA), the Precast/Prestressed Concrete Institute (PCI), or equal, and must have a minimum of 5 years of experience manufacturing precast concrete buildings.

20.3.3 Design Requirements

The supplied precast concrete Hub Building shall conform to the following design requirements:

1. Dimensions:

a. Exterior: Minimum 10’ x 12’ x 9’-2” (length x width x height)

b. Interior: Minimum 9’-6” x 11’-6” x 8’-6” (length x width x height)

2. Design Loads:

Design loads shall be in accordance with all applicable technical specifications listed above including but not limited to seismic load, wind load, roof live load, and floor load. Seismic loading shall be based on location of the Hub Building within the state.

3. Roof:

Roof panel shall be sloped for positive drainage to the roof edge at a minimum 1/4” vertical per 12” horizontal. The roof shall extend a minimum of 3” beyond the wall panel on each side and have a turndown design which extends½”” below the top edge of the wall panels to prevent water migration into the Hub Building along top of wall panels. Roof shall be minimum 4” thick, reinforced and/or prestressed concrete to meet specified loading.

Use a single, continuous tendon when post-tensioning. The tendon shall form a rectangular configuration that has gently curving corners and a corner where the tendon members are anchored. If post-tensioning is not used in the roof panel, the following guidelines must be followed to ensure a watertight roof design:

a. The entire precast concrete roof panel surface must be cleaned and primed with a material that prepares the concrete surface for proper adherence to the coating material.

b. The entire precast concrete roof panel surface shall be sealed with a continuous UV resistant, white colored waterproof membrane. Membrane may be 0.045 white EPDM membrane fully adhered to the concrete with an adhesive designed for this purpose, or a liquid applied elastomeric roof coating with manufacturer recommended primer.

4. Floor:

Floor shall be minimum 4” thick reinforced or prestressed concrete. There shall be a 1/2” recess around the perimeter, the width of the wall panels, cast into the floor. The 1/2” recess makes the interior floor surface 1/2” higher than the joint between the wall panel and floor slab preventing intrusion of water.

Use a single, continuous tendon when post-tensioning. The tendon shall form a rectangular configuration that has gently curving corners and a corner where the tendon members are anchored. If post-tensioning is not used in the floor slab, floor must be designed to support the weight of the Hub Building without special footings.

5. Walls:

Walls shall be minimum 3” thick, steel reinforced, concrete. Wall panels shall set on top of floor slab. No vertical wall joints shall be allowed, except at corners. Refer to Subsection 20.3.6 for exterior finish requirements.

20.3.4 Products

The supplied precast concrete Hub Building shall conform to the following product descriptions:

1. Concrete:

4000-PSI minimum 28-day compressive strength or higher, as required per Hub Building design.

2. Reinforcing Steel:

   Steel shall comply with ASTM A615, grade 60 minimum.

3. Steel Strand for Pre-Stressing and Post-Tensioning:

   Strand shall comply with ASTM A416.

4. Caulking:

   All joints between panels shall be caulked on the exterior and interior surface of the joints. Caulking shall be Sikaflex-1A elastic sealant or accepted equal. Exterior caulk joints to be 3/8” x 3/8” square so that sides of joints are parallel for correct caulk adhesion. Back of joint to be taped with bond breaking tape to ensure adhesion of caulk to parallel sides of joint and not the back.

5. Vents and Penetrations:

   Vents shall be designed and installed in accordance with the requirements of the air conditioning system. Penetrations through the Hub Building exterior shall be sealed water and air-tight.

6. Panel Connections:

   All panels shall be securely fastened together with steel brackets. Bracket steel to be hot-rolled carbon complying with ASTM A36 and hot dipped galvanized after fabrication. All fasteners to be 1/2” diameter bolts complying with ASTM A307 for low-carbon steel bolts. Coil inserts used for panel connections shall meet OSHA 29 CFR 1926.704 requirements, at minimum. All inserts for corner connections must be secured directly to form before casting panels. Floating of connection inserts shall not be allowed.

20.3.5 Accessories

1. Door and Frame:

   Shall comply with Steel Door Institute’s “Specifications for Standard Steel Doors and Frames” (SDI-l00). The Hub Building shall be equipped with double 3’-0” x 7’-0” x 1-3/4”, minimum 18-gauge galvanized steel doors with insulated core. Doors shall be located and shall open as indicated on the Plans. Frames shall be minimum 16-gauge galvanized steel. Doors and frames shall be painted with epoxy primer, vinyl wash, and two finish coats of pigmented polyurethane, medium brown in color.

2. Door Hardware:

   Door hardware shall be as stated below or accepted equal:

   a. Lockset: Full mortise lockset with vandal-resistant lever handles and latch/bolt retraction controlled by complete key card access system compatible with the existing key card access system at the TDOT Regional TMC.

   b. Hinges: Hager stainless steel 5 knuckle ball bearing with non-removable pins.

   c. Weatherstripping: ANSI/BHMA A156.22, Type R-3-D-1-7-5 National Guard Products extruded aluminum with neoprene seal 120NA.

   d. Threshold: Hager or National Guard Products extruded aluminum with silicone seal.

   e. Drip Cap: Hager or National Guard Products aluminum with stainless steel screws.

   f. Door Closer: Norton, LCN, or Yale with hold open.

   g. Surface Bolts: Upper and Lower.

   h. Astragal: Galvanized steel, same finish and brand as door.

   i. Door Position Switch: Compatible with the existing system at the TDOT Regional TMC.

20.3.6 Finishes and Insulation

1. Interior of Hub Building:

   Smooth steel form finish on all interior face of concrete panel surfaces. Inside walls and ceiling to be finished with smooth finish fiberglass-reinforced plastic (FRP), HDPE or melamine on minimum 1/2" thick moisture-resistant particleboard or plywood. Floor finish shall consist of a minimum 1/8” static-dissipative vinyl sheet or vinyl tile flooring. Provide concrete moisture mitigation as required by flooring manufacturer for adhesive warranty.

2. Exterior of Hub Building:

   Washed river-stone aggregate finish on all exterior wall surfaces. Exposed-Aggregate Finish: Use chemical retarding agents applied to concrete forms and washing and brushing procedures to expose aggregate to a depth of 1/8” after form removal.

3. Insulation:

   Provide continuous foam plastic insultation between concrete wall and ceiling panels and interior finish panels. Complete wall and roof assemblies shall comply with the International Energy Code and ASHRAE 90.1 in effect at the time of construction. Design criteria is Climate Zone 4, semi-heated building. Provide thermal barrier between insulation and interior environment per building code or provide product data or certification stating it is not required.

20.3.7 Electrical and Mechanical Equipment

The following equipment shall be powered from the electrical panelboard that shall be installed as part of this contract and specified elsewhere.

1. Air conditioning:

a. Provide 2 wall-mount single package vertical unit (SPVU) commercial air conditioners. Air conditioners shall be manufactured by an ISO 9001 certified manufacturer. Units shall be certified to AHRI Standard 390-IP (latest edition) for SPVU.

b. Each air conditioner shall be rated with a 3-ton capacity, shall contain a 3 kW (minimum) heat strip, and shall provide humidity control.

c. Include a single HVAC controller system operating thermostat and humidistat sensors providing with automatic change over between heating, cooling, dehumidification, and temperature stabilization during dehumidification. The HVAC controller shall balance the operating wear of the 2 units in a lead/lag arrangement and shall preclude both units from simultaneously starting. Alternating between lead and lag role shall be user selectable (1-30 calendar days).

d. Provide integral air filtration with the HVAC system.

e. Ensure that all components of the complete HVAC system including interior and exterior frames are internally bonded and grounded through the branch circuit to the load panel.

2. Receptacles:

   a. 5-120V duplex receptacles (NEMA 5-20R) shall be provided.

   b. 3-120V simplex locking receptacles (NEMA L5-20R) shall be provided, 1 above each equipment rack.

   c. 3-240V simplex locking receptacles (NEMA L6-20R) shall be provided, 1 above each equipment rack.

3. Interior lighting:

   a. Interior lighting shall consist of 2 fixtures, sized at 2’ x 4’, surface mounted, containing LED panels and drivers, and shall operate on 120V.

   b. A lighting switch shall be provided on the inside wall near the entrance to the Hub Building.

20.3.8 Hub Building Uninterruptible Power Supply

1. The Uninterruptible Power Supply (UPS) shall be line interactive or on-line (double conversion) type with 120VAC single phase input and output. All components shall be UL 1778 listed.. The UPS shall be designed to meet the following: The uninterruptible power supply (UPS) system must be sized to provide 1 hour run time for all communications equipment, CCTV cameras, and hub monitoring equipment.

2. The unit and supplemental battery packs (if required) shall include mounting hardware for a 19” equipment rack.

3. 8 output receptacles, type NEMA5-15R.

4. Operating temperature range 0°C to 40°C.

5. Relative humidity 0 – 95%.

6. The UPS shall automatically return to utility power after an event.

7. The UPS shall include SNMP manageable hardware and software with 10Base-T connection (RJ-45). Addressable SNMP command set shall minimally include: UPS state, battery condition (capacity, age, internal temperature); current AC input conditions (voltage, phase, frequency, failure condition); current AC output conditions (voltage, frequency, load); and diagnostic/self-test control and status.
8. The vendor shall provide for submittal approval, hub internal wiring, and load calculations, as well as a rack elevation showing the UPS unit physically sized adequately to fit within the equipment rack spaces available.
9. Provide electronic user documentation for all management, configuration and operation hardware and firmware settings, installation procedures, and the MIB.
10. All calculations and layouts, wiring, and overcurrent protection shall meet NEC.
11. Should there be any changes in the configuration of the hub equipment, it shall be the responsibility of the Contractor to advise the UPS vendor for any adjustments required to the sizes of the UPS as required to meet any new load demands.

Contractor shall abide by the following installation requirements:

1. Install in the equipment rack location designated on the Plans.
2. Ensure area around vents are free of obstructions.
3. All UPS and supplemental battery packs (if required) shall be mounted adjacent within the equipment rack.
4. Connect UPS input directly to the cabinet equipment receptacle. Extension cords or power strips are not acceptable.
5. Connect all battery packs and allow UPS to charge completely prior to connecting loads.
6. All load connections shall be clearly identified with printed labels, and cables neatly routed within the cabinet.

20.3.9 Equipment Racks

The 3 2-post equipment racks to be in the Hub Building shall meet the following requirements:

1. Overall dimensions of approximately 7’-6” high by 20.25” wide and meeting EIA standards for mounting 19” equipment.
2. Equipment racks upright channels fabricated from 6061-T6 aluminum extrusions with minimum depth of 5.75”, flange thickness of 0.19” and web thickness of 0.16”.
3. Equipment racks upright channels manufactured with threaded #12-24 mounting holes of entire channel length front and rear with standard EIA spacing. Do not use non-threaded clearance holes with separate “clip nuts.”
4. Provide front and rear mounting base angles fabricated from 6061-T6 aluminum extrusions with minimum 6” footing extension. Secure base angles to floor in accordance with Hub Building and rack manufacturers’ recommendations.
5. Provide front and rear top angles fabricated from 6061-T6 aluminum extrusions with minimum 1.5” x 2.0” web.

6. Provide a front-mounted lower guardrail fabricated from minimum 0.25” by 2.0” bar stock with 6” to 7” standoff from the upright channel.
7. Provide vertical cable management ducts in between all equipment racks and at each end of a row of equipment racks that meets the following minimum requirements:
    a. Use vertical cable management ducts that reach from the bottom of the equipment frame fully to the top of the rack.
    b. Use ducts that are double-sided, opening to the front and rear of the equipment rack, with each side having the minimum inside dimensions of 3.5” wide by 6.25” deep.
    c. Provide plastic or rubber grommeted openings, between the 2 sides of the duct, with a minimum opening of 2” and a maximum spacing of 12”.
    d. On the opening of each side of the duct, provide positive cable restraint through opening latches or removable covers.
8. For all assembly or fastening hardware use zinc-plated steel, nickel-plated brass, or stainless steel unless otherwise specified.
9. Use a black color finish on upright channels, top and base angles, and lower guardrails.
10. With each equipment rack provide a minimum of 50-#12-24 x 0.75” (minimum) cup head mounting screws with pilot points and nylon washers. Use zinc-plated steel, nickel-plated brass, or stainless-steel screws. Provide more screws if necessary to properly mount all equipment as shown on the Plans.
11. With each equipment rack provide 1 rear-mounted, 20A, power strip with a minimum of 8 receptacles and secured with a minimum of 4 rigid standoff brackets. Do not use threaded bolts or rods as standoff brackets. Power strip cord shall be SJ or equal and shall be equipped with a plug to match the UPS receptacle.

20.3.10 Hub Monitoring System

Provide a self-contained interior hub monitoring system device connected to the hub network switch with the following minimum requirements:

1. 19” rack mounted, maximum height of 6 rack units.
2. Environmental monitoring including temperature and humidity.
3. Motion detection with automatic email notification and alarm logging.
4. A PTZ camera shall be mounted inside the Hub Building as shown on the Plans. The PTZ camera shall have minimum 1920x1080 resolution at 30 fps and infrared night mode.
5. Power management sensor with automatic notification and logging.
6. Copper phone line connection with ATT to provide phoneline communications with the TDOT Regional TMC.
7. SNMP manageable hardware and software with 10Base-T network interface (RJ-45 connection) that includes all required functions.
8. SNMP management user interface and MIB software package, fully licensed to TDOT.

9. Provide an email and phone call notification when configurable environmental parameters are exceeded.
10. Provide an email notification that the main Hub Building door has been opened.

20.3.11 Fire Extinguisher

Provide a wall mounted CO2 fire extinguisher rated for electrical fires with a minimum 15 lb. capacity. Locate the fire extinguisher inside the Hub Building adjacent to the hub door opening.

20.3.12 Work Desk

Provide a wall-mounted folding work desk if required by the Plans with minimum working area of 36” wide by 24” deep and an opened height of 29” from the floor to the surface.

1. All work desk components and materials shall be non-metallic except for the folding, bracing, and hinging mechanism.
2. The work desk surface shall be a gray or off-white colored plastic laminate.
3. The work desk shall store flat against the wall when closed secured by a mechanical mechanism.
4. No tools shall be necessary to fold or unfold the work desk.
5. The work desk shall be constructed to support a 100 lb. load on the center of the front edge without damage and no more than 1/2” deflection.
6. When the work desk is unfolded, it shall provide clear knee space for the 24” width.
7. Provide a non-metallic folding chair with back that secures with the work desk for storage.
    a. Ensure there is a standard power outlet located in the Hub near the work desk.

20.3.13 CCTV Cameras

The Contractor shall provide 2 NTCIP-compliant, IP-video cameras. The cameras shall be mounted on opposite corners of the outside of the Hub Building as shown on the Plans and shall meet the requirements in Section 10.2. Of the 2 outdoor cameras, 1 of the cameras shall be intended to monitor the generator equipment. The cameras shall be connected to the Layer 3 Ethernet switch located in the equipment rack in the Hub Building.

20.4 Site Preparation

Site preparation shall consist of:

1. Clearing and Grubbing: The Contractor shall clear and grub the site in accordance with Section 201 of TDOT’s Standard Specifications.
2. Excavation and Embankment:
    a. The Contractor shall grade the site to provide positive drainage extending from the area of the Hub Building toward the perimeter. The Contractor shall provide additional embankment material if needed to accomplish drainage. Excavation and Embankment shall comply with Section 203 of TDOT’s Standard Specifications.

b. The finished floor elevation of the Hub Building shall be above the 100-year flood elevation at a minimum. Grade, level, and compact the area of the hub site from within the fenced area to an area a minimum of 8' outside the fence and transitioning into the concrete paved parking area. The lowest point of the grade of the area inside the fence should be 1' higher than any other adjacent area so that water does not drain into the fenced Hub Building area.

c. Within the limits of the fenced area, place and compact 6" of graded aggregate and place 6" Class M, concrete pavement with 1064 welded wire fabric (WWF) 4x4 in accordance with Section 701 of the TDOT Standard Specifications. For storm water drainage, slope the final surface of the pavement away from the Hub Building foundation at a minimum ½" per foot.

d. Maintaining the specification requirements, outside the fenced area for a minimum of 8', grade and slope the final surface at no more than a 4:1 slope. At more than 8' from the fenced area, transition into surrounding grade at a maximum 2:1 slope. Reseed or sod all areas that are to remain unpaved in accordance with TDOT Standard Specifications.

e. Construct the concrete paved driveway and associated drainage structures between the hub location and the roadway shoulder as shown on the Plans. Do not deviate from the driveway alignment as shown on the Plans, and do not place any communications or electrical conduit under the driveway paving. 6" depth, Class M Paving with 1064 welded wire fabric (WWF) 4x4 and a 4" base course shall be placed in accordance with the Plans and TDOT Standard Specifications.

3. Hub Building Foundation.

The Hub Building fabricator shall provide Hub Building foundation details with the stamped drawings and calculations for the Hub Building. The foundation shall include the following minimum requirements.

a. Sub-base Course: 4"-thick non-plastic material complying with Section 207 of the Standard Specifications.

b. Vapor Barrier: ASTM D2103, 6 mil thick clear polyethylene film.

c. Reinforced Concrete: Class M Concrete (3000 psi) in accordance with Section 501 of the Standard Specifications and Reinforcement with Section 806.

4. Incidental paving.

The Contractor shall provide incidental paving outside of the Hub Building foundation and within the fenced area as shown on the Plans. This shall include a loading ramp sloped up to the Hub Building door. The ramp shall have a maximum slope of 12:1 (H:V) and shall leave no more than a 0.5" lip at the door threshold. Paving shall have the following minimum requirements

a. Sub-base Course: 4"-thick non-plastic material complying with Section 207 of the Standard Specifications.

b. Reinforced Concrete: Class M Concrete (3000 psi) with 1064 welded wire fabric (WWF) 4x4 in accordance with Section 501 of the TDOT Standard Specifications and Reinforcement with Section 907 of the TDOT Standard Specifications.

20.5 Electrical Power System

20.5.1 General Requirements

Shop drawings showing the details for each component shall be submitted to the Engineer for review and acceptance prior to construction.

The ITS hub site shall receive primary electrical power from the local electrical utility, to be installed under this contract.

All non-current carrying metal parts of the ITS hub site shall be grounded per NEC specifications. In addition, all non-current carrying metal parts shall have a voltage potential of zero relative to reference ground. This reference ground shall be achieved via the equipment-grounding conductor.

All power system wiring and cabling shall be within conduit. No exposed wiring or cabling shall be acceptable.

20.5.2 Main Service Disconnect

Main service disconnect shall be UL listed, sized and fused in accordance with plan details. Conduit shall enter and exit the enclosure through grounding hubs with insulated throat bushings. Enclosure shall be lockable and locks shall be provided for each disconnect. Locks shall be keyed alike at the direction of the Engineer.

20.5.3 Transformer

Where required, Contractor shall install dry type transformer(s) in the size and at the location(s) as shown on the Plans. Transformers will be used to step down voltage from 480V to 120/240V for single phase applications or from 480V to 208Y/120V for three phase applications. All transformers shall comply and must be tested in accordance with UL, NEMA and ANSI standards.

Transformers shall have the kVA ratings shown on the drawings. Transformers shall be phase and voltage as shown on the Plans. Transformers shall be self-cooled. When transformer is delivering full kVA load continuously, temperature rise shall not exceed 302ºF (150ºC) above a 104ºF (40ºC) ambient with 428ºF (220ºC) temperature class insulation system. The average sound level shall not exceed NEMA standards. Transformers shall have 4 external type taps, two 2-1/2% FCBN and two 2-1/2% FCAN.

Transformers shall be floor or wall mounted as indicated on the Plans. Enclosure shall be heavy gauge steel with ventilation openings protected against falling dirt and drip and shall be shielded against actual touching of live parts. A nameplate in accordance with NEMA standards shall be permanently affixed to the enclosure. The transformer enclosure shall be NEMA 3R rated.

20.5.4 Grounding

The contractor shall install a grounding system for the Hub Building. The grounding system shall be designed to meet the following:

1. Provide a complete hub building interior and exterior grounding and bonding system.
2. The grounding and bonding system materials and installation given in this SP are a minimum. Design and shall be installed to provide a maximum ground impedance of 10 ohms from the MGB with electrical service not connected.

20.5.5 Distribution Panelboards – ITS Hub Site

1. General Requirements:
    a. Interiors shall be completely factory-assembled devices. They shall be designed such that switching and protective devices can be replaced without disturbing adjacent units and without removing the main bus connectors.
    b. Trims for lighting and appliance panelboards shall be supplied with a hinged door over all circuit breaker handles. Doors in panelboard trims shall not uncover any live parts. Doors shall have a semi-flush cylinder lock and catch assembly. Doors over 48” in height shall have auxiliary fasteners.
    c. Distribution panelboard trims shall cover all live parts. Switching device handles shall be accessible.
    d. Surface trims shall be same height and width as box. Flush trims shall overlap the box by ¾” on all sides.
    e. A directory card with a clear plastic cover shall be supplied and mounted on the inside of each door.
    f. All locks shall be keyed alike. 3 sets of keys shall be turned over to the Engineer.
2. Ratings and Description:
    a. Panelboards shall have short-circuit ratings and number of circuits as indicated on the Plans.
    b. Panelboards shall be labeled with a UL short-circuit rating.
3. Bus:
    a. Main bus bars shall be copper sized in accordance with UL standards to limit temperature rise on any current carrying part to a maximum of 65°C above an ambient of 50°C maximum.
    b. A bolted equipment ground bus shall be included in all panels.
    c. Full-size (100%-rated) insulated neutral bars shall be included for panelboards. Bus bar taps for panels with single-pole branches shall be arranged for sequence phasing of the branch circuit devices. Neutral busing shall have a suitable lug for each outgoing feeder requiring a neutral connection.
4. Branch Circuit Panelboards:
    a. The minimum integrated short-circuit rating for branch circuit panelboards shall be as indicated on the Plans.
    b. Bolt-in type, heavy-duty, quick-make, quick-break, single- and multi-pole circuit breakers of the types specified herein, shall be provided for each circuit with toggle handles that indicate when unit has tripped.
    c. Circuit breakers shall be thermal magnetic type with common trip handle for all multiple pole circuit breakers. Circuit breakers shall be minimum 100A frame and through 100A trip sizes shall take up the same pole spacing. Circuit breakers shall be UL listed as type Switching Duty (SWD) for lighting circuits.

d. For each panelboard, the main breaker in each shall be rated as shown on the Plans.

5. Enclosure:

   a. Enclosures shall be at least 20” wide made from galvanized steel and rated NEMA 1 for interior locations and NEMA 3R for exterior locations. Provide minimum gutter space in accordance with the National Electric Code. Where feeder cables supplying the mains of a panel are carried through its box to supply other electrical equipment, the box shall be sized to include the additional required wiring space. At least 4 interior mounting studs with adjustable nuts shall be provided.

   b. Enclosures shall be surface mounted and provided with blank ends.

6. Nameplates and Finish:

   a. Provide an engraved nameplate for each panel section with labels according to these Specifications.

   b. Surfaces of the trim assembly shall be properly cleaned, primed, and a finish coat of gray ANSI 61 paint applied.

20.6 Standby Generator Power System

Contractor shall provide all materials according to the requirements in the following sections.

All equipment shall be new and constructed using the highest quality, commercially available components and techniques to assure high reliability and minimum maintenance. Prior to installation, the Contractor shall submit and receive approval from the Engineer on a complete set of shop drawings of all the equipment and components listed within this Special Provision and included as part of the installation, including but not limited to the following.

1. Generator Set and Concrete Foundation
2. Remote Annunciator Alarm Panel
3. Automatic Transfer Switch
4. Remote Monitoring System
5. Load Bank

20.6.1 Standby Engine Generator Set

Contractor shall provide new 4-cycle, liquid cooled, diesel engine generator sets with characteristics, warranty and testing as specified herein. The generator set shall be complete in all respects as described in these Specifications and installed at each of the locations shown on the Plans.

1. The generator shall be sized per plan specifications. The unit shall be UL 2200 (latest edition) listed as a stationary engine generator rated below 600V.

2. Generator set shall utilize an engine which complies with U.S. EPA New Source Performance Standards (NSPS) for Stationary Emergency engines under the provisions of 40 CFR Part 60 Subpart IIII when tested per ISO 8178 D2 .

3. The unit shall be enclosed in a weatherproof housing properly treated for corrosive atmospheres.

4. The housing shall have hinged, or easily removable doors equipped with key locks and fitted vertical exhaust outlet with a stainless-steel rain cap.
5. The unit shall have a mounted radiator, pusher type fan, water pump, and thermostat, sized to properly cool the engine generator in a 52ºC atmosphere.
6. The unit shall have vibration isolators between the skid and the unit mounts.
7. The unit shall have end mounted controllers for both engine and generator.
8. The unit shall have manufacturer recommended, thermostatically controlled block heater and float type battery charger. Voltage shall be as required.
9. The generator shall include a double-walled sub-base fuel tank with capacity for 2 calendar days at 100% load based upon generator manufacturer published data for the generator set that is installed plus an additional 10%. The fuel tank shall be furnished with a digital fuel level sensor.

20.6.2 Generator Foundation

Generator foundation shall be constructed according to plan details and applicable sections of these Specifications.

20.6.3 Remote Annunciator Alarm Panel

Contractor shall provide an annunciator alarm panel for remote installation with signals indicating condition and possible malfunction of the emergency generator system. The annunciator alarm panel shall be installed inside the ITS Communications Hub Building. Exact location shall be determined in the field by the Engineer. Indication signals shall be as follows:

1. High battery voltage
2. Low battery voltage
3. Normal battery voltage
4. Generator running
5. Normal utility power
6. EPS supplying load
7. Pre-low oil pressure
8. Low oil pressure
9. Pre-high engine temperature
10. High engine temperature
11. Low engine temperature
12. Over-speed
13. Over-crank
14. Not in automatic
15. Battery charger malfunction

16. Auxiliary

There shall be both audible and visual signals for the conditions 7 through 16 as stated above. Panel shall have an option to silence the audible alarm until alarm condition is corrected. A new alarm condition shall resound the audible alarm. Annunciator wiring from the generator to the annunciator panel shall be as required by the manufacturer of generator set.

20.6.4 Automatic Transfer Switch (ATS)

Automatic transfer switch shall be an open transfer type and shall have voltage, current, and number of poles as specified on the Plans. For outdoor application, the transfer switch shall be mounted in a pad-lockable NEMA 3R, steel weatherproof housing, properly treated for corrosive atmospheres. The housing shall be fitted with mounting ears for structure mounting and shall be securely fastened per manufacturer recommendations.

The transfer switch shall be furnished, tested, and warranted by the engine generator set manufacturer.

The short circuit withstand and closing ratings shall be minimum 30,000A RMS at 600VAC.

Where used as service equipment, the ATS shall be service entrance rated and shall include overcurrent protection as indicated on the Plans. The ATS shall be UL listed per Standard 1008, shall be suitable for standby systems in accordance with ANSI C1 and NFPA 110, rated for total system loads to carry 100% of their rated current in a continuous standby condition in an ambient of –30°C to +60°C. Power switch contacts shall be rated for 600V minimum.

A programmed neutral position shall be provided to allow voltage generated by inductive loads to decay before transfer or retransfer when exercising under load. Adjustable time delay of 0.5 to 7.5 seconds shall momentarily stop the transfer to allow this to occur. The ATS shall include adjustable timers/delays for: engine start, transfer to generator source, re-transfer to normal source, and generator cool down. Time delay shall be adjusted upon installation and testing.

Indicator lights shall be LED. Display shall at minimum indicate availability of sources, position of switch, and countdown for delay timers.

A programmable exercise clock shall be provided to automatically run the generator set at regular intervals (weekly or monthly) and shall include adjustable run time for exercise. A switch shall provide loaded or unloaded operation.

This ATS controller shall include a test button to simulate loss of utility power and shall also include a bypass for delay timers.

20.6.5 Remote Monitoring System

Generator and ATS shall be furnished with additional hardware as required to allow remote monitoring and control. To provide these features for remote access, the control system shall meet the following requirements:

1. Shall provide, at a minimum, 1 RJ-45/Ethernet port for WAN/LAN connection.
2. Shall provide connections (inputs and outputs, both discrete and analog) as required between generator and ATS. Where copper conductors are used for communication interface, the control system shall include surge protective devices on each end of cables entering/leaving an enclosure or building.

3. Shall be rated to operate between -20°C and +70°C.
4. Shall be capable of displaying instantaneous data (voltage, current, power factor, temperature, fuel level, etc.) and status (ATS position, generator running/stopped, utility loss, etc.) and shall allow user to retrieve/receive this information via SNMP.
5. Shall be capable of recording data (voltage, current, power factor, temperature, fuel level, etc.) and event (ATS position change, generator running/stopped, utility loss, etc.) logs and allowing users to export the log data.
6. Shall be capable of email alerts for each event.
7. All other requirements shall be per plan details and manufacturer requirements.
8. Shall include a web-interface hosted on the local device. Cloud-based or client software dependent solutions are not acceptable.

20.6.6 Load Bank

The generator manufacturer shall provide a permanent automatic load bank which shall be supplied by a second generator output circuit breaker. The automatic load bank shall be mounted on the generator radiator or shall have integral cooling fans and be separately mounted on a concrete foundation as indicated on the Plans. The automatic load bank shall have minimum 3 load steps with individual field adjustable set points and the load bank controller shall monitor actual site load via manufacturer supplied current transformers installed on the generator feeder conductors. The resistive load steps shall be connected/disconnected via contactors and shall be protected with overcurrent devices. Cabling between the generator and automatic load bank shall be as required for proper operation of the load bank. The minimum total resistive load of the automatic load bank shall meet or exceed the highest rating specified among the Plans, NFPA 110 minimum loading requirements, and 125% of the manufacturer's recommended continuous minimum loading. The voltage and frequency shall match generator nameplate power rating. The load bank shall include all control power transformers required for operation at the rated generator output voltage. No separate control power source shall be allowed.

20.7 Testing Requirements

20.7.1 General Requirements

1. The Contractor shall conduct a project testing program for all materials specified in this section and as required in Section 2.5 of this SP725.
2. All test results shall confirm physical and performance compliance with this SP725.
3. The Contractor shall submit all test results documentation to the Engineer within 7 calendar days of completion of the tests. The Engineer will review test documentation in accordance with the Submittal Review Process in Section 2.7.
4. Payment for all testing is included in the cost of the ITS Communications Hub Building.

20.7.2 Factory Acceptance Test

FAT is required for ITS Communications Hub Building.

1. Verify building dimensions, exterior color, and interior finishes are correct per the Plans and this SP725.

2. Verify the ITS Communications Hub Building has no internal or external damage.
3. Verify that ITS Communications Hub Building doors properly seal, lock, unlock, and smoothly open and close.

FAT is required for the Standby Generator Power System. The Standby Generator Power System shall be factory tested, and certified test reports shall be furnished to the Engineer. In addition to the normal factory tests, the units shall be tested with reactive loads of 0.8 PF as follows:

1. Test speed and voltage regulation for instant on and off load change with loads of ¼, ¾, and full load rating.
2. Continuous operation at full load for not less than 3 hours with voltage, frequency, oil pressure and engine temperature being recorded at no load beginning of test, and at 30-minute periods thereafter through duration.

20.7.3 Bench Test Component

BTC is not required for ITS Communications Hub Building nor Standby Generator Power System.

20.7.4 Bench Test System

BTS is not required for ITS Communications Hub Building nor Standby Generator Power System.

20.7.5 Stand Alone Site Test

SAT shall be performed in the presence of the Engineer. The SAT shall include the following tests and inspections:

1. Verify all components have been installed per manufacturer requirements.
2. Verify all items have been attached properly (as per manufacturer recommendations and the Plans) to each other and to any applicable structures including the Hub Building to the Hub Building Foundation.
3. Verify the ITS Communications Hub Building has no internal or external damage.
4. Verify the grading of surrounding land is sloping away from the Hub Building to the perimeter.
5. Verify that grounding has been installed as required and installation follows NEC and other applicable codes/standards.
6. Verify that ITS Communications Hub Building doors properly seal, lock, unlock, and smoothly open and close.
7. Test all ITS Communications Hub Building equipment including circuit breaker, receptacles, thermostat, lights, and door switches to verify functionality.
8. A ground resistance test shall be performed at each electrical service grounding point. Ground resistance tests shall be conducted using a 3- or 4-Point Fall-of-Potential method defined by IEEE Standard #81 or other industry approved test method. Each grounding electrode shall be tested prior to connection to the ground system. Resistance-to-Ground of the ground system shall not exceed 10 ohms. Ground resistance measurements shall be conducted in normally dry conditions not less than 48 hours after the latest rainfall. All ground resistance tests shall be conducted in the presence of the Engineer. The Contractor shall document all test recordings and provide a copy of all test reports to the Engineer upon completion in accordance with the Project Submittal Program Requirements in Section 2.7.

9. Test heating and air conditioning system to verify controller system operating thermostat and humidistat sensors provide automatic change over between heating, cooling, dehumidification, and temperature stabilization during dehumidification. Verify that both HVAC units do not start simultaneously.

10. Test and document transformer voltage, current, and insulation resistance.

11. Test and document the duration for which the UPS can run all connected equipment at the site autonomously by disconnecting the site from grid power and the standby generator. The test shall be performed from 100% battery charge to 5% battery charge. At 5% battery charge remaining, the site shall be reconnected to grid power and, subsequently, the standby generator. Include the average load over the course of the test in the documentation.

12. Test the Standby Generator Power System (including transfer switch and automatic load bank) after all other electrical hook-ups have been completed. The provide generator commission testing procedures shall be provided by the generator manufacturer's representative. The testing shall include a multipoint inspection of all of the sub-systems for proper operation and fluid levels. Document pass/fail checklist results and additional comments on the manufacturer's standardized commissioning form.

    a. Enclosure
    b. Engine Belts/Pulleys
    c. Lubrication
    d. Cooling/ventilation
    e. Fuel
    f. Exhaust
    g. A/C electrical system
    h. Transfer Switch
    i. Batteries and DC electrical system
    j. Safety shutdowns

13. Following successful completion of the inspection checklist, the Commissioning Testing shall include running the generator under building load for 90 minutes and recording the following parameters and 15-minute intervals:

    a. Line-line voltage and Line-neutral voltage for all phases (Volts)
    b. Line current for all phase (Amps)
    c. Output Frequency (Hertz)
    d. Battery Voltage (Volts)
    e. Water Temperature (°F)
    f. Oil Pressure (PSI)
    g. Ambient Temperature (°F)

14. Following the 90 minute run test, demonstrate the automatic load bank with each of the available load steps turning on and off.

15. Provide full capacity of oil, fuel and anti-freeze coolant to the Standby Generator Power System in accordance with manufacturer recommendations after testing and restore all items to full condition before Final Acceptance.

16. Test Hub Monitoring System to ensure alarms are received by the TDOT Regional TMC and that all components of the system can be accessed and monitored from the TDOT Regional TMC.

20.8 Warranty

The complete Standby Power System, as detailed in this section, including the engine generator set, the annunciator alarm panel, and the automatic transfer switch, complete in all respects with all accessories, as provided by the single source manufacturer, shall be warranted by the Contractor for a period of 5 years or 1500 operating hours, from the date of Final Acceptance. Coverage shall include parts, labor, travel expenses, and labor to remove/reinstall said equipment. There shall be no deductible applied to this warranty. The warranty shall also include a semi-annual inspection and tests run to perform NFPA 110 required maintenance testing and manufacturer's recommended preventive maintenance services on the unit, including operation of the unit under power failure condition, adjustment of generator and engine controls as required, and certification in owner's log of repairs made and proper functioning of all engine and auxiliary systems.

All other materials specified in this section shall carry a minimum one-year manufacturer's warranty from the date of Final Acceptance against any imperfections in workmanship or materials. Warranties shall cover complete replacement at no charge for the equipment.

Warranties shall be transferred to TDOT upon Final Acceptance of the project as per the requirements in Section 2.6 of this specification.

20.9 Method of Measurement

20.9.1 ITS Communications Hub (Building)

ITS Communications Hub (Building) will be measured in units of each and paid for at the contract price per each for each site furnished, installed, made fully operational, and tested in accordance with this SP725. The bid price shall include providing the site grading and earthwork, clearing and grubbing, excavation, fill material and installation/compaction required to level and/or elevate the site, precast concrete building, building foundation, paved driveway, drainage structures, signs, fencing and gates, communication equipment racks, conduits, cabling, lightning protection equipment, HVAC units, electrical power system, uninterruptible power supply, standby generator power system, foundations, mounting, wiring, connections, fire extinguisher, hub monitoring system, site restoration, seeding and sodding, hardware, factory and manufacturing inspection, testing, storage, packaging, shipping, warranty, work, equipment, appurtenances, as well as all labor, equipment, materials, and incidentals as required to support the full operation and control of ITS Communications Hub Building as detailed on the Plans and as described in this SP725 complete in place and ready for use. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

20.10 Payment

Payment for ITS Communications Hub Building shall be made at the contract unit price per each.

Item No.	Description	Unit
725-24.11	ITS COMMUNICATIONS HUB (BUILDING)	EA

ITS Communications Hub Building will be paid per each as follows:

1. 25% of the contract unit price upon completion of the site work and foundation.

2. 25% of the contract unit price upon completion of Hub Building installation.
3. 25% of the contract unit price upon build out of the interior of the Hub Building.
4. 20% of the contract unit price upon acceptance of Stand Alone Site Test results.
5. Final 5% of the contract unit price upon Final System Acceptance.

21 PORTABLE SMART WORK ZONE SYSTEM (PSWZS)

21.1 Description

This section specifies the minimum requirements and materials for the Portable Smart Work Zone System (PSWZS) to be furnished and installed as shown on the Plans and in accordance with the contract documents.

21.2 Materials

All PSWZS shall be comprised of the highest quality materials and meet the requirements of this section.

The PSWZS shall be comprised of a trailer, mast assembly, Portable Closed-Circuit Television (PCCTV) camera, Portable Radar Detection System (PRDS), Portable Changeable Message Signs (PCMS), two pairs of flashing LED beacons, edge-lit traffic sign, localized encrypted RF relay system, flash controller, charge controller, battery bank, and solar panel array.

The PSWZS shall require multiple trailers in multiple configurations to be effective utilizing solar advanced warning systems, PCMS, edge lit regulatory signs, wig wag beacons, CCTV devices, and field programmable radio frequency communications.

Each trailer that is part of the PSWZS shall be equipped with sensors, changeable message sign, edge lit regulatory signs with wig wag beacons, CCTV devices, and/or and field programmable radio frequency communications.

All signs and traffic control devices are to conform to the latest adopted edition of the Manual on Uniform Traffic Control Devices (MUTCD).

21.2.1 General Capabilities and Device Performance Requirements

PSWZS capabilities and performance requirements include the following:

1. PSWZS components shall be placed at locations shown on the Plans or specified by the contract documents, to provide full coverage over the project limits. This includes mainline travel lanes, shoulders, and side streets where applicable. The Department reserves the right to request relocation of devices throughout the life of the project.
2. The PSWZS field devices shall be compatible with each other and with the PSWZS software.
    a. They shall be of rugged make and suitable for reliable operation in adverse weather conditions.
3. The Contractor shall ensure the installed equipment provides unobstructed real-time data from the roadway, other current conditions around the field site, and within the project limits.
    a. The PSWZS shall respond to control signals and transmit data and video to a remote operator interfaced with the system.
4. Each device shall be capable of being remotely controlled and programmed via provided PSWZS software from the TDOT Regional TMC.
5. Field programmable radio frequency communications shall be fully integrated with the PSWZS devices and software and be part of the system.

21.2.2 Portable Smart Work Zone System (PSWZS) Trailer Requirements

The portable trailer shall serve as a standard platform for the components of the PSWZS.

The trailer shall be comprised of the following materials:

1. Minimum 11-gauge rectangular steel tubing that has been electrically welded following current ANSI specifications and powder coated with appropriate safety colored paint, orange, or other TDOT approved color.
2. A vertically raising mechanical mast assembly which can raise and lower the attached signs and sensors to a minimum height of 7 feet above the pavement.
    a. The mast assembly shall be operated with a brake and cable assembly that levers the mast into a position where it can be pinned for safety.
    b. The mast assembly shall allow for 360-degree sign rotation to allow the operator to easily turn the signs into the display position. Mast locks shall be provided at regular intervals to provide varied set up positions.
3. Adjustable, extendable (telescoping) crank type swivel jacks will be placed at all 4 corners of the trailer to allow the user to level and stabilize the system upon deployment to allow for maximum wind loading and stability.

The trailer shall be of sufficient size and capacity to allow safe travel at highway speeds up to 70 mph. it shall be designed in such a manner as to act as a stable platform for safe operation of all equipment, signs, beacons, and sensors.

21.2.3 Portable Closed-Circuit Television (PCCTV) Camera Requirements

The Portable Closed Circuit Television camera (PCCTV) shall be fully integrated with the PSWZS software. Pan, Tilt, Zoom (PTZ) functions and video streams shall be accessible through the PSWZS software, and shall not be accessed through a separate control software or link.

The PCCTV shall adhere to the following minimum requirements:

1. The PCCTV shall deliver high quality, full high definition (FHD) color images, at a minimum, and be fully compliant with all aspects of the National Television Standards Committee (NTSC) specifications and produce NTSC compatible video.
2. The PCCTV shall be able to operate in a wide variety of dynamic lighting conditions, including but not limited to, low light/dusk, full sunlight, and night.
    a. It shall have switchover iris control (color to monochrome) with user selectable manual and automatic control capabilities.
3. The PCCTV shall be able to deliver multiple streams simultaneously.
    a. The streams shall be H.264 and Motion JPEG video at up to 30 fps in all resolutions.
    b. Placement of the camera and local communications options withing the project limits shall determine best video frame rate at which to provide video.
    c. Contractor shall strive for the best frame rate and shall place the camera in an area with the best possible cellular coverage while keeping within the relative area shown on the Plans.
4. The PCCTV shall be of dome type 360-degree PTZ and be IP66 rated, at a minimum.

5. The PCCTV shall include iris capability to auto-focus during zoom-in and zoom-out operations and the ability to manually override it via the PSWZS software.
6. The PCCTV shall be of rugged nature and an all-weather installation integrated into a mobile trailer type mount.
   a. The mount shall be adjustable for camera height (mast) and solar array.
   b. The trailer shall be able to power the camera via solar panels and charger.
   c. The PCCTV shall not rely on outside power source.
   d. Adjustable height of camera mast shall be 32 feet measured from top of the roadway surface.
7. Battery bank shall be sized for 30-day autonomy, charged from solar array.

21.2.4 Portable Radar Detection System (PRDS) Requirements

The Portable Radar Detection System (PRDS) device, or queue detection system, shall be fully compatible and integrated with the PSWZS software. The device shall be auto-configurable, trailer mounted, battery-powered, solar charged, and provide HD microwave-based lane count, occupancy, and speed data to the PSWZS software. The PRDS must be capable of operation in all weather conditions, including rain, snow, freezing rain, wind, dust, and fog.

The PRDS shall pass all data in real-time to the PSWZS processing server and disseminated to the Operator and automated message generator to produce automated messages on the PCMS a maximum of 60 seconds after PRDS detects the data.

The PRDS shall adhere to the following minimum requirements:

1. The PRDS shall consist of a dual zone radar and transmit on a frequency band of 24 GHz ±25 MHz or other TDOT approved spectral band.
   a. The detector shall also comply with the limit for a Class A digital device, pursuant to Part 15 of the FCC rules or the appropriate Spectrum Management Authority.
   b. The PRDS shall not interfere with any known equipment.
   c. The transmitter power shall not exceed 10 milliwatts (mW).
2. The PRDS shall have no less that ten (10) detection zones at a maximum of twenty (20) feet from the detector.
   a. Minimum separation between detected vehicles shall be no more than six (6) feet.
   b. The detector shall be capable of detection over barriers.
   c. Data collected shall include:
      1) Volume
      2) Travel Times
      3) Lane Occupancy
      4) Average Speed
      5) Vehicle Classification by length. Minimum 3 user defined classes.

3. The PRDS shall be rugged in nature and sealed in a weatherproof box to protect from water intrusion, dust, and other airborne particles.
   a. The PRDS shall be resistant to wind speeds up to 90 mph.
   b. Its enclosure shall be NEMA Type 3R or 4x rated.
4. The PRDS unit shall be operable from 12-24 VDS.
   a. It shall be powered by battery bank charged by an adjustable solar array on an industrial grade trailer platform.

5. PRDS communications connections and equipment to be determined by the manufacturer and PSWZS vendor for the fastest and most reliable data communications to the software and automated message generator.

21.2.5 Portable Changeable Message Signs (PCMS) Requirements

The PSWZS shall include Portable Changeable Message Signs (PCMS) at locations specified on the Plans or by the Department.

The PCMS shall provide autonomous automated messaging for motorists regarding congestion levels, travel times, detour routings, queue information, and cautions along the project limits and associated Smart Work Zone. Message override shall be available to the TDOT TMC Operators to display pertinent information as necessary.

The PCMS shall adhere to the following minimum requirements:

1. The PCMS shall be trailer mounted on an industrial grade trailer as described in this Specification.
2. The PCMS shall either be standard mono-color or full color matrix display.
    a. Sign case minimum dimensions for full matrix display shall be between 4.5’ H x 8.5’ W to 6’ H x 11’ W.
    b. The PCMS shall have at a minimum 5 high-intensity, solid state LEDs per 2-inch pixel.
    c. Individual Line matrix signs of individual characters shall not be allowed.
3. The PCMS panel shall be at least 7 feet above the pavement and present a level appearance.
    a. The panel shall be capable of displaying a minimum of eight (8) characters in each of the three lines of the full matrix display, at an eighteen inch (18”), character height.
    b. The panel shall be capable of displaying other fonts and character heights. Other fonts and heights may be used to display different traffic data.
    c. Those fonts shall be used at the discretion of the TDOT TMC Operations staff.
4. The full 18” Character height shall be visible from ¼ mile under both day and night conditions in accordance with MUTCD standards.
    a. Other font sizes and options for the full matrix display shall be documented and submitted to TDOT TMC operations personnel.
5. The sign shall be capable of providing 250 text, 60 graphics, and 20 arrow board display messages programmed in the controller.
    a. Additionally, 100 user-created messages shall be able to be stored in the controller.
6. The PCMS shall be compliant with NTCIP 1203v03.
7. The PCMS shall include automatic dimming feature for nighttime operations.
8. The PCMS shall utilize a hydraulic lift to raise the unit to the required display height.
9. The PCMS shall be battery powered and charged via adjustable soral panel array.
    a. Solar panels shall be sized to replace power used in a typical daily operation with less than four (4) hours of sun.
10. The battery bank shall have adequate amp-hour capacity to operate the PCMS continuously in the absence of solar recharge for a minimum of 21 days.

21.2.6 Edge-Lit Traffic Sign and Wig Wag Beacon Requirements

The PSWZS shall include edge-lit traffic signs with wig wag beacons at locations specified on the Plans or by the Department.

The edge-lit traffic signs and wig wag beacons shall provide autonomous automated activation of wig wag beacons for motorists regarding the presence of construction vehicles emerging from the work zone into the roadway along the project limits and associated Smart Work Zone.

The edge-lit traffic signs shall adhere to the following minimum requirements:

1. The edge-lit traffic signs shall be placed at locations shown on the Plans or specified by the contract documents, to provide full coverage over the project limits. The Department reserves the right to request relocation of devices throughout the life of the project.
2. Warning signs shall consist of a 48” x 48” panel with 8 amber LEDs arranged inside the sign border per MUTCD.
3. Regulatory signs shall consist of a 36” x 36” panel with 8 red or white LEDs arranged inside the sign border per MUTCD.

The wig wag beacons shall adhere to the following minimum requirements:

1. Two wig wag beacons shall be placed around each of the edge-lit traffic signs.
2. The beacons shall be 12” diameter and consist of PAR 46 LED lamps.
3. The beacons shall communicate over an onboard RF relay system.

21.2.7 Portable Smart Work Zone System (PSWZS) Communications Requirements

The Portable Smart Work Zone System (PSWZS) communications configurations shall adhere to the following minimum requirements:

1. The communications devices shall be of rugged design and support machine-to-machine applications.
    a. The communications devices shall be able to report GPS coordinates of the PSWZS devices.
2. The communications devices shall utilize appropriate security measures to prevent outside sources from connecting to and controlling the PSWZS devices.
    a. The security measures shall be at a minimum include onboard IPsec SSL VPN, MAC Address Filtering, IP filtering, Port Filtering, SSH and HTTPS.
3. Cellular communications and satellite communications are acceptable forms of communication.
    a. The selected form of communication shall provide the highest level of connectivity at the required data rates for the PSWZS devices, at the locations per the plans.
    b. The wireless communications system shall be reliable, dependable, and capable of operating at all times regardless of weather conditions, density of customers, and location on the project limits.
    c. Any adjustments to PSWZ device locations shall not affect the communications and shall be approved by the Engineer.
4. All required configurations will be performed by the contactor during system initialization at the beginning of the project.
    a. The system shall be fully operational prior to the beginning of any work on the project.
5. Each individual device shall communicate to the server independently and not rely on communication with another device or sensor.
6. The PSWZS shall have incorporated an error detection/correction mechanism to ensure the integrity of all traffic data and messages, as well as providing notification to Operators for action.

The contractor shall be responsible for all communications costs, utilities, and satellite or cellular services needed to provide dependable communications to the PSWZS components.

21.2.8 Portable Smart Work Zone System (PSWZS) Software Requirements

The PSWZS shall be provided and operate on an intuitive web-based portal (web-client) that adheres to the following minimum requirements:

1. The web-client shall provide a graphical user interface (GUI) for data verification, overall monitoring, and control of all of the system components by Operators at the Regional TMC.
    a. The web-client shall be accessible on all operator workstations at the Regional TMC.
2. The PSWZS software servers, or core collection system, shall collect data from the portable traffic sensors and automatically update the PCMS in real time, as required in the Automated Messaging Requirements Sections below.
3. TDOT Operators shall be given access to web-client with administrative rights, via username and password, for device control.
    a. Operators shall be able to access all historical and current data for download and use by the Department.
4. The web-client shall have the capability to provide access to the public and stakeholders at different user levels as deemed necessary by the Department.
5. The GUI shall be intuitive and user-friendly displaying a real-time color-coded map of the project corridor with a color-coded map displaying current roadway conditions.
    a. Color coding on the map shall be as follows: Red-Stopped Traffic, Yellow-Slowed Traffic, Green-Free Flowing Traffic.
    b. The messaging shall be able to be viewed by any person given access to the web-client.
    c. TDOT Regional TMC Operations and TDOT Construction personnel shall be given administrative access to the web-client to access command and control of the devices.
6. The PSWZS software shall be capable of providing automatic email updates to designate personnel when speeds drop below certain thresholds, as well the ability to download device data for performance monitoring or later evaluation as deemed necessary by the Department.
    a. The software shall also provide notification upon device error or malfunction.
    b. A message shall appear in the software to alert the Operator that communications have been lost, a device is malfunctioning, or power/ battery levels are low.
    c. All status and monitoring capabilities of the software shall be available to the TDOT Operators and Personnel.

21.3 Portable Smart Work Zone System (PSWZS) Operational Requirements

This section describes the operational requirements of the PSWZS.

All equipment shall be installed according to the manufacturers recommendations at the locations as shown on the Plans. Any necessary deviations from the plans for device placement shall be coordinated with and approved by the Department and the Engineer prior to placement and system configuration. The Contractor shall ensure that personnel deploying the PSWZS system shall be experienced with similar deployment configurations prior to installation.

During anytime throughout the life of the project, and at the request of the Department or the Engineer, the Contractor shall relocate the PSWZS devices to locations with better communications, data collection accuracy, message viewing, or overall camera coverage along the project.

To ensure prompt response to any device failure, upon notification from the Department, the Contractor shall have six (6) hours to investigate and rectify any issues identified. This includes all devices as part of the PSWZS system including but not limited to, PCCTV, PRDS, PCMS, wig wag beacons, edge lit signs, communications, etc.

The department reserves the right to terminate the use of a malfunctioning system at any time during the life of the project. A failing system is defined by the department or its representatives as any device that has failed a total of five (5) or more days during a 30-day period.

21.3.1 Portable Closed-Circuit Television (PCCTV) Operational Requirements

The PCCTV trailers shall be placed throughout the project corridor as shown on the Plans. These trailers shall be used to verify PCMS trailer messages and traffic conditions within the project limits.

The Department reserves the right to relocate the PCCTV trailers at any time during the life of the project in order to provide better accessibility and visibility to TMC staff and stakeholders.

21.3.2 Portable Radar Detection System (PRDS) Operational Requirements

The PSWZS shall include vehicle detection devices placed at areas indicated on the Plans where irregular queues and delays are anticipated or where construction vehicles may be entering the roadway. The vehicle detection devices shall calculate and relay real time travel speeds within the project limits and relay that data to TMC operators and TDOT staff. Or in the case, of locations where construction vehicles may be entering the roadway, they shall detect the presence of a vehicle to activate the edge-lit traffic signs and wig wag beacons.

The Department reserves the right to relocate vehicle detection devices at any time during the life of the project, should available data indicate the need or new areas of irregular queue and delay present themselves.

Each PRDS device shall be properly configured and calibrated once the device is placed as indicated on the Plans or as directed by the Engineer. The following error levels shall be achievable and demonstrated during testing:

Parameter	Error Percentage
Volume	8%
Lane Occupancy	10%
Average Speed	10%
Length Classification Limits	10%

21.3.3 Portable Changeable Message Signs (PCMS) Operational Requirements

The PSWZS shall include PCMS placed at locations as shown on the Plans. The PCMS shall be placed in such a way as to provide information to motorists regarding detours, travel times, congestion levels, and possible incidents of stopped traffic along the corridor. The PCMS shall relay the data in real time to the PCMS from sensors within the PSWZS.

All PCMS shall provide advanced warning of construction activities, accidents, congestions, or queues, based on TDOT's operational criteria.

The department reserves the right to move or adjust the PCMS devices as deemed appropriate throughout the life of the project.

21.3.3.1 Portable Changeable Message Signs (PCMS) Automated Messaging Requirements

The automated messages will be determined by the Department in conjunction with the PSWZS vendor. The contractor shall coordinate and verify the automated messages with TDOT personnel and TMC Operations Manager prior to setting up the PCMS and sensors.

The Purpose of the PSWZS automated messaging is to alert and/or warn motorists of congestion, delays, and queues from data provided by the system's sensors. The messaging requires, at a minimum, a two-phased message.

1. The first message shall describe the problem, such as, *"slow traffic ahead",* or *"stopped traffic ahead"*
2. The second message shall provide motorists with a warning, delay estimate, or instructions such as, *"expect delays", "be prepared to stop",* or estimate delay durations.

The content of the automated messages shall be determined by the Department. The messages shall be invoked on the basis of vehicle speed within the Smart Work Zone and at the Department's discretion.

The Department reserves the right to edit these automated messages at any time during the life of the project as it sees fit to give motorist the most information available from the PSWZS.

21.3.4 Portable Smart Work Zone System (PSWZS) Software Operational Requirements

In addition to the requirements in this section the Contractor shall program the PSWZS to ensure the following general operational requirements are met:

1. The PSWZS shall operate continuously (24 hours a day, 7 days a week) when deployed on a project.
    a. It shall always be collecting and storing data while providing real time data feed to the TDOT Regional TMC.
2. The PSWZS shall be capable of providing current operational status, including but not limited, to current traffic data, messages, communication system, signs, sensors, and video feeds via a dedicated project web client.
3. The PSWZS shall provide remote sign operation through a password protected web client.
    a. Operators shall have the ability to manually override the automated messaging to display manual messages at any time.
    b. Operators shall be able to send pre-programed or manual messages to one or multiple signs simultaneously (Vendor to provide a "group send" feature).
    c. Operators shall be able to cancel manual override and reinstate all of the systems automated messaging features at any time.

4. The PSWZS shall allow project field staff with password privileges to manually override the automated messaging for a user specified duration, after which the automatic operation will resume.
5. The PSWZS shall have the capability to autonomously restart in the case of power failure in any part of the system.

21.4 Testing

The Contractor shall perform Stand Alone Tests (SAT) on all components of the PSWZS. The SAT shall demonstrate that all equipment and materials are in full compliance with all project and operational requirements. The SAT shall also demonstrate the PSWZS is fully functional as installed in its operational configuration. Refer to section 2.5 for additional Testing requirements and individual device sections for specific operational requirements, such as accuracy, movement, etc.

21.4.1 General Requirements

1. The Contractor shall conduct a project testing program for all materials specified in this Section.
2. All test results shall confirm physical and performance compliance with this SP725.
3. Payment for all testing is included in the cost of the Portable Smart Work Zone System.

21.4.2 Factory Acceptance Test

FAT is not required for PSWZS.

21.4.3 Bench Test Component

BTC shall be performed in the presence of the Engineer. The BTC shall include the following tests and inspections:

1. Verify the PSWZS devices have no internal or external damage.
2. Test all PSWZS equipment functionality using vendor software.
3. Perform communication test with all PSWZS functionality, ensuring that the devices can communicate with the PSWZS.

21.4.4 Bench Test System

BTS shall be performed in the presence of the Engineer. The BTS shall include the following tests and inspections:

1. Perform communication test with all PSWZS functionality, ensuring that the devices can communicate with the PSWZS software.
2. Verify the PSWZS devices can be configured and calibrated using the vendor software.
3. Verify that the required operational characteristics of the PSWZS devices are valid including the counting of volume and speed and posting of messages.

21.4.5 Stand Alone Site Test

SAT shall be performed once the PSWZS devices are in position in the field and shall be performed in the presence of the Engineer. The SAT shall include the following tests and inspections:

1. Verify all components have been installed per manufacturer requirements.
2. Verify all items have been attached properly (as per manufacturer recommendations and the Plans) to each other and to the trailer structure.

3. Verify the PSWZS devices have no internal or external damage.
4. Test and document the accuracy of the PRDS in accordance with the accuracy requirements specified in this SP. A portion of this test requires the contractor to use a calibrated radar gun to compare observed speeds on a per lane basis between the calibrated radar gun and PRDS data over a 5-minute period. All data collected during the test shall be documented and submitted to the Engineer for approval.

21.4.6 System Acceptance Test

System Acceptance Testing shall be performed in the presence of the Engineer. System Acceptance shall be granted upon the successful completion of the following tests and at the approval of the Engineer.

1. Perform communication test with all PSWZS functionality, ensuring that the devices can communicate with the PSWZS software.
2. Verify the PSWZS devices can be configured and calibrated using the PSWZS Software in the TDOT Regional TMC.
3. Verify that the required operational characteristics of the PSWZS devices are valid including the counting of volume and speed and posting of messages.

21.5 Training

Training shall be provided for up to ten (10) TDOT designated individuals, or a number, as specified in the contract documents and/or the plans. Training shall be a minimum of 6 hours, provided to the Department's operations personnel on a live system, once all devices have been fully deployed, tested, and integrated in the field with communications established with the PSWZS Software. The training shall provide personnel with general knowledge of the devices and advanced user knowledge of any PSWZS web-client interface. A second 6-hour training session shall be provided, on a different day, if requested by the Department.

Training shall encompass all areas of any web-client software, including:

1. Login and credentials.
2. Navigation of the PSWZS Software, including description of menu tabs and help tabs.
3. Description of the map.
4. General monitoring of the PSWZS through the web-client.
5. General operation of the automated function and procedures for changing the automated messages of intervals/speeds related to displaying those messages.
6. Operational override of the PCMS and procedure for posting manual messages on the PCMS, along with return to automated function.
7. Retrieval of PRDS data.
8. Monitoring of video streams and operation of PTZ system of the PCCTV cameras.

The Contractor shall submit to the Engineer for approval a detailed Training Plan including course agendas, detailed description of functions to be demonstrated, deviations in training location, and a schedule. The Contractor shall also provide all training material in electronic format to the Engineer.

21.6 Warranty

All materials specified in this section shall carry a warranty from the date of System Acceptance through completed use of the system against any imperfections in workmanship or materials. Warranties shall cover complete replacement at no charge for the equipment.

21.7 Method of Measurement

The PSWZS shall be measured for the entire system, fully deployed and functional per day for both directions.

21.7.1 Furnishing and Installing

The cost for furnishing and installing the PSWZS shall be included in the mobilization cost for the overall project under Pay Item 717-01. This will include initial procurement, setup, and transportation to the project site.

21.7.2 Operations

The operation, management, and maintenance of the PSWZS will be measured in units of days and paid for at the contract price per day. The per day cost shall include, integrating (including carrier communications), operating, maintaining, configuring, testing, and training of the complete PSWZS. The price shall also include all local and remote configuration and all central and local control manufacturer PSWZS software. Price shall include all documentation including but not limited to shop drawings, operations and maintenance manuals, block diagrams, and other materials necessary to document the operation of the PSWZS. The price shall be full compensation for all labor, tools, materials, equipment, and incidentals needed to complete the work.

21.7.3 Provisions for Non-Working System

Should a device fail to communicate or become inoperative for more than hours six (6) hours after the department's notification, the system will be considered non-working and payment for the entire system will be withheld for that day.

Should the department exercise its right to terminate a malfunctioning system payment will cease seven (7) days after the request has been sent by the department or when the system is removed from the project, whichever comes first.

21.8 Payment

The contract unit price shall be full compensation for all work specific in this section.

Payments will be made under:

Item No.	Description	Unit
725-21.07	PORTABLE SMART WORK ZONE SYSTEM	DAY

PSWZS will be paid per day as follows:

1. Payment for the Per Day item shall commence once the contractor shows all devices are deployed and communicating to the TDOT Regional TMC.
2. Should any project in which the PSWZS is deployed prior to or after the scheduled number of days shown on the Plans, the Department reserves the right to terminate the use of and payment of the PSWZS. Likewise, if the PSWZS proves to be not functioning as specified in this section, the Department reserves the right to terminate the PSWZS and cease payment thereof.

22 SYSTEMS INTEGRATION

22.1 Description

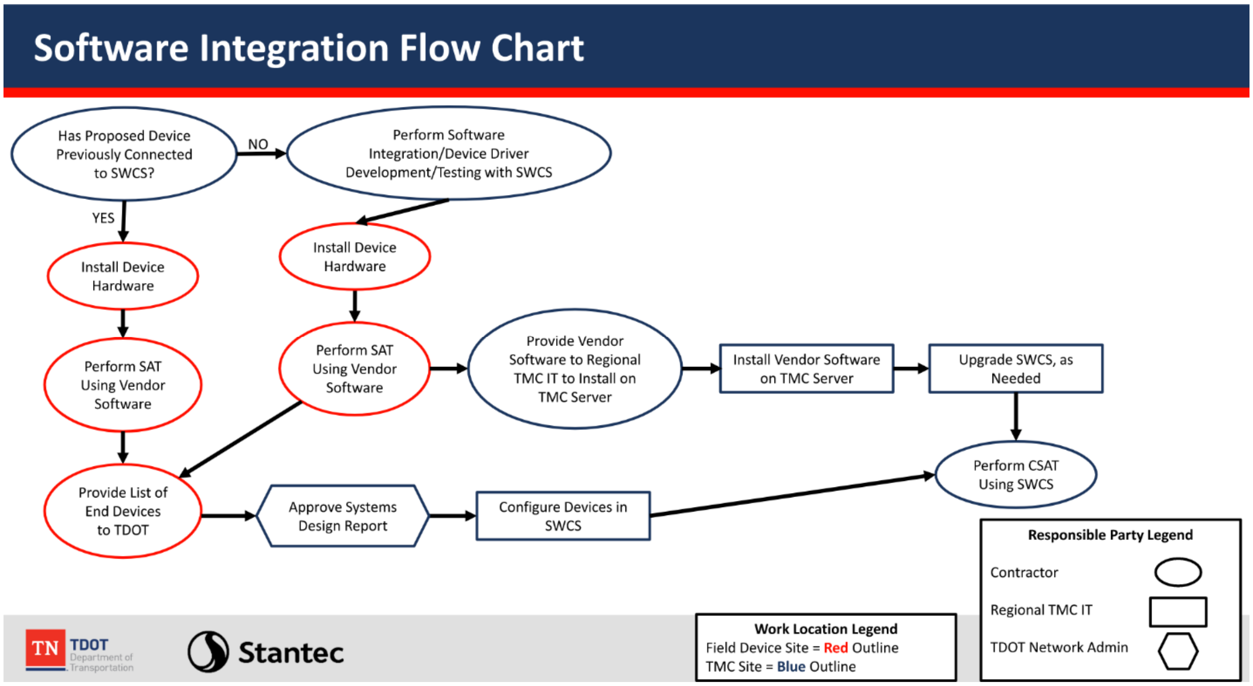
This section describes the system integration specifications and requirements for this project. The work consists of providing all labor, materials, software, software development, and incidentals necessary to integrate the proposed ITS devices into the TDOT ATMS software on the TDOT TMC Network. The work includes all additional licensing, documentation, and software necessary to operate the system as required in this SP725.

The Contractor shall be responsible for integrating the ITS devices provided in this contract into the TDOT ATMS software. This system supports multiple ITS device makes and models, but new device makes and models may require driver, API, and other software development for integration. Therefore, this contract is a total "turn-key" solution that ensures the DMS, RDS, ESS, RSU, flashing beacons, OVDS, HAR, CCTV subsystems, or any other ITS subsystem that is part of the project are fully functioning within the TDOT ATMS software.

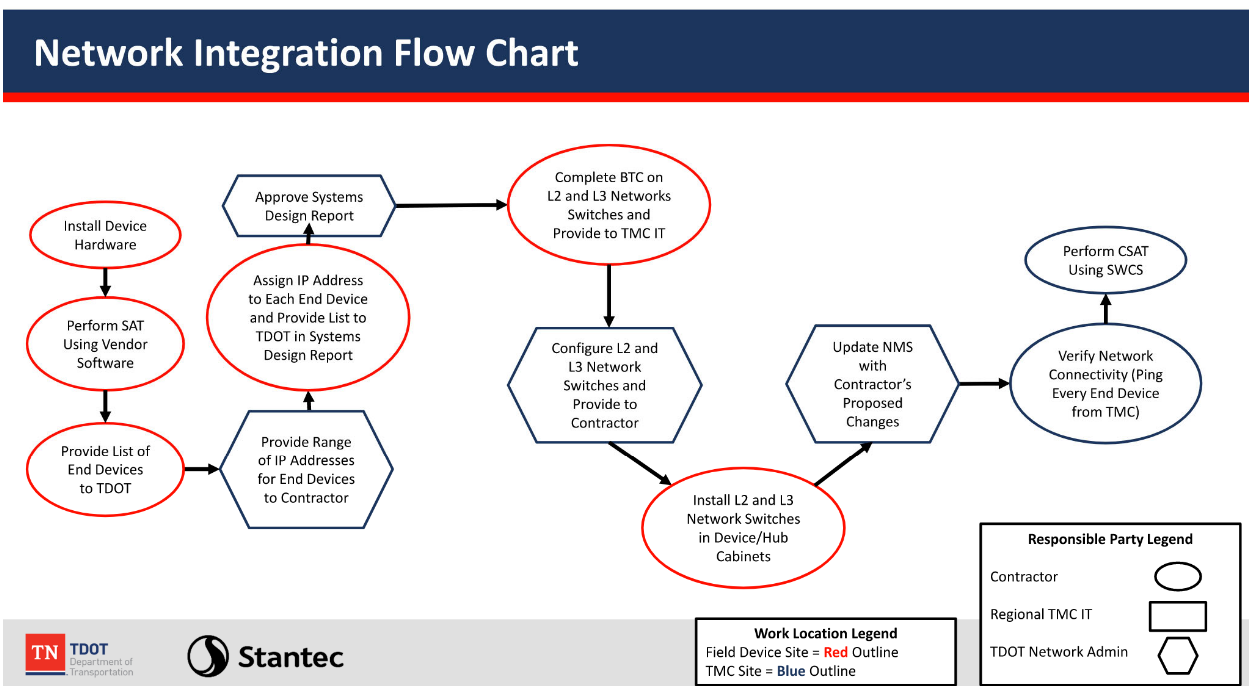
For all active electronic devices controllable through any type of communications interface, the Contractor shall coordinate with each respective system representative for each piece of equipment supplied, to support direct communication with and control of devices by the TDOT ATMS software. The Contractor shall be responsible for coordinating with the system vendors to ensure sufficient drivers are developed to support the proposed new device make and/or model provided and installed under this contract.

The systems integration may consists of two components: Software Integration and Network Integration.

The roles, responsibilities, location of work, and overall process for coordinating and completing the integration of devices into the TDOT ATMS software is detailed in the figure below and described further in this Section.



The roles, responsibilities, location of work, and overall process for coordinating and completing the network integration is detailed in the figure below and described further in this Section.



22.2 Materials

Contractor shall provide all materials according to the requirements in the following sections.

All equipment shall be new and constructed using high quality, commercially available components and techniques to assure high reliability and minimum maintenance. Prior to installation, the Contractor shall submit and receive approval from the Engineer on a complete set of shop drawings of all the equipment and components listed within this Special Provision and included as part of the installation.

22.2.1 General Requirements

The components and system procured and installed by the Contractor under this contract shall support daily operations and maintenance activities associated with the TDOT SmartWay ITS Program.

1. Systems Design Report Submittal

   During mobilization, the Contractor shall document and submit a Systems Design Report to the Engineer for review and approval. Approval shall be received from the Engineer prior to any integration of new ITS field devices within the TDOT Regional TMC. The Systems Design Report shall document the Contractor's overall integration design into the TMC including overall network/architecture modification configuration, and confirmation of device support by the TDOT ATMS software management team. Detailed submittal requirements are included in Section 22.2.4. The cost for this submittal is included in the Network Integration pay item.

2. Local Area Network (LAN)

   a. The TDOT ATMS software operates over a TCP/IP client/server architecture, which will support operations over the TMC ATMS software local area network (LAN) and the TDOT network.

   b. The Contractor shall document in the Systems Design Report submittal the TMC building infrastructure (e.g., cabling, patch panels/cords, etc.) requirements needed to support the TMC system configuration.

3. TMC Hardware / Equipment

   a. The Contractor shall be responsible for the integration, configuration, and testing of all ITS field devices with TMC hardware and equipment through the TDOT ATMS software as specified herein.

   b. It is the Contractor's responsibility to install and test the TMC ATMS software LAN modifications along with the field network devices and ITS subsystems. This work must be performed in coordination with and at the approval of TDOT Regional TMC IT, specifically to allow time for TDOT Regional TMC IT to configure and provision the Ethernet Switches as detailed in Section 19.

4. Communications

   a. The TDOT Regional TMC shall be able to communicate with field devices via cellular, wireless, and fiber optic infrastructure that supports Ethernet communications.

22.2.2 Software Integration

Software Integration shall include all ATMS software integration tasks that are needed to meet all specification requirements but are not included specifically in the cost of other items.

This includes but is not limited to device integration with the ATMS software, coordination with TDOT Regional TMC IT and Network Administrators, and other related software integration activities to ensure full functionality of the hardware with the TDOT ATMS software such as the development of APIs, Device Drivers, and new ATMS Modules.

22.2.2.1 Wireless Ethernet Radio Network Software

The Contractor shall provide vendor supplied, Windows-compatible software capable of configuring the Wireless Ethernet Radios from the TDOT Regional TMC over the network. This software will be used for configuring, testing, and verification only. Cost of the Wireless Ethernet Radio Software shall be included in the cost of the Wireless Ethernet Radio and Antenna units.

22.2.2.2 CCTV Software

The Contractor is responsible to determine TDOT's current operating software(s) at the TDOT Regional TMC for video management. The Contractor shall coordinate with the video distribution and TDOT ATMS software developer(s) to provide the required software drivers and any necessary ATMS software modifications for full integration of the CCTV elements included as part of this contract. Cost of the CCTV Software shall be included in the cost of the CCTV Camera units.

22.2.2.3 DMS Software

The Contractor shall provide vendor supplied, Windows-compatible software capable of testing DMS commands from the TDOT Regional TMC over the network. This software will be used for testing and verification only. Cost of the DMS Software shall be included in the cost of the DMS units. The software shall not require serial data converters (i.e., terminal servers) to establish DMS communications. The Contractor shall also coordinate with the TDOT ATMS software developer to provide the required software drivers and any necessary ATMS software modifications for full integration of the for all new DMS elements included as part of this contract.

22.2.2.4 RDS Software

The Contractor shall provide vendor supplied, Windows-compatible software capable of testing RDS data from the TDOT Regional TMC over the network. This software will be used for testing and verification only. Cost of the RDS Software shall be included in the cost of the RDS units. The Contractor shall also coordinate with the TDOT ATMS software developer to provide the required software drivers and any necessary ATMS software modifications for full integration of the RDS elements included as part of this contract.

22.2.2.5 ESS Software

The Contractor shall provide vendor supplied, Windows-compatible software capable of testing ESS data from the TDOT Regional TMC over the network. This software will be used for testing and verification only. Cost of the ESS Software shall be included in the cost of the ESS units. The Contractor shall coordinate with the TDOT ATMS software developer to provide the required software drivers and any necessary ATMS software modifications for full integration of the ESS elements included as part of this contract.

22.2.2.6 RSU Software

The Contractor shall provide vendor supplied, Windows-compatible software capable of testing RSU data from the TDOT Regional TMC over the network. This software will be used for testing and verification only. Cost of the RSU Software shall be included in the cost of the RSU units. The Contractor shall coordinate with the TDOT ATMS software developer to provide the required software drivers and any necessary ATMS software modifications for full integration of the RSU elements included as part of this contract.

22.2.2.7 Flashing Beacon Software

The Contractor shall provide vendor supplied, Windows-compatible software capable of testing flashing beacon data from the TDOT Regional TMC over the network. This software will be used for testing and verification only. Cost of the flashing beacon Software shall be included in the cost of the flashing beacons. The Contractor shall coordinate with the TDOT ATMS software developer to provide the required software drivers and any necessary ATMS software modifications for full integration of the flashing beacon elements included as part of this contract.

22.2.2.8 OVDS Software

The Contractor shall provide vendor supplied, Windows-compatible software capable of testing OVDS data from the TDOT Regional TMC over the network. This software will be used for testing and verification only. Cost of the OVDS Software shall be included in the cost of the OVDS. The Contractor shall coordinate with the TDOT ATMS software developer to provide the required software drivers and any necessary ATMS software modifications for full integration of the OVDS elements included as part of this contract.

22.2.2.9 WIM Software

The Contractor shall provide vendor supplied, Windows-compatible software capable of testing WIM data from the TDOT Regional TMC over the MS2 network. This software will be used for configuration, testing, verification, and operations. Cost of the WIM Software shall be included in the cost of the WIM.

22.2.2.10 HAR Software

The Contractor shall provide vendor supplied, Windows-compatible software capable of testing HAR data from the TDOT Regional TMC over the network. This software will be used for testing and verification only. Cost of the HAR Software shall be included in the cost of the HAR. The Contractor shall coordinate with the TDOT ATMS software developer to provide the required software drivers and any necessary ATMS software modifications for full integration of the HAR elements included as part of this contract.

22.2.3 Network Integration

Network Integration shall include all network integration tasks that are needed to meet all specification requirements but are not included specifically in the cost of other items.

This includes but is not limited to LAN integration, Fiber integration, WAN integration, wireless network link integration and configuration, cellular head end equipment integration, network monitoring integration and configuration, firewall integration and configuration, coordination with TDOT Regional TMC IT, network integration diagrams to document the overall configuration of the system, and other related network integration activities to ensure full access of the field devices to the TDOT TMC network.

22.2.3.1 Fiber Optic

Fiber Optic Network Integration shall include the necessary SFP optical transceivers, fiber optic patch cords, and CAT 6 (or greater) cables to complete the end-to-end communications between ITS field devices as well as communication hubs and the TDOT Regional TMC. Fiber Optic Network Integration shall also include end-to-end testing of the network in accordance with the testing requirements within this SP725. All materials provided including SFPs, fiber optic patch cords and CAT 6 cables must meet the material requirements within this SP725.

22.2.3.2 WAN

Wide Area Network Integration shall include any necessary VPN software licensing, service provider connection fees, service provider equipment, the configuration and integration of the MPLS or VPN communication links into the TDOT TMC Network, and any other software, materials, and hardware necessary to complete the end-to-end communications between ITS field devices as well as communication hubs and the TDOT Regional TMC. Wide Area Network Integration shall also include end-to-end testing of the network in accordance with the testing requirements within this SP725.

22.2.3.3 Wireless Ethernet Radio

Wireless Ethernet Radio Integration shall include the configuration and integration of the wireless communication links into the TDOT TMC Network to provide complete end-to-end communications between ITS field devices as well as communication hubs and the TDOT Regional TMC. Wireless Ethernet Radio Integration shall also include end-to-end testing of the network in accordance with the testing requirements within this SP725.

22.2.3.4 Cellular

Cellular Integration shall include any necessary cellular head-end equipment, service provider connection fees, service provider equipment, the configuration and integration of the cellular communication links into the TDOT TMC Network, and any other software, materials, and hardware necessary to provide complete end-to-end communications between ITS field devices as well as communication hubs and the TDOT Regional TMC. Cellular Integration shall also include end-to-end testing of the network in accordance with the testing requirements within this SP725.

22.2.3.5 Network Management and Remote Monitoring Software (NMS)

TDOT currently uses an existing NMS platform to monitor the field network. The existing platform is SNMPc by Castle Rock. Network Configuration Management and Network Performance Monitoring modules are monitored using the Orion Platform by SolarWinds. All new communications links and endpoints as well as any modifications to existing communications links and endpoints shall be configured into TDOT's NMS via coordination with TDOT Regional TMC IT.

22.2.3.6 Firewall

Any required Firewalls shall be provided by TDOT IT and installed and configured by the Contractor. The Firewall shall include management software and shall be compliant with TDOT's Cisco Network.

22.2.4 Project Submittal Program Requirements

1. General Requirements

    a. The Contractor shall provide project submittals for all TMC Systems as required in Section 2.7 of this SP725, including scheduling requirements. The project submittals for Systems Integration shall include but not be limited to the additional specific requirements in this Subsection.

2. Systems Design Report Submittal

    a. During mobilization, the Contractor shall develop and submit to TDOT Regional TMC IT for review and approval a Systems Design Report, which documents the detailed systems integration approach and includes all the elements specified in this section of this SP725. The Systems Design Report shall be a word-searchable electronic copy signed by the Contractor's qualified networking professional that must be reviewed and approved by TDOT Regional TMC IT at least 30 calendar days prior to any procurement. Response and/or approval will be provided by TDOT Regional TMC IT and TDOT Network Administrators within 60 calendar days of Contractor submittal. The cost of the Systems Design Report shall be included in the cost of Network Integration.

b. The Contractor shall coordinate with TDOT Regional TMC IT to define the network. The document will contain:

    i. Complete description of the proposed implementation of the access, distribution, and core layers for the ITS network as described on the Plans and this SP725.

    ii. Client/server network and operating system requirements, if different from that specified in this section.

    iii. Development of an IP Design Scheme with ranges assigned to each node to be integrated by the Contractor using guidance from TDOT (e.g., address ranges, geographic distribution, and standards for addresses within each cabinet). The TDOT Regional TMC IT staff will provide the Contractor with an IP address range or ranges from which the Contractor shall develop the IP address scheme. The network architecture and IP address allocation shall be prepared by a qualified networking professional (minimum CCNA or a manufacturer-approved equivalent based on the approved hardware vendor) and will be approved by the Engineer. The Qualified network professional shall be present during the installation and testing of the local area network as well as during system testing.

    iv. Proposed IP subnet definition and addressing including all masks.

    v. Proposed IP multicast configuration including multicast routing (i.e., Protocol Independent Multicast (PIM) sparse or dense) and Rendezvous Point (RP) designation, as necessary.

    vi. Proposed recommendations for failover and redundancy including network device power, supervisor cards, and network ports.

    vii. Proposed expansions to the network addressing schemes and network traffic routing modifications.

    viii. Proposed configuration and guidelines for L3 routing including OSPF, VRRP, EIGRP, and RIP.

    ix. Proposed configuration and guidelines for VLAN assignments including management VLANs, device VLANs and routing VLANs.

    x. Proposed configuration and guidelines for L2 broadcast storm prevention, loop prevention and fault tolerance mechanisms. (Spanning Tree diagram with designated, blocking, and forwarding ports indicated. Root bridge and backup root bridge must also be specified.) Incorporation of Multiple Spanning Tree Protocol.

    xi. Proposed configuration and guidelines to mitigate common security threats such as denial of service, man in the middle, MAC/IP spoofing, and brute force dictionary attacks.

    xii. Proposed configuration and guidelines for 802.1p Class of Service (COS) queue assignments.

xiii. Proposed configuration and guidelines for specific port assignments on each of the L2 devices.

3. Other Submittal Documents

   a. The Contractor shall provide documentation on application data file format/structure as specified herein to TDOT Regional TMC IT at least 60 calendar days prior to CSAT.

   b. The Contractor shall provide detailed discussion and rationale for any and all requested changes or modifications to system design configuration, hardware, and software operating system requirements as specified in this section of this SP725.

   c. The Contractor may request that 1 or more of the requirements as specified herein be modified or replaced in support of their system solution. All requested modifications and changes to requirements shall be documented in detail in the submittal for consideration and approval by TDOT Regional TMC IT. The Contractor shall be responsible for any additional costs resulting from the requested changes.

22.3 Installation Requirements

Contractor shall abide by the installation requirements in the following sections. All equipment and software shall be installed according to the manufacturer's recommendations, TDOT Regional TMC IT policies, and the Plans.

Any beneficial use by TDOT of any portion of the ITS device deployment or integrated software system prior to CSAT completion does not constitute TDOT acceptance or waive any Contractor responsibility or testing requirements.

22.3.1 General

1. The Contractor shall configure, integrate, and test the networking hardware and equipment and ITS device and ATMS software in accordance with the Plans and this SP725.

2. Additional SFPs for existing Layer 3 switches to support communications back to the Regional TMC as indicated on the Plans shall be provided and installed by the Contractor.

3. The complete fiber pathway as indicated on the Plans, which may include existing and new fiber, is to be fully tested and characterized to identify any errors and impedance. If any errors or impedance are identified, they shall be a notice shall be located. If the errors or impedance are within the newly deployed fiber, the Contractor shall resolve the issues. If the errors or impedance are within the existing fiber infrastructure, the Engineer shall be notified. The Engineer will work with TDOT's ITS Maintenance Contractor to repair the fiber.

4. All patch cords and cabling within the TDOT Regional TMC and network hubs shall be consistent and meet the minimum cabling requirements as specified in this SP725.

5. The Contractor is responsible for ensuring that all cables, connectors, interfaces, supplies, and any other items necessary for the proper operation and function of any component or software product shall be installed, integrated, and tested to provide a fully operational system.

6. The Contractor shall be responsible for obtaining any Management Information Base (MIB) information for all field devices supporting simple network management protocol (SNMP). The Contractor shall coordinate with TDOT Regional TMC IT and TDOT Network Administrators to configure NMS software to meet all requirements of Section 11.2. In the NMS user interface, the

Contractor shall coordinate with TDOT Regional TMC IT and TDOT Network Administrators to configure the ITS Device IDs for each SNMP device on the network.

7. The Contractor shall fully integrate proposed switches with existing TDOT Regional TMC Core switches and computer and ATMS hardware to form a complete local area network that allows users from the TDOT Regional TMC as shown on the Plans to access applications on the application servers, the CCTV central hardware, and the proposed field communication network.
8. The Contractor shall fully integrate upgraded LAN to accomplish/maintain L2 Field Ethernet Switch, L3 Aggregation Ethernet Switch, L3 Field Aggregation Ethernet Switch, L3 Core Ethernet Switch, or Ethernet Bridge failover and fault tolerance.
9. The Contractor shall fully integrate network equipment to provide user authentication and security functions to prevent unauthorized users and data from entering the TDOT TMC Network.
10. If included in the project, the Contractor shall fully integrate wireless ethernet radio equipment, cellular head end equipment, and firewalls into the overall TDOT TMC Network.
11. If included in the project, the Contractor shall fully configure and connect the VPN tunnel or MPLS connection to the remote TDOT Communications Hub.
12. The Contractor shall coordinate with TDOT Regional TMC IT to install any software or software modifications on Test and Production TDOT Servers. All updates to software on Production Servers must be approved by the Change Advisory Board in advance.

22.4 Testing Requirements

22.4.1 General Requirements

1. The Contractor shall conduct a project testing program for System Integration as required in Section 2.5 of this SP725 and as detailed in this Subsection.
2. All test results shall confirm physical and performance compliance with this SP725.
3. The Contractor shall submit all test results documentation to the Engineer within 7 calendar days of completion of the tests. The Engineer will review test documentation in accordance with the Submittal Review Process in Section 2.7.
4. Payment for all testing related to activities within this Section of the SP725 is included in the cost of Software Integration and Network Integration.

22.4.2 Factory Acceptance Test

FAT is not required for Systems Integration.

22.4.3 Bench Test Component

BTC shall be performed in the presence of the Engineer. The BTC shall demonstrate that any TDOT furnished equipment operates with Contractor furnished and installed software and network equipment. BTC shall include verification that the proposed equipment has no internal or external damage.

22.4.4 Bench Test System

BTS shall be performed in the presence of the Engineer. The Contractor shall use TDOT Regional TMC Test Environment servers during the BTS for Software and Network Integration to demonstrate that the

System Integration meets the requirements of this SP725 and is operable with the new and existing systems.

22.4.5 Stand Alone Site Test

SAT for Network Integration shall be performed in the presence of the Engineer and shall include the following tests and inspections on components included within the Network Integration pay item such as SFPs, fiber optic patch cords, and CAT 6 cables:

1. Verify all components have been installed per manufacturer requirements.
2. Verify all items have been attached properly (as per manufacturer recommendations and the Plans) to each other and within the Equipment Cabinet or Equipment Rack.
3. Verify the components have no internal or external damage.

SAT for Software Integration shall include oversight by the Engineer and shall include the following tests and inspections:

1. Software shall be installed in the TDOT ATMS Test Environment.
2. User Acceptance Testing (UAT) shall take place in the TDOT ATMS Test Environment for at least of 30 days to identify any software bugs or functionality issues.
3. If issues are identified, a follow-up UAT of at least 7 days shall be provided to verify the identified issues have been corrected.
4. Once the UAT has been approved, installation of the software in the TDOT ATMS Production Environment can be scheduled with the Change Advisory Board.

Final testing and verification of the Software Integration and Network Integration shall be performed as part of the Conditional Systems Acceptance Testing for the project.

22.5 Warranty

All materials specified in this section shall carry a minimum one-year manufacturer’s warranty from the date of Final Acceptance against any imperfections in workmanship or materials. Warranties shall cover complete replacement at no charge for the equipment. Warranties shall be transferred to TDOT upon Final Acceptance of the project as per the requirements in Section 2.6 of this specification.

22.6 Method of Measurement

22.6.1 Software Integration

Software Integration will be paid for on a lump sum basis wherein no measurement will be made. The bid price for Software Integration shall include all tasks that are needed to meet all specification requirements to integrate the ITS field devices into the ATMS software but are not included specifically in the cost of other items. This includes but is not limited to integration with the video distribution management system, device drivers as required by the proposed field devices, modifications to the ATMS software, integration between the various software packages, integration with the Hub UPS and security monitoring systems, integration with the building UPS monitoring systems, integration of all devices with the TDOT ATMS software, coordination with TDOT Regional TMC IT, Project Submittal documents, and other related software integration activities. Any additional application software, tools, and associated licenses that are not listed in items 22.2 but are needed to provide a complete and operational system as well as meet the requirements of this SP725 shall be considered incidental and shall be included in the cost of the most appropriate item.

The bid price for Software Integration shall include full compensation for all labor, tools, materials, equipment, software, hardware, and incidentals necessary to complete the work.

22.6.2 Network Integration

Network Integration will be paid for on a lump sum basis wherein no measurement will be made. The bid price for Network Integration shall include all tasks that are needed to meet all specification requirements to integrate the communications infrastructure into the TDOT TMC Network but are not included specifically in the cost of other items. This includes but is not limited to LAN configuration and integration, WAN configuration and integration, wireless network configuration and integration, cellular head end equipment configuration and integration, NMS configuration, firewall configuration, coordination with TDOT Regional TMC IT, Project Submittal documents, and other related integration activities. Network Integration shall also include hardware required to complete the network integration as identified on the Plans. Additional Layer 3 SFPs, fiber optic patch cords, and CAT 6 cables required to connect the project back to adjacent Hub Buildings, Hub Cabinets, or the Regional TMC as indicated on the Plans shall be incidental and not paid for separately. All cabling, hardware, accessories, labor, and materials not provided with TDOT furnished network equipment required to make the unit function as part of this project shall be considered incidental and not paid for separately.

The bid price for Network Integration shall include full compensation for all labor, tools, materials, equipment, software, hardware, and incidentals necessary to complete the work.

22.6.3 Wireless Ethernet Radio Software

Wireless Ethernet Radio Software is vendor software for configuration, testing, monitoring, and operations. The software shall be paid for under the Wireless Ethernet Radio and Antenna pay items.

22.6.4 CCTV System Software

For all active CCTV related devices controllable through any type of communications interface, the Contractor shall coordinate with the TDOT ATMS and video distribution software representatives to support direct communication with and control of devices by the TDOT ATMS software and video distribution system. Software development may be required to complete this integration. The effort required to accomplish this task shall be paid under the Software Integration pay item. The cost of acquiring, installing, and configuring the vendor software shall be paid under the CCTV Cameras System pay item.

22.6.5 DMS System Software

DMS Software is vendor software for configuration and testing only; therefore, there is no separate payment for this item. For DMS devices controllable through any type of communications interface, the Contractor shall coordinate with the TDOT ATMS software representatives to support direct communication with and control of devices by the TDOT ATMS software. Software development may be required to complete this integration. The effort required to accomplish this task shall be paid under the Software Integration pay item. The cost of acquiring, installing, and configuring the vendor software shall be paid under the Dynamic Message Sign pay item.

22.6.6 RDS System Software

RDS Software is vendor software for configuration and testing only; therefore, there is no separate payment for this item. For RDS devices controllable through any type of communications interface, the Contractor shall coordinate with the TDOT ATMS software representatives to support direct communication with and control of devices by the TDOT ATMS software. Software development may be required to complete this integration. The effort required to accomplish this task shall be paid under the Software Integration pay item. The cost of acquiring, installing, and configuring the vendor software shall be paid under the Radar Detection System pay item.

22.6.7 ESS System Software

ESS Software is vendor software for configuration and testing only; therefore, there is no separate payment for this item. For ESS devices controllable through any type of communications interface, the Contractor shall coordinate with the TDOT ATMS software representatives to support direct communication with and control of devices by the TDOT ATMS software. Software development may be required to complete this integration. The effort required to accomplish this task shall be paid under the Software Integration pay item. The cost of acquiring, installing, and configuring the vendor software shall be paid under the Environmental Sensor System pay item.

22.6.8 RSU System Software

RSU Software is vendor software for configuration and testing only; therefore, there is no separate payment for this item. For RSU devices controllable through any type of communications interface, the Contractor shall coordinate with the TDOT ATMS software representatives to support direct communication with and control of devices by the TDOT ATMS software. Software development may be required to complete this integration. The effort required to accomplish this task shall be paid under the Software Integration pay item. The cost of acquiring, installing, and configuring the vendor software shall be paid under the Roadside Unit pay item.

22.6.9 Flashing Beacon System Software

Flashing Beacon Software is vendor software for configuration and testing only; therefore, there is no separate payment for this item. For flashing beacon devices controllable through any type of communications interface, the Contractor shall coordinate with the TDOT ATMS software representatives to support direct communication with and control of devices by the TDOT ATMS software. Software development may be required to complete this integration. The effort required to accomplish this task shall be paid under the Software Integration pay item. The cost of acquiring, installing, and configuring the vendor software shall be paid under the Flashing Beacon Controller pay item.

22.6.10 OVDS System Software

OVDS Software is vendor software for configuration and testing only; therefore, there is no separate payment for this item. For OVDS devices controllable through any type of communications interface, the Contractor shall coordinate with the TDOT ATMS software representatives to support direct communication with and control of devices by the TDOT ATMS software. Software development may be required to complete this integration. The effort required to accomplish this task shall be paid under the Software Integration pay item. The cost of acquiring, installing, and configuring the vendor software shall be paid under the Overheight Vehicle Detection System pay item.

22.6.11 WIM System Software

WIM Software is vendor software for configuration, testing, and operations. For WIM devices controllable through any type of communications interface, the Contractor shall integrate with the MS2 Network to support direct communication. Software development may be required to complete this integration. The effort required to accomplish this task as well as the cost of acquiring, installing, and configuring the vendor software shall be paid under the Weigh in Motion pay item.

22.6.12 HAR System Software

HAR Software is vendor software for configuration and testing only; therefore, there is no separate payment for this item. For HAR devices controllable through any type of communications interface, the Contractor shall coordinate with the TDOT ATMS software representatives to support direct communication with and control of devices by the TDOT ATMS software. Software development may be required to complete this integration. The effort required to accomplish this task shall be paid under the Software Integration pay item. The cost of acquiring, installing, and configuring the vendor software shall be paid under the Highway Advisory Radio System pay item.

22.7 Payment

The contract unit price shall be full compensation for all work specified in this section.

Payment will be made under:

Item No.	Description	Unit
725-24.52	SOFTWARE INTEGRATION	LS
725-24.54	NETWORK INTEGRATION	LS

Integration items will be paid on a lump sum basis as follows:

1. 30% of the contract unit price upon successful completion of the Bench Test System as stated in Section 2.5.4 of this SP725.
2. Additional 60% of the contract unit price upon Conditional System Acceptance as stated in Section 2.5.6 of this SP725.
3. Final 10% of the contract unit price upon Final System Acceptance as stated in Section 2.5.9 of this SP725.

23 SPARE PARTS INVENTORY

23.1 Description

This Section specifies the requirements for furnishing and maintaining a Spare Parts Inventory.

23.2 Materials

The Contractor shall have available and maintain the listed quantity of spare parts detailed in APPENDIX C. Spares will be replenished as used, so that the quantities in working order are available at all times and will be delivered to TDOT at the conclusion of the Burn-In Period. Note that the items listed as Spares shall include all components and equipment included in the pay item specified for that particular item. All supporting, incidental, ancillary, and peripheral items necessary for a fully populated and complete installation shall also be maintained in the inventory. For example, conduit would also require couplers, pull tape, tone wire, blank duct plugs, cable duct plugs, etc. Prior to Conditional System Acceptance, the Contractor shall submit a full Spare Parts Inventory list including the incidental items in Microsoft Excel format to the Engineer. The Spare Parts Inventory shall include as a minimum:

- Manufacturer
- Model number
- Descriptive title
- Serial number
- Location
- Purchase date
- Date installed – when applicable
- Location of installation – when applicable
- Warranty expiration date – when applicable

All items in the Spare Parts Inventory measured by linear foot shall be single continuous unspliced lengths. If a portion of a length in inventory is used for repair, the remainder of the original length shall remain TDOT property in the inventory and the Contractor shall procure a replacement continuous length of the minimum above.

All items in the Spare Parts Inventory must match the approved products installed in the field under the project.

All items in the Spare Parts Inventory shall have bar code labels attached using the existing bar code system equipment supplied by TDOT in accordance with the requirements in Section 24.7.

23.3 Storage

The Contractor shall store and maintain all Spare Parts in a secure environment that aims to avoid theft or damage to the Spare Parts. The Contractor is fully responsible for the Spare Parts and shall insure the inventory of spares against all hazards or loss and name TDOT as the beneficiary in the case of loss. A copy of the insurance documents must be provided to TDOT. TDOT has the right to audit the inventory at any time by providing the Contractor with a five-day notice. When items from the Spare Parts inventory are used, the Contractor shall replenish the inventory within 30 calendar days of use. Contract payments will be held if this is not done within 30 calendar days.

Maintenance of the Spare Parts shall be performed while in storage in accordance with the Maintenance requirements in Section 24.

23.4 Testing Requirements

All Spare Parts shall include BTC as required for that particular item within this SP725.

23.5 Warranties

All Spare Parts shall include the same warranty required in the pay item specified for that particular item within this SP725.

23.6 Method of Measurement

23.6.1 Spare Parts

Spare Parts will be paid at the lump sum bid price for Spare Parts. The bid price shall include the furnishing and testing of the specified parts. Any installation costs are covered in Section 24. The bid price shall be full compensation for all labor, tools, materials equipment, and incidentals to furnish and test the Spare Parts. The cost of storing and maintaining the inventory of Spare Parts and equipment should also be included in the lump sum cost of the Spare Parts.

Prior to the Conditional System Acceptance of the project, the Contractor shall submit to TDOT an itemized breakdown of the lump sum cost indicating the amount for each item in the Spare Parts inventory. Should changes during construction require a change in the number or type of Spare Parts needed, this breakdown of the initial bid price will be used to determine the appropriate change in the lump sum bid price. As Spare Parts are used, replacements to the inventory will be at the Contractor's expenses unless the additional equipment is needed due to an act of God or another special request from TDOT. In these cases, the replacements will be reimbursed at invoice price including tax plus 15%.

Compensation for materials requested by TDOT, in addition to the Spare Parts listed, will also be at the rate of actual invoice price including tax plus 15% for procurement expenses. Any extraordinary costs to the Contractor will not be paid unless approved in advance by TDOT.

23.7 Payment

Payment will be made under:

Item No.	Description	Unit
725-24.31	SPARE PARTS	LS

Spare Parts will be paid at the lump sum price upon complete delivery to TDOT.

24 SYSTEM MAINTENANCE REQUIREMENTS

24.1 Description

The purpose of this Section is to describe the required maintenance activities that the Contractor must provide during the Burn-In Period in accordance with the timeframe detailed in Section 2.5.7. The Contractor shall provide these maintenance activities for all equipment installed as part of this Contract. The maintenance requirements described in the Section shall include all necessary labor, materials, equipment, tools, transportation, supplies, and incidentals required to complete the work. The maintenance period is divided into Preventive Maintenance and Unscheduled Maintenance. The duration of the maintenance period may be extended at the discretion of TDOT via exercising of the Annual Maintenance options.

24.1.1 Definitions

Preventive Maintenance shall begin at the completion of CSAT. Preventive Maintenance for the System consists of regularly scheduled activities including but not limited to electrical testing, replacement of necessary parts, cleaning, and lubrication. Each device shall have at least one Preventive Maintenance cycle completed during the Burn-In Period. The Contractor shall perform all Preventive Maintenance activities in accordance with the Preventive Maintenance Procedures detailed in the Project's Regional Maintenance Contract SP in APPENDIX B. This shall include the periodic inspection and cleaning of the equipment and updating the resulting documentation of this inspection.

Repair Maintenance consists of responding to the various failures reported concerning the various field components of the system. Repair Maintenance will include the reactive, day-to-day repair, replacements, and diagnostic work necessary to keep the System fully operational. A Repair Maintenance response is defined as the Contractor receiving notice from TDOT of a failure and the Contractor responding with a field assessment of the problem, preparation of a plan, and schedule for repair and submission of that report to TDOT. The Response Report shall be submitted via email.

24.1.2 General Requirements

The Contractor shall manage all ITS assets within the project limits and will perform work that produces end results in accordance with TDOT Standard Specifications including all Supplemental Specifications and Special Provisions. These include but are not limited to:

1. TDOT Standard Specifications (Latest Adopted Edition).
2. Manual on Uniform Traffic Control Devices (Latest Adopted Edition).
3. TDOT Standard Drawings (Latest Adopted Edition).

The Contractor shall take proper health and safety measures to ensure safety for the traveling public, TDOT employees, Contractor employees, Subcontractor employees, and any other personnel within the project limits.

Maintenance of traffic during system maintenance is solely the responsibility of the Contractor. Under no circumstances will maintenance of traffic be an additional pay item.

Unless specified otherwise on the Plans, TDOT will pay all monthly electric and any required leased line communication bills. Responsibility for maintaining power to devices will be as follows:

1. From the utility to the demarcation point (or end of overhead secondary conductors) – Local Utility Companies.
2. From the demarcation point (or end of overhead secondary conductors) to the control cabinet or breaker and from the control cabinet or breaker to and within the devices – Contractor.

The Contractor shall maintain an electronic maintenance log which shall detail all maintenance action items and the dispositions of the items contained in the log. The log will be kept on the maintenance computer within the TDOT Regional TMC. Prior to the beginning of the Burn-In Period, TDOT will provide the Contractor an empty Microsoft Access or Excel database file that contains the required formatting for the database. In Regions where an ITS asset management software is being utilized to track maintenance, the Contractor shall provide device information to the Engineer in a pre-formatted Excel spreadsheet. The spreadsheet will then be imported into the ITS asset management software by a TDOT System Administrator via coordination with TDOT Regional TMC IT. Once imported, the Contractor shall utilize the ITS asset management software to track system maintenance during the remainder of construction and burn-in.

All overhead work over impacted traffic lanes shall include proper lane closures in accordance with MUTCD, except when the Contractor is working inside a DMS enclosure. TDOT must approve all lane closures in advance. Requests for lane closures shall be submitted at least 7 calendar days in advance of work for all preventive maintenance activities.

The Contractor is required to provide all operational crews with working cell phones at all times. In addition, the Contractor shall provide a single phone contact for the Contractor's supervisor. The Contractor shall provide to TDOT and keep current all cell phone contact numbers. It is essential that the operating crews can contact the TDOT Regional TMC to ensure correct operation of equipment and verify equipment status in the control center.

TDOT will appoint a representative that will act as contract administrator with the responsibility of ensuring that work is done to a specified standard defined in this SP725. This representative will be responsible for verifying that the Contractor satisfactorily completes the work. The TDOT representative will be responsible for the overall monitoring of the Contractor's work.

24.1.3 Form of Contract

Under the terms of this contract there are several requirements:

1. The first requirement will be for performing the Preventive Maintenance for the System. Preventive Maintenance consists of regularly scheduled activities including but not limited to communications and electrical testing, replacement of necessary parts, cleaning, and lubrication. The Contractor shall perform all Preventive Maintenance activities in accordance with the Preventive Maintenance Procedures detailed in the Project's Regional Maintenance Contract SP in APPENDIX B. This shall include the periodic inspection and cleaning of the equipment and the resulting documentation of this inspection.
2. The second requirement is for performing Repair Maintenance. Repair Maintenance consists of responding to the various failures reported concerning the various field components of the system. Repair Maintenance will include the reactive, day-to-day maintenance, replacements, and diagnostic work necessary to keep the System operational. The Contractor must provide all necessary labor, tools, equipment, and engineering for the repair maintenance work. A Response Report containing the items identified must be submitted to TDOT within the time frames noted

below. Notice of a failure will be communicated to the Contractor via a phone call and a follow up email or fax.

The Repair Maintenance during the Burn-In Period shall be included in the cost bid for the Burn-In Period. With the exception of acts of God as described below, no separate payment will be made for keeping the system operational during the Burn-In Period. Repair Maintenance beyond the Burn-In Period will be considered “Unscheduled Maintenance.”

Work items generated by failures caused by acts of God, other construction activities, or other special requests from TDOT shall be considered Unscheduled Maintenance. The Contractor must provide the required number of personnel and all necessary tools, equipment, and engineering for the unscheduled maintenance work. All labor and material items described above shall be included in hourly unit price as described in the payment section.

If a failure involves a DMS Sign, multiple cameras, or poses a safety threat to the motoring public as determined by TDOT, the Contractor shall respond on-site within 4 hours of notice of a failure by TDOT. This four-hour response requirement applies 24 hours a day, 7 days a week.

For other failures that do not include a DMS sign, multiple cameras, or do not pose a safety threat, the Contractor shall respond on-site within 8 hours of notice of a failure by TDOT. This eight-hour response requirement is limited to normal business hours (8:00 am to 5:00 pm) Monday thru Friday.

The Contractor and TDOT will work together to develop a tracking system to document and track all Unscheduled Maintenance Labor. Once a repair task is complete, the Contractor shall submit final paperwork including a follow-up maintenance response report within 3 calendar days. Failure to submit this paperwork within the specified time is subject to non-payment. If ITS asset management software is used in the TDOT Region that the project is located within, the ITS asset management software shall be used as the tracking system.

3. In addition to the items of work described above, there may be special circumstances where TDOT requests work that cannot be covered by one of the pay items included in this contract. (Example situations may include pole knock downs, re-location of facilities to accommodate other construction activities, minor system modifications or expansions, etc.). If and when those situations occur, the Contractor may be asked to submit a separate cost proposal and schedule to TDOT for consideration and approval. Once approved the Contractor shall start the work within 10 calendar days of approval and execute the work with due diligence according to the schedule agreed upon. It will be TDOT’s sole decision to determine whether or not a specific item of work can be completed within the existing pay items.

24.2 Schedule Of Work

TDOT will permit access to facilities as required by the Contractor for the purposes of maintenance. The Contractor shall provide the Maintenance Activities throughout the entire contract period.

TDOT reserves the right to either cancel this Maintenance Agreement in part, or in its entirety without liability to TDOT on 30 calendar days written notification to the Contractor or at the end of an option period. TDOT shall direct that the work under this Maintenance Agreement be performed by the Contractor in one-year increments with each yearly increment being exercised at the sole option of TDOT. Failure of TDOT to exercise an option will terminate the Contract. TDOT shall have no obligation in excess of the amount contracted for, or for services rendered by the Contractor, which are not performed within the specified period.

24.2.1 Monthly Status Meetings

Each month the Contractor shall hold a status meeting with TDOT. At these meetings, the Contractor shall discuss the previous month's repairs, anticipated work for the next month, spare purchases for the month, and other operational problems that may arise. The Contractor is responsible for taking and distributing the minutes of these meetings. These minutes must be transmitted to TDOT within 7 calendar days for approval by TDOT. Progress payments for Annual Maintenance may be withheld until meeting minutes are submitted to TDOT. Note that on some occasions more frequent meetings may be warranted for special conditions. No additional costs will be allowed for these additional meetings.

24.3 Equipment To Be Maintained

All equipment installed by the Contractor as part of this project shall be subject to the Preventive, Repair, and Unscheduled Maintenance procedures through the Burn-In Period until Final Acceptance is given. Following Final System Acceptance, the Contractor may enter into an Annual Maintenance contract that will be renewable in one-year increments at TDOT's discretion. The Contractor would continue to be responsible for Preventive, Repair and Unscheduled Maintenance during the Annual Maintenance Period for all subsystems listed above.

24.4 Maintenance Procedures

For each major equipment type there are defined minimum Preventive Maintenance procedures. These minimum procedures are defined in APPENDIX B. Each equipment's preventive maintenance procedure has a fixed period between procedures. These are defined in APPENDIX B. It is also the Contractor's responsibility to obtain and submit to TDOT the Preventive Maintenance procedures recommended by the equipment manufacturers including but not limited to all requirements to meet warranty standards.

Maintenance procedures performed under Repair Maintenance shall use materials and installation procedures as specified in this SP725 for new construction. At the sole discretion of the Engineer, certain repairs that are not possible to complete to the same standard as the new construction may be made utilizing materials and procedures as directed by the Engineer.

Should the Contractor perform an Unscheduled Maintenance action and within 5 calendar days the same fault is reported on the same piece of equipment, it is the Contractor's responsibility to make the second and any subsequent same-fault repairs at no cost to TDOT. Should a particular device persist in its failures, upon TDOT's instruction, such device shall be replaced and paid for by TDOT under the Unscheduled Maintenance procedures.

Upon completion of any maintenance activity, the work shall be subject to a random inspection by TDOT. Work that is determined to be unacceptable shall be re-performed by the Contractor at the Contractor's expense.

For damage caused by acts of God, other Contractors, or TDOT personnel, the Contractor is responsible for photographing all damaged structures and equipment; obtaining crash reports and/or driver information; and for submitting this information to TDOT.

24.5 Record Keeping Procedures

The Contractor shall use an existing database that will be provided by TDOT to the Contractor to track all Preventive, Repair, and Unscheduled Maintenance activities. If a maintenance tracking software is used in the TDOT Region that the project is located within, the maintenance tracking software shall be used as the tracking system. The required format for each input will be provided to the Contractor by TDOT prior to Conditional System Acceptance. The Contractor shall prepare a separate database to track the inventory of current spares. The database files shall be updated and emailed to TDOT weekly beginning prior to Conditional System Acceptance. If a maintenance tracking software is being used to track maintenance in the TDOT Region that the project is located within, sending the maintenance tracking software database will not be required as the software is cloud-based, providing access to all parties at any time. This email shall also include a summary of the next week's planned maintenance activities.

The records for both Preventive Maintenance and an Unscheduled Maintenance Response Report on the database shall at a minimum include the following information. Additional information may also be required as requested by TDOT:

1. Date and time of failure report or date of unscheduled maintenance
2. Person or source of the report
3. Location of device
4. Description of failure or symptom
5. Name of person responding
6. Arrival time at location of reported failure
7. Weather and condition of the site
8. Actions taken
9. Schedule of initiating corrective work and estimated completion of work
10. Date and time of completion of work
11. Spare part details
12. Any consequential events including but not limited to failure to operate or secondary failure

The Contractor shall maintain accurate and complete records of all work activities, status reports, meeting notes, cost proposals, invoices, inventory records, etc. The project As-built documentation, including the System Equipment Inventory, shall be updated if any information contained therein is changed due to scheduled or unscheduled maintenance activity. As-built documentation shall include but not be limited to modifying cabinet drawings, wiring diagrams, device layouts, conduit routing and location, fiber optic splice and termination details, and all other plan details. As-built documentation during maintenance shall be in accordance with the standards and requirements in this SP725. All project records will be the property of TDOT and shall be returned to TDOT prior to final payment of the Contract.

24.6 Equipment Control

The Contractor shall maintain a sufficient inventory of spares to ensure the repair response time specified in APPENDIX B. The minimum amount of required Spare Parts by equipment type is also defined in APPENDIX C. These spares will be purchased by the Contractor and owned by TDOT in accordance with the requirements in Section 23. As equipment is used from the Spare Parts inventory during Burn-In and Device Warranty Period, the Contractor shall replace at their own expense.

However, if the need to use spare parts equipment is due to acts of God, other special requests by TDOT, or repairs beyond the Device Warranty Period during the Annual Maintenance Period, the Contractor may invoice TDOT for replacement spares added back to the inventory. However, the cost of the replacement spares shall be submitted to TDOT for approval prior to ordering. A 15% markup will be allowed on direct material costs of the replacement spares needed due to acts of God or other special requests by TDOT. Shipping, insurance, and purchase costs should be paid directly by the Contractor and billed to TDOT. TDOT must give prior written approval for each monthly order made by the Contractor.

In addition to maintaining the Spare Parts inventory, the Contractor shall also ensure the availability and access to all vehicular equipment (trucks, bucket trucks, backhoes, front end loaders, and diagnostic equipment, etc.) and engineering/technical equipment needed to respond to and repair equipment failures and malfunctions. All equipment that is typically needed for an ITS maintenance contract shall be available and on-site within the required response time frame requirement outlined. If typical maintenance equipment is not available within this timeframe, the Contractor shall be considered to have missed the required response requirement. If specialty equipment is needed that is not typical, the Contractor shall notify TDOT of this need and TDOT will determine if an exception can be made in that situation.

24.7 Bar Code System

TDOT has an existing bar code system. The Contractor shall ensure that all new and replacement equipment has bar code labels attached using this existing bar code system equipment supplied by TDOT. The purpose of the bar code system is to track the equipment inventory and to be able to determine the various maintenance activities that have occurred with that piece of equipment. The Contractor shall initially install bar code labels on all equipment prior to installation during the construction phase. The cost of installing the initial bar code labels shall be included in the cost of other items. Data corresponding to each equipment item must be recorded in the barcode system at TDOT. The implementation of the bar code system must be completed by the Contractor prior to the installation of any electronic equipment. The Contractor shall follow TDOT's existing bar code system structure but shall provide the bar code labels needed for the equipment.

24.8 Staffing / Management Plan

The Contractor must provide a minimum of 1 technician for the duration of maintenance related contract periods to ensure satisfactory completion of all maintenance and repair activities. Before the start of Burn-In Period, the Contractor shall submit a Staffing/Management Plan defining the key staff for ITS Maintenance and the Project Management Team for approval by the Engineer. Resumes for the key staff must be provided. Changes to the key staff and Project Management Team shall require approval of TDOT or TDOT's authorized designee prior to use of the staff on the project. TDOT shall have the right to reject any proposed replacement staff and request another replacement.

The staffing/management plan should be:

1. Proposed plan for communication and coordination among the Team and key staff.
2. Qualifications of all personnel. All staff must be qualified for the various types of devices and equipment they will be working on. Qualifications must include at least 1 year of installing and/or maintaining the types of ITS devices in this contract, or equivalent experience as approved by the Engineer. If qualified personnel are not available on Contractor's staff, a factory trained manufacturer representative must perform the work.

24.9 Staffing Qualifications

All staffing associated with this project must be qualified for the work that is to be performed. Specifically, technicians that are responsible for the electronic components, must have a minimum of a two-year associate degree plus 2 years relevant work experience or equivalent. An equivalent to this qualification would be more than 3 years of relevant experience. Any proposed equivalent must be approved by TDOT. The Contractor shall furnish staff that is familiar with the equipment that is installed in this project.

24.10 Safety Plan

The Contractor is required to follow all applicable safety laws, regulations, and TDOT standard safety procedures. This includes compliance to the requirements of the MUTCD, OSHA, and others as applicable. Appropriate safety attire for personnel in the field, clear markings, and functional yellow lights on vehicles must be part of the safety plan.

24.11 Contractor's Responsibility for Utility, Property, and Service

At point where the Contractor's operations are adjacent to the properties of any utility, including railroads, and damage to which might result in considerable expense, loss, or inconvenience, work shall not commence until arrangements necessary for the protection thereof have been completed.

The Contractor shall cooperate with owners of utility lines so that removal and adjustment operations may progress in a reasonable manner, duplication of adjustment work may be reduced to a minimum, and services rendered by those parties will not be unnecessarily interrupted.

Should the Contractor cause a cut in any communications media it is the Contractor's responsibility to repair that cut within 1 hour of the cut occurring.

If any utility service is interrupted as a result of accidental breakage or of being exposed or unsupported, the Contractor shall promptly notify the proper authority and shall cooperate with the authority in the restoration of service. If utility service is interrupted, repair work shall be continuous until service is restored. No work shall be undertaken around fire hydrants until the local fire authority has approved provisions for continued service.

24.12 Performance Of the Contractor

Throughout this Contract, TDOT will conduct a review of the various works performed by the Contractor. These reviews shall be to determine the compliance of the Contractor's operations with the maintenance requirements, the terms of the Contract, and the policies and procedures of TDOT. The Contractor shall fully cooperate with these reviews. If deficiencies are found, TDOT shall inform the Contractor of this in writing. The Contractor shall take immediate remedial action to cure any deficiencies. No additional compensation will be due to the Contractor associated with such remedial actions. Payments may be withheld, or the Burn-In Period may be extended, if the Contractor fails to take immediate remedial action to cure any deficiencies.

The Contractor is required to maintain the devices uniformly and consistently throughout the Burn-In and Annual Maintenance Periods, meeting both TDOT and, as appropriate, the manufacturer's performance specifications, as well as respond to failures identified by TDOT. Continued poor performance of work or failure to perform shall cause the Contractor to be declared in default of the Contract. Failure to meet the maintenance requirements specified in this contract shall result in a written notice from TDOT. This information shall inform the Contractor of non-compliance, as well as the withholding of progress payments that will occur, or an extension of the Burn-In Period if non-compliance continues. Progress payments will be withheld under the following conditions.

1. Regarding Preventive Maintenance: If any devices are found to be behind schedule for the regularly scheduled maintenance procedures, all progress payments will be withheld until all devices are verified back on schedule.
2. Regarding Repair Maintenance: All repair maintenance requests should be responded to within the timeframes outlined. A response is defined as being on site and beginning to diagnose the problem. When the response times exceed the requirements on more than 2 requests during any given month, the current monthly progress payment will be withheld until the following month. Items where the failure to respond is beyond the control of the Contractor, will not be included in this calculation.
3. Regarding Maintenance Database: If database is not updated every Tuesday and is more than 1 week behind schedule, all progress payment will be withheld until database is current. If TEAMS is being used as the maintenance database, it shall be updated as maintenance is performed to timely track acknowledgement of maintenance tickets and completion of maintenance activities.

It is not the intent of TDOT to unfairly penalize the Contractor for events beyond their control such as acts of God, vehicle hits, severe weather conditions, major power failure, etc. Failure to perform either repair maintenance or preventive maintenance during such periods will not be used to penalize the Contractor, provided the Contactor returns to standard operations after such periods have ended.

The Contractor must ensure that all warranties remain valid. To achieve this, the Contractor shall perform all the preventive work specified by the manufacturer within the periods specified by the manufacturer for all equipment. If these tasks are covered by the standard preventive maintenance, then both conditions apply.

The Contractor shall provide vehicular equipment including but not limited to bucket trucks, inspection trucks, field engineering equipment, tools, materials, cellular phones, and other equipment necessary to perform the work. An approved vendor as per the equipment specification requirements shall calibrate all electronic maintenance and measurement equipment.

The Contractor shall provide conveniently located secure premises to store all test equipment. The Contractor shall provide workbench facilities to enable diagnostic testing and remedial work.

24.13 Method of Measurement

24.13.1 Preventive Maintenance for System

Preventive Maintenance shall be measured on a lump sum basis. Preventive Maintenance shall include the labor, overhead, bucket trucks, inspection trucks, field engineering equipment, tools, materials, cellular phones, and other equipment necessary to perform the work in accordance with the provisions of the Contract. Each device shall have at least one Preventive Maintenance cycle completed during Burn-In following the Preventive Maintenance Procedures detailed in the Project's Regional Maintenance Contract SP in APPENDIX B. Additional cycles may be required per specific device requirements in the Project's Regional Maintenance Contract SP in APPENDIX B.

24.13.2 Repair Maintenance During Burn-In Period

Repair Maintenance shall not be measured separately and shall be included in the bid price for the Burn-In Period. This shall include but not be limited to all labor, overhead, bucket trucks, inspection trucks, field engineering equipment, tools, materials, cellular phones, and other equipment necessary to perform the work in accordance with the provisions of the Contract.

For work items resulting from acts of God or other special requests from TDOT, the Contractor shall be compensated their hourly labor costs for such operations at the hourly rate bid for Unscheduled Maintenance Labor. This hourly rate includes but is not limited to all labor, overhead, bucket trucks, inspection trucks, field engineering equipment, tools, materials, cellular phones, and other equipment necessary to perform the work. Hours shall be based on actual time on task plus a maximum of 2 hours travel time, or actual travel time if less than 2 hours. No further labor costs will be allowed. The bid price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work. The bid price per hour includes all labor charges regardless of the number of people at the site.

24.13.3 Unscheduled Maintenance Labor

During Burn-In, the Contractor shall be compensated their hourly labor costs for such operations at the hourly rate bid for Unscheduled Maintenance Labor only for work items resulting from acts of God or other special requests from TDOT. This hourly rate includes but is not limited to all labor, overhead, bucket trucks, inspection trucks, field engineering equipment, tools, materials, cellular phones, and other equipment necessary to perform the work. Hours shall be based on actual time on task plus a maximum of 2 hours travel time, or actual travel time if less than 2 hours. No further labor costs will be allowed. The bid price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work. The bid price per hour includes all labor charges regardless of the number of people at the site.

24.14 Payment

Payment will be made under:

Item No.	Description	Unit
725-24.21	PREVENTIVE MAINTENANCE FOR SYSTEM	LS
725-24.25	UNSCHEDULED MAINTENANCE LABOR	HOUR

System Maintenance Requirements will be paid per each as follows:

1. Preventive Maintenance for System (for quarters authorized by TDOT) will be paid on a lump sum basis of 1/3rd of the contract unit price upon successful completion of a month of the Preventive Maintenance activity.
2. Unscheduled Maintenance Labor (where requested by TDOT) will be paid at the hourly rate upon completion and acceptance of a repair or modification.

25 PROJECT ACCEPTANCE

25.1 Description

This section specifies the minimum requirements for acceptance procedures and tasks that must be completed prior to project acceptance. These items include the project testing program, Burn-In Period, training, warranties, project submittals, system documentation, and as-built documentation.

25.2 Task Requirements

25.2.1 Project Testing Program

1. The project testing plan requirements and acceptance procedures are outlined in Section 2 of this SP725. Additional specific testing requirements are detailed in the individual SP725 sections.

25.2.2 Burn-In Period

1. The Burn-In Period requirements are outlined in Sections 2.5.7 and 24.13.2 of this SP725.

25.2.3 Training

1. The training requirements are outlined in Section 2.4 of this SP725. Additional specific training requirements are detailed in the individual SP725 sections.

25.2.4 Warranties

1. The warranties requirements are outlined in Section 2.6 of this SP725. Additional specific warranty requirements are detailed in the individual SP725 sections.

25.2.5 Project Submittal Program

1. The project submittal program requirements are outlined in Section 2.7 of this SP725. Additional specific submittal requirements are detailed in the individual SP725 sections.

25.2.6 System Documentation

1. The system documentation requirements are outlined in Section 2.8 of this SP725. Additional specific system documentation is detailed in the individual SP725 sections.

25.2.7 As-Built Documentation

1. Prior to the Conditional System Acceptance Test, all TDOT approved changes shall be incorporated by the Contractor into all submitted documents and drawings, including the project Plans. An electronic copy of the updated drawings shall be submitted to the Engineer to serve as the final as-built configuration drawings. In the project Plans, each drawing shall be identified under the sheet number block, with the words "AS-BUILT," the date and the approval. The as-built drawings shall consist of a neatly marked-up set of plans using red linework and text in a PDF document. The drawing shall indicate the as-built location of all equipment including poles, cabinets, conduit, pull boxes, gates, etc., as well as deviations to details such as fiber optic splicing and terminations. As part of the as-built drawings, the Contractor shall use a hand-held GPS (1ft accuracy or better) unit to determine the GPS coordinates (in Decimal Degrees with 6 decimal places and a format approved by the Engineer) for all standalone devices, structures, and outside plant infrastructure including field devices, poles and sign structures, pull boxes, equipment cabinets, signs, etc. These coordinates shall be summarized in a GPS Coordinates Database in a Microsoft Excel table that indicates the following minimum information:

a. Device type

b. Device name and number (where applicable)

c. Roadway name

d. Roadway direction

e. Mile Marker to the nearest one tenth mile marker

f. Sheet number in Plans

g. GPS coordinates in Decimal Degrees with 6 decimal places

h. Demarcation information that includes what devices are fed from that location along with the utility provider and contact information

i. Provide GPS location and depth data for all conduit routings and bore pits. The data shall be provided at 20’ increments along the conduit path and at locations where the conduit line changes direction. The GPS data shall be accurate to within 6’ horizontal and 3’ vertical.

This information shall also be included in the equipment inventory and maintenance database described in this SP725.

2. The Contractor shall submit a PDF file (with markups created using digital entries) of each as-built sheet in a PDF format.

3. The Contractor shall also submit Shapefiles of the as-built system as documented in the GPS Coordinates Database as well as the fiber conduit, electrical conduit, and wireless paths. A separate Shapefile shall be submitted for each of the system components (each ITS device type, each pull box type, fiber conduit, electrical conduit, wireless paths, etc.) as well as a master file with all as-built information. All Shapefiles shall be in a format that can be referenced into MicroStation/ORD.

4. As-built documentation shall be prepared and submitted in the following 2 stages:

   a. Preliminary as-built documentation shall include all materials, devices, and infrastructure included in this contract. Preliminary as-built documentation shall be submitted and approved prior to requesting the Conditional System Acceptance Test.

   b. Final as-built documentation shall be an update reflecting any changes that occurred during the Burn-In Period. Final as-built documentation shall also include installation data forms provided by TDOT to the Contractor throughout the project that shall be completed by the Contractor. These forms require various information such as cable length IDs into and out of each pull box, site specific information, etc. Final as-built documentation shall be submitted and approved as part of the Final Systems Acceptance Testing and Inspection.

5. As part of the as-built drawings, the Contractor shall also submit a complete System Equipment Inventory of all equipment utilized on the project. The Contractor shall create and maintain the System Equipment Inventory as a Microsoft Excel database. The System Equipment Inventory shall include GPS coordinate information from the as-built documentation. As an alternate, the GPS Coordinates Database and the System Equipment Inventory may be combined in 1 relational database provided that all required data components are maintained.

As a minimum, the System Equipment Inventory shall include the following information about each equipment item:

a. Device/equipment item name

b. Pay item number

c. Location (roadway name, direction, nearest mile marker, and device ID)

d. Sheet number in Plans

e. GPS coordinates in Decimal Degrees with 6 decimal places

f. Make, model, and manufacturer part number

g. Serial number

h. Barcode equipment ID

i. Barcode location ID

j. Revision ID

k. Firmware ID

l. Purchase date

m. Installation date

n. Manufacturer contact information

o. Expiration date of manufacturer's warranty

6. The Contractor shall provide project submittals for as-built documentation in accordance with the requirements in Section 2.7 of this SP725. The project submittals for as-built documentation shall include but not be limited to the following:

   a. GPS Coordinates Database (template shall be submitted for approval)

   b. System Equipment Inventory (template shall be submitted for approval)

7. Beginning with the first activities of field construction, all as-built documentation including but not limited to updated drawings, completed installation data forms, GPS Coordinates Database, and System Equipment Inventory, shall be kept up to date on a weekly basis and shall be made available for review by the Engineer upon request.

25.3 Testing Requirements

1. General Requirements

   a. The Contractor shall conduct a project testing program for all materials specified in this section as required in Section 2.5 of this SP725. The project testing program for DMS shall include but not be limited to the additional specific requirements in this Subsection.

   b. All test results shall confirm physical and performance compliance with this SP725.

2. Bench Test Component (BTC)

a. The Contractor shall perform BTC on all materials specified in this section as they arrive from the factory. The goal of the BTC is to verify that the materials were not damaged during shipping. The BTC shall test or inspect the following components:

    i. External or internal visible damage.

    ii. Verify that all components function as intended, including running diagnostic tests as applicable.

    iii. Verify structural and other components have no damage and all loose parts are secured properly.

3. Bench Test System (BTS)

    a. The Contractor shall perform BTS on all materials specified in this section to verify that the materials are compatible and operationally interoperable with the communication equipment, TDOT ATMS software, and existing equipment. The Contractor shall refer to Section 2 of this SP725 for additional BTS requirements.

4. Stand Alone Test (SAT)

    a. The Contractor shall perform SAT on all materials specified in this section as they arrive from the factory. The goal of the SAT is to verify that the materials have been properly installed and commissioned according to the manufacturer requirements. The SAT shall include at minimum the following tests and inspections:

        i. Verify all components have been installed per manufacturer requirements.

        ii. Verify all items have been attached properly (as per recommendations and the Plans) to each other and any applicable structures.

        iii. Verify that grounding has been installed as required, power and communications have been connected as required, and installation follows NEC and other applicable codes/standards.

        iv. Verify that no components have internal or external damage.

        v. Verify that all components operate as intended and per manufacturer's specifications.

        vi. Witness operation of all electronic components, including fans, lights, and other accessories as applicable.

25.4 Warranty

All materials specified in this section (individually and as a system) shall carry a one-year manufacturer's warranty from the date of final acceptance against any imperfections in workmanship or materials. Devices shall carry a three-year manufacturer's warranty at minimum; such warranty shall be transferred to TDOT upon final acceptance of the project as per the requirements in Section 2.6 of this specification.

25.5 Method of Measurement

25.5.1 Burn-In Period

The Burn-In Period item shall be a lump sum item and shall include all labor, materials, tools, equipment, and engineering necessary to maintain the system as specified in Section 2.5.7. The Burn-In Period item also includes all labor, materials, tools, equipment, and engineering necessary for all maintenance work as described in accordance with this SP725. The bid price for the Burn-In Period shall also include the labor and bar code labels for the bar code system described in Section 24.7. The Burn-In Period pay item is the only payment that will be made during the Burn-In Period with the exception of items described below.

25.5.2 As-Built Plans

As-Built Plans shall be a lump sum item and shall include all labor, equipment, materials, production and reproduction, and miscellaneous items needed to produce the as-built documentation as specified.

25.5.3 Training

The Training item shall be paid on an hourly basis and shall include all labor, equipment, materials, travel, facilities, production and reproduction, and miscellaneous items needed to conduct the training as specified.

25.5.4 Project Testing Program

Project testing shall be included in the cost of other pay items and will not be measured separately for payment, except for Burn-In Period as specified above.

25.5.5 Warranties

Warranties shall be included in the cost of other pay items and will not be measured separately for payment.

25.5.6 Project Submittal Program

Project submittals shall be included in the cost of other pay items and will not be measured separately for payment.

25.5.7 System Documentation

System documentation shall be included in the cost of other pay items and will not be measured separately for payment.

25.6 Payment

The contract unit price shall be full compensation for all work specified in this section.

Payment will be made under:

Item No.	Description	Unit
725-24.41	BURN-IN PERIOD	LS
725-24.55	AS-BUILT PLANS	LS
725-24.62	TRAINING	HOUR

Project Acceptance will be paid per each as follows:

1. As-built documentation will be paid on a lump sum basis as follows:

a. 90% of the contract unit price for approved as-built documentation prior to Conditional System Acceptance.

b. Final 10% of the contract unit price upon Final System Acceptance.

2. Training will be paid on an hourly basis as follows:

a. 100% of the contract unit price upon completion of required training.

3. Burn-In Period will be paid on a lump sum basis as follows:

a. 50% of the contract unit price upon successful completion of 90 calendar days of the Burn-In Period.

b. Final 50% of the contract unit price upon Final System Acceptance.

APPENDIX A   ABBREVIATIONS AND ACRONYMS

°C – Centigrade

°F – Fahrenheit

3GPP – 3G Peer to Peer

AAMA – American Architectural Manufacturers Association

AASHTO – American Association of State Highway and Transportation Officials

ABS – Acrylonitrile Butadiene Styrene Plastic Polymer

AC – Alternating Current

ACCY – Accessory (power)

ACI – American Concrete Institute

ACL – Access Control List

ADA – Americans with Disabilities Act

ADSI – Active Directory Service Interface

AES – Advanced Encryption Standard

AGC – Automatic Gain Control

AHRI – Air Conditioning, Heating & Refrigeration Institute

ALTOS – Manufacturer Product Reference

AM – Amplitude Modulation

ANSI – American National Standards Institute

AP – Application Profile

API – American Petroleum Institute

ARP – Address Resolution Protocol

ASCE – American Society of Civil Engineers

ASCII – American Standard Code for Information Interchange

ASHRAE – American Society of Heating, Refrigeration and Air Conditioning Engineers

ASN – Abstract Syntax Notation

ASN.1 – Abstract Syntax Notation – 1

ASSY – Assemblies

ASTM – American Society for Testing and Materials

ATMS – Advanced Traffic Management System

ATS – Automatic Transfer Switch

ATSC – Advanced Television Systems Committee

ATT – Communications Company

AV – Autonomous Vehicles

AVB – AV Bridging

AWG – American Wire Gauge

AWS – American Welding Association

BER – Bit Error Rate

BHMA – Builders Hardware Manufacturers Association

BICSI – Building Industry Consulting Service International

BIL – Breakdown Insulation Level

BNC – Binary Network Connector

BS – British Standard Institutions

BSC – Bare Solid Copper

BSM – Basic Safety Message

BSU – Base Station Unit

BTC – Bench Test Component

BTS – Bench Test System

CA – Manufacturer Product Reference

CAD – Computer Aided Design

CAN – Construction Advisory Notice

CAT – Community Access Television

CATV – Community Access Television

CBR – Constant Bit Rate

CCITT – International Telegraph and Telephone Consultative Committee, now being referred to as **ITU**

CCNA – Cisco Certified Network Associate

CCTV – Closed-Circuit Television

CE – Common Emitter

CFM – Cubic Feet Per Minute

CIF – Common Intermediate Format

CLD – Camera Lowering Device

CLI – Command Line Interface

CMX – Outdoor Ethernet Cable Rating

CO – Change Order

CODEC – Compressor/Decompressor (of Video files)

COM(M) – Communications

CORBA – Common Object Request Broker Architecture Protocol

COS – Class of service

CPU – Central Processing Unit

CRC – Cyclical Redundancy Check

CSA – Compliance Safety Accountability

CSAT – Conditional System Acceptance Testing

CSR – Combined Stress Ratio

DB – Decibel

DC – Direct Current

DCE – Data Circuit Terminating Equipment

DHCP – Dynamic Host Configuration Protocol

DI – Ductile Iron

DIN – Digital Input

DMS – Dynamic Message Sign

DNA – Manufacturer Product Reference

DNS – Domain Name System

DOT – Department of Transportation

DRAM – Dynamic Random Access Memory

DSP – Digital Signal Processing

DSRC – Dedicated Short Range Communication

DTE – Data Terminal Equipment

DVICE - Device

DVMRP – Distance Vector Multicast Routing Protocol

EA – Each

EE – End Entity

EIA – Electronics Industries Association

EIGRP – Enhanced Interior Gateway Routing Protocol

EIRP – Effective Isotropic Radiated Power

EMI – Electromagnetic Interference

EOP – Edge of Pavement

EOTL – Edge of Travel Lane

EOTW – Edge of Travel Way

EPA – US Environmental Protection Agency

EPDM – Ethylene Propylene Diene Monomer

EPS – Emergency Power Supply

EQUIP – Equipment

ESS – Environmental Sensor Station

ETH-BN – Ethernet Bandwidth Notification

ETL – Electrical Testing Laboratories

ETSI – European Telecommunications Standards Institute

EX - Ethernet

FAT – Factory Acceptance Test

FCAN – Full Capacity Above Normal

FCBN – Full Capacity Below Normal

FCC – Federal Communications Commission

FDD – Frequency Division Duplexing

FDS – Fog Detection System

FHWA – Federal Highway Administration

FIPS – Federal Information Processing Standard Publication

FLIR – Forward Looking Infrared

FNF – Flexible Net Flow

FO – Fiber Optic

FOCIS – Fiber Optic Connector Intermateability Standard

FOTP – Fiber Optic Test Procedures

Fps – Frames Per Second

FRP – Fiberglass-Reinforced Paneling

FSK – Frequency Shift Keying

FT – Foot

FTP – File Transfer Protocol

G.M. – Ground Mounted

GB – Gigabyte

GB/S – Gigabytes per Second

GBIC – Gigabit Ethernet Interface Card

GFCI – Ground Fault Circuit Interrupter

GH/GHz – Gigahertz

GIS – Geographic Information System

GMRP – Generic Multicast Registration Protocol

GOP – Group of Pictures

GPS – Global Positioning System

GR – Guardrail

GUI – Graphical User Interface

GVRP – Generic VLAN Registration Protocol

HAR – Highway Advisory Radio

HART – Highway Advisory Radio Transmitter

HDPE – High Density Polyethylene

HMI – Human Machine Interface

HOV – High Occupancy Vehicle

HSPG – Hub Single Point Ground

HTTP – Hypertext Transfer Protocol

HTTPS – Hypertext Transfer Protocol Secure

HVAC – Heating, Ventilation and Air Conditioning

IAB – Internet Activities Board

IANA – Internet Assigned Numbers Authority

IBC – International Building Code

ICC – Intelligent Cruise Control

ICEA – Insulated Cable Engineers Association

ICMP – Internet Control Message Protocol

ICS – Industrial Control Systems

ID – Identification

IEC – International Electrotechnical Commission

IEEE – Institute of Electrical and Electronic Engineers

IETF – Internet Engineering Task Force

IGEPAL – Manufacturer Product Reference

IGMP – Internet Group Multicast Protocol

IMSA – International Municipal Signal Association

IN – Inch

IP – Internet Protocol

IPCPS – IP Camera Positioning System

IR – Insulation Resistance

ISO – International Organization for Standardization

IT – Information Technology

ITE – Institute of Transportation Engineers

ITS – Intelligent Transportation Systems

ITSA – Intelligent Transportation Society of America

ITU – International Telecommunications Union

JPL – Jet Propulsion Laboratories

kAIC – one thousand amps interrupting current

Kbps – Kilobits per second

KHz – Kilohertz

km – Kilometer

KSI – Kilopound Per Square Inch

KV – Kilovolt

KVA – Kilovolt Amp

LAN – Local Area Network

LC – Lucent Connector

LCD – Liquid Crystal Display

LCN – Manufacturer Product Reference

LED – Light Emitting Diode

LF – Linear Feet

LHCP – Left hand circular polarization

LOS – Line of Sight

LR – Specification Reference

LRFD – Load and Resistance Factor Design

LS – Lump Sum

LT – Left

LU – Type of Conduit Body (Elbow)

LWRNG – Lowering

LX – Long Wavelength

MAC – Mandatory Access Control

MAP – Motorist Assistance Patrol

MAX – Maximum

MB – Megabyte

Mbps – Megabits per Second

MCB – Main Circuit Breaker

MCOV – Maximum Continuous Operating Voltage

MCTT – Multi Channel Test Tool

MD – Machine Direction

MDIX – Medium-Dependent Interface Crossover

MIMO – Multiple Input Multiple Output

MGB – Main Ground Busbar

MH/MHz – Megahertz

MIB – Management Information Base

MJPEG – Motion Joint Photographic Experts Group

MMFO – Multimode Fiber Optic

MPEG – Motion Picture Experts Group

MPH – Miles Per Hour

MPPS – Mega Packets Per Second

MS – Millisecond

MSEC – Millisecond

MTBF – Mean Time Before failure

MTP – Media Transfer Protocol

MTU – Maximum Transmission Unit

MUTCD – Manual on Uniform Traffic Control Devices

N.T.S – Not to Scale

NAB – National Association of Broadcasters

NC – Normally Closed

NEC – National Electric Code

NEMA – National Electrical Manufacturers Association

NESC – National Electric Safety Code

NETA – National Electrical Testing Association

NFPA – National Fire Protection Association

NHI – National Highway Institute

NHTSA – National Highway Traffic Safety Administration

NIST – National Institute of Standards and Technology

NMS – Network Management System

NO – Normally Opened

NOAA – National Oceanic and Atmospheric Administration

NPCA – National Precast Concrete Association

NPT – National Pipe Thread

NSF – National Science Foundation

NTCIP – National Transportation Communications for ITS Protocol

NTP – Network Time Protocol

NTSB – National Transportation Safety Board

NTSC – National Television System Committee

NWS – National Weather Service

OAM – Specific Ethernet Protocol

OBU – On Board Unit

OFS – Manufacturer Product Reference

O/H – Overhead

ONVIF – Open network Video Interface Forum

OSHA – Occupational Safety and Health Administration

OSP – Outside Plant

OSPF – Open Shortest Path First

OTDR – Optical Time Domain Reflectometer

OVDS – Over-height Vehicle Detection System

P – Power

PB – Pull Box

PC – Intel/Windows-based personal computer

PCB – Printed Circuit Board

PCI – Precast/Prestressed Concrete Institute

PDF – Portable Document Format

PE – Polyethylene

PF – Pound-Force

PICS – Profile Implementation Conformance Specifications

PIM – Protocol Independent Multicast

PLC – Programmable Logic Controller

PM – Preventive Maintenance

PMP – Point-to-Multipoint

PMPP – Point-to-Multipoint Protocol

POC – Point of Connection

POCSAG – Post Office Code Standardization Advisory Group

POE – Power Over Ethernet

PPM – Parts per Million

PPS – Packets Per Second

PPT – Puncture Propagation Tear

PSF – Pound Per Square Foot

PSI – Pounds Per Square Inch

PSWZS – Portable Smart Work Zone System

PT – Pan and Tilt

PTC – Positive Temperature Coefficient

PTP – Precision Time Protocol

PTU – Pan and Tilt Unit

PTZ – Pan Tilt and Zoom

PV – Photovoltaic

PVC – Polyvinylchloride

PVDF – Polyvinylidene Fluoride

PWM – Pulse Width Modulation

QoS – Quality of Service

RADIUS – Remote Authentic Dial-in User Server/Service

RAM – Random Access Memory

RDS – Radar Detection System

RF – Radio Frequency

RFI – Radio Frequency Interference

RG – Radio Guide

RGS – Rigid Galvanized Steel

RI – Resistor, Input

RIP – Routing Information Protocol

RJ – Registered Jack

RMON – Remote Networking Monitoring

RMS – Ramp Metering System

ROW – Right-of-Way

RP – Recommended Preference

RS – Recommended Standard

RSL – Received Signal Level

RSU – Road Side Unit

RT – Right

RTP – Real Time Transport Protocol

RTSP – Real Time Streaming Protocol

RUS – Rural Utilities Service

SAE – Society of Automotive Engineers

SAP – Session Announcement Protocol

SAT – Stand Alone Site Test

SCH – Schedule

SCMS – Security Credential Management System

SCTE – Society of Cable Telecommunication Engineers

SCU – Sign Controller Unit

SD – Secure Digital

SDI – Single Double Insulated

SDP – Session description protocol

SDR – Standard Dimension Ratio

SEI – Solid Electrolyte Interface

SFP – Small Form-Factor Pluggable

SFTP – Secure File Transfer Protocol

SIA – Security Industry Alliance

SIF – Standard Interchange Format

SJ – Hard Service

SM – Single Mode

SMFO – Single Mode Fiber Optic

SNMP – Simple Network Management Protocol

SNTP – Simple Network Time Protocol

SP/SP725 – Special Provision (specifically refers to this document)

SPD – Surge Protective Device

SPVU – Single Package Vertical Unit

SRAM – Static Random-Access Memory

SSD – Solid-State Drive

SSH – Secure Shell Protocol

SSL – Secure Socket Layer

SST – Sub-system Test

ST – Super Tension

STA. – Station

STMF – Simple Transportation Management Framework

STMP – Simple Transportation Management Protocol

STP – Shielded twisted pair

STS – Strategic Technology Solutions

SU – Subscriber Unit

SWD – Switching Duty

SWR – Standing Wave Radio

SZ – Reverse Oscillating

TACACS – Termination Access Controller Access Control System

TCIP – Transit Communications Interface Protocol

TCP – Transmission Control Protocol

TCP/IP – Transmission Control Protocol / Internet Protocol

TD – Tunnel Diode

TDMA – Time Division Multiple Access

TDOT – Tennessee Department of Transportation

TEES – Transportation Electrical Equipment Specifications

TELNET – Teletype Network Protocol

TFTP – Trivial File Transfer Protocol

THHN – Thermoplastic High Heat Resistant Nylon Coated

THWN – Thermoplastic Heat- and Water-Resistant Nylon Coated

TIA – Telecommunications Industry Association

TIM – Traveler Information Message

TIS – Traveler Information Service

TMC – Transportation Management Center

TOAD – Toggle Only Actuated Device

TP – Triple Pole

TS – Thermo Switch

TTMS – Travel Time Message Sign

TV - Television

TX – Transmitter

UDP – User Datagram Protocol

UDP/IP – User Datagram Protocol/Internet Protocol

UHF – Ultra-High Frequency

UL – Underwriter's Laboratory Incorporated

UNII – Unlicensed National Information Infrastructure

UPS – Uninterruptible Power Supply

USB – Universal Serial Bus

USDOT – United States Department of Transportation

UTP – Unshielded Twisted Pair

UV – Ultraviolet

VA – Volt Ampere

VAC – Volts Alternating Current

VBR – Voltage Breakdown

VDC – Volts Direct Current

VDS – Video Detection System

VHF – Very High Frequency

VLAN – Virtual Local Area Network

VPR – Voltage Protection Rating

VRRP – Virtual Router Redundancy Protocol

VSWR – Voltage Standing Wave Radio

VTP – VLAN Trunking Protocol

WAN – Wide-Area Network

WIM – Weigh In Motion

WRED – Weighted Random Early Detection

WWF – Welded Wire Fabric

XHHW – XLPE (Cross-Linked Polyethylene) High Heat-Resistant Water-Resistant

XLPE – Cross-Linked Polyethylene

XPIC – Cross Polarization Interference Cancellation

ZX – Extended Wavelength

APPENDIX B PREVENTIVE MAINTENANCE PROCEDURES

See Regional Maintenance SP below.

APPENDIX C SPARE PARTS

The following Spare Parts shall be kept on-hand by the Contractor and replenished as they are used.

Item Number	Description	Quantity

APPENDIX D LATEST DEVICE FIRMWARE

The latest supported device firmware is shown on the following pages.

APPENDIX E INSTRUCTIONS FOR ADDING SECTIONS/DOCUMENT MAINTENANCE

1. Go to end of section before desired new section, hit enter until new, empty line (no numbering)
2. Select "Heading 1" Style and enter section header in all caps
   a. If Appendix, use "Appendix Heading 1" instead
3. Hit enter, paste or type new information
4. Check or add headers using "Heading 2", "Heading 3" (or "Appendix Heading 2", "Appendix Heading 3")
5. Adjust line spacing before and after by right clicking and selecting "paragraph" or go to ribbon tab "Layout" and adjust in "Paragraph" section; note: expand the section or right click and select "paragraph" to uncheck "don't add space between paragraphs of the same style" to space out lists
6. To fix page numbering, select Heading 1 between automatic number and new text and go to ribbon tab "Layout", click "Breaks" and insert "Continuous Section Break"
7. If footer doesn't auto-update, open footer and select page number text, go to ribbon tab "Header & Footer", select "Page Number" and then "Format Page Number"; check the box for including header information (not checked for most appendices) and restart numbering at 1 if desired
8. Add new reference fields by selecting text to be replacing or placing cursor where reference should go and go to ribbon tab "References", then "Cross-reference" under "Captions" Section; use dialog box – typically show headers or numbered items and then insert header number or header text
9. Select all text in document with "ctrl" + "a", then use F9 to update all reference fields and table of contents; this should be done automatically upon saving and printing as well

Tips and Tricks:

1. Right click and select "Paragraph", "Indents and Spacing" tab, then uncheck "don't add space between paragraphs of the same style" to space out lists
2. In the same "paragraph" dialogue box, select "Line and Page Breaks" tab to find "Keep with next" and "keep lines together" check boxes; select an entire section you want to stay together on same page and check both of these boxes to force it to the next page; uncheck if you dislike how much white space is left on the previous page
3. Using the Navigation pane (hit "ctrl" + "f" or go to ribbon tab "View" and check "Navigation Pane" under "show" section), you can drag and drop headers to re-organize sections but back-check that everything moved properly please

APPENDIX F   UNUSED/OUTDATED SPECIFICATIONS

26 FORWARD LOOKING INFRARED CAMERA SYSTEM

26.1 Description

This section specifies the minimum requirements for Forward Looking Infrared (FLIR) Camera Systems furnished and installed on this project.

The FLIR Camera System will provide TDOT Regional TMC personnel with live streaming video of the roadway network, through both a daylight color camera and a thermal imaging camera, via FLIR Camera Systems installed at locations shown on the Plans.

26.2 Materials

Contractor shall provide all materials according to the requirements in the following sections.

All equipment shall be new and constructed using the highest quality, commercially available components and techniques to assure high reliability and minimum maintenance. The Contractor shall submit, prior to installation, a complete set of shop drawings of all the equipment and components listed within this Special Provision and included as part of the installation.

26.2.1 General Capabilities and Performance Requirements

Overall FLIR Camera System capabilities and performance requirements include the following:

1. FLIR Camera System shall be placed at fixed locations as shown on the Plans to provide full coverage within the project limits including the mainline travel lanes and shoulders.
2. The FLIR Camera System components shall be compatible with each other and be of rugged design and suitable for reliable operation when mounted in the configuration as specified in this SP725 and the Plans.
3. The FLIR Camera System shall be capable of attended and unattended, continuous 24 hours per day operation at the sites as shown on the Plans.
4. The Contractor shall ensure that the installed equipment provides unobstructed video of the roadway, traffic, and other current conditions around a road side FLIR field site; that it responds to camera control signals from an operator of the system; and that the video images can be transmitted to remote locations interfaced to the system for observation.
5. The camera shall be fully compliant with all aspects of the National Television Standards Committee (NTSC) specification and produce NTSC compatible video. The camera shall be fully digital, IP addressable, and compliant with the H.264 video encoding standard.
6. The camera shall operate over wide dynamic light conditions ranging from low light/dusk to full sunlight having day (color)/night (monochrome) switchover and iris control with user-selectable manual and automatic control capabilities.
7. The FLIR Camera System shall be capable of being remotely controlled and programmed.
8. Dome type enclosures shall be provided with the ability to be pressurized for environmental protection.
9. The camera shall be mounted together with the zoom lens and integrated into the pan and tilt device within the dome enclosure forming a totally integrated, easily removable assembly.

10. The camera shall include a high quality integrated camera/lens combination.
11. The camera shall also be equipped with an auto-iris lens capability compatible with the zoom lens supplied.
12. Iris capability shall include a provision for manual override via software.
13. The camera shall be capable of auto-focus during zoom-in or zoom-out, with provisions for override via software.
14. Overexposure protection shall be provided - the camera shall not be degraded or damaged under normal reasonable operating conditions.
15. The capability for local control of pan, tilt, and zoom functions shall be provided at the road side cabinet using vendor-supplied software installed on a laptop computer.
16. FLIR cameras shall support the NTCIP 1205 v1.08 communication protocol.

26.2.2 Camera Unit

The minimum Camera Unit requirements include:

1. The camera unit shall incorporate solid-state design and provide digital signal processing (DSP) capable of providing clear and low-bloom color video pictures during daylight hours and monochrome video at night when the roadway is illuminated with minimal roadway lighting.
2. The camera unit shall be equipped with a low light level sensor to automatically switch the camera to Black and White mode.
3. The camera unit shall be equipped with an override capability to allow the camera to be manually switched via software to turn off the automatic low light level sensor switch feature for Color or Monochrome operation.
4. Image se¼”: ?1/4" charge-coupled device (CCD) employing digital video signal processing (DSP) technology with a minimum Effective Picture Elements of 768 horizontal x 494 vertical pixels.
5. **Sensitivity**: The camera shall maintain usable video under both day and nighttime lighting conditions. The Contractor shall provide an explanation of how their proposed camera equipment will provide usable video meeting the performance requirements specified herein. This explanation shall take into account as a minimum, the following parameters: usable video level (full video), reflectance (day and night scenarios), F-Stop, AGC and Shutter Speed.
6. Video output synchronization shall be 2 to 1 interlace and will observe the NTSC (color) and EIA RS-170 (black and white) standards.
7. **Resolution**: 540 lines horizontal and 350 TV lines vertical, NTSC equivalent.
8. **Signal-to-noise ratio**: 48 dB, minimum with AGC off, un-weighted, and 4.5MHz filter.
9. **Video Signal Format**: National Television Standards Committee (NTSC) composite video output of 1V p-p at 75 ohms, unbalanced.

26.2.3 Camera Lens

The minimum camera lens requirements include:

1. The camera lens shall have a minimum F-Stop of 1.4 to 1.6.

2. **Optical and Digital Zoom**: Shall provide an optical zoom of 35X and a digital zoom of 8X, minimum.

3. **Zoom Control**: The zoom magnification shall be fully controllable via the remote PTZ mechanism. The time to pass through the full range of movement of iris, zoom, and focus shall in no case exceed 10 seconds.

4. **Iris and Focus**: Support automatic iris and focus control with manual override capability. The iris shall be in a closed position when there is no power.

5. **White or Color Balance**: Support automatic or set to yield optical results under various outdoor lighting conditions.

6. **Shutter Speed**: Support automatic or set to yield optimal results under low lighting conditions without blooming or smearing, auto-iris on. Provide electronic shutter that is selectable in steps.

7. The lens shall be equipped for continuous remote control of zoom, focus, and iris.

8. Mechanical or electrical means shall be provided to protect motors from overrunning in extreme positions.

9. The zoom lens shall be an integrated camera/lens combination.

10. Vibration or ambient temperature changes shall not affect the automatic iris function, focus mechanism, and zoom mechanism.

11. The lens shall be optically clear, impact resistant and acrylic. The acrylic lens shall not yellow and shall not introduce appreciable light loss or geometric distortion over a 10-year service life when exposed to the environment.

12. The zoom mechanism shall be designed for maintenance-free operations. All gearing and bearings shall be self-lubricating with lubrication and gearing tolerances compatible with the environmental specifications contained herein.

26.2.4 Character Generator

The minimum character generator requirements include:

1. The capability of generating and superimposing lines of English language text on the video image/stream shall be provided.

2. A minimum of 20 characters per line that are between 10 and 30 horizontal TV lines in height shall be provided.

3. Control (enable, disable, and edit) of this feature shall be available remotely and at the field site using a laptop computer.

4. The text messages shall be stored in non-volatile memory.

5. Characters shall be white with a black border to ensure legibility in varied scenes.

6. The following minimum text insertion requirements shall be provided with the ability to individually turn each one on or off:

    a. Camera ID
    b. Sector Message
    c. Alarm Messages
    d. Pan/Tilt Azimuth/Elevation

e. Compass Direction in 8 discreet zones

26.2.5 Dome Enclosure

The minimum dome enclosure requirements include:

1. Sealed, pressurized dome enclosure that provides complete protection for the camera and lens assembly from moisture and airborne contaminants.
2. Environmental resistant and tamper proof meeting NEMA 4X or IP-67 rating requirements.
3. The dome enclosure shall be constructed in such a way that unrestricted camera views can be obtained at all camera and lens positions.
4. Dome environmental control shall be provided by nitrogen pressurization with a Schrader Valve for pressurization and purging. The enclosure shall be designed to be pressurized at 5 PSI of dry nitrogen. The notation "CAUTION – PRESSURIZED" shall be permanently printed on the rear plate of the enclosure and shall be clearly visible and readable.
5. An alarm shall be displayed under low-pressure conditions and displayed on the camera video. The low-pressure alarm shall be on/off selectable by the operator at the TDOT Regional TMC.
6. The dome enclosure shall consist of a two-piece (upper and lower half) dome. The bottom half of the dome shall be attached to the upper half with a plastic-coated safety cable to prevent the lower half from falling to the ground.
7. A harness and cables shall be provided with each enclosure to extend the video, power, and data from the FLIR Camera System to the field cabinet. No harness shall be exposed. All entry points shall have gaskets to prevent moisture entry. A sealed connector shall be at the top of the dome.
8. The dome enclosure shall assist in preventing lens fogging and effectively reduce internal temperatures.
9. The enclosure shall minimize glare and provide overexposure protection for the camera when pointed directly at the sun.
10. The enclosure shall be equipped with a heater, a defroster, and a thermostat.
11. The camera equipment inside the dome enclosure shall meet all its specified requirements when operating under the following conditions:
    a. Ambient Temperatures: -34ºC to +74ºC (-30ºF to +165ºF). A heater/blower shall be used to maintain internal dome temperatures within the manufacturer required operating temperatures for their equipment.
    b. Relative Humidity: 5% and 95%, non-condensing.
12. Total weight of FLIR cameras (including the housing, sunshield, and all internal components) shall be less than 18 pounds.
13. Dome enclosure shall be secured with a mounting plate/attachment designed to withstand a 90 mph sustained wind speed with a 30% gust factor.

26.2.6 Pan and Tilt Unit (PTU)

The minimum Pan and Tilt Unit requirements include:

1. The motorized, remotely controlled Pan/Tilt unit shall be mounted within the dome enclosure. The unit shall be integrated with the FLIR control system.
2. The unit shall provide continuous tilt (vertical) movement of 90 degrees from horizontal and continuous pan (horizontal) movement of 360 degrees.
3. Tilt speed shall be variable from zero up to 40 degrees per second, minimum, and the pan speed shall be variable from zero up to 80 degrees per second, minimum.
4. The unit shall be capable of simultaneous pan, tilt movements and zoom on 1 camera
5. Drive motors shall be capable of instantaneous reversing, be corrosion resistant, not require lubrication, and have overload protection.
6. Braking shall be provided in both pan and tilt movements to enable fast stop and reversal and to prevent drifting.
7. The viewing limits shall be set by a minimum of 8 discreet privacy zones that are software selectable.

26.2.7 Camera Control Receiver – Driver

The minimum camera control receiver-driver requirements include:

1. The camera control receiver shall provide a single point interface for control, power, and video communications.
2. The camera control receiver-driver shall be included within the dome enclosure and control the camera, pan/tilt and lens functions at each FLIR site.
3. The unit shall provide alphanumeric generation for on-screen titles.
4. The unit shall provide the ability to display diagnostic information on the screen in response to user commands.
5. The diagnostic information shall include current pan, tilt, zoom, and focus positions, and error codes for power, communication, position, and memory problems.
6. The capability for programmed tours shall be provided.
7. The camera control receiver shall use non-volatile memory to store the required information for presets, camera ID and sector text.
8. Presets shall meet the following requirements:
   a. A minimum of 64 presets shall be supported. Each preset shall consist of pan, tilt, zoom, and focus positions.
   b. The Contractor shall develop and install 10 presets for each camera. The Contractor shall submit the preset locations to TDOT for review and approval.
9. Protocols: FLIR cameras shall support the NTCIP 1205 v1.08 communication protocol. No camera control receiver-driver shall use non-published protocols. The Contractor shall provide protocol documentation.
10. Communications Interface: The communications interface shall support communications compliant with RS-422 and/or 485 (user selectable).

11. Connectors: Standard connectors compatible with communications and interface equipment/cables shall be provided.
12. The video input and output connections shall be the BNC type.
13. Connector(s) shall also be used for connecting the control outputs from the control receiver-driver unit to the camera, lens, and pan/tilt mechanisms.

26.2.8 Electrical

The minimum electrical requirements include:

1. The FLIR Camera System shall be furnished with any and all equipment required for a fully functional system, including all appropriate power and communications cables as defined by the manufacturer.
2. The power cables shall be sized to meet the applicable National Electrical Code (NEC) requirements.
3. Total power consumption shall not exceed 125W.
4. All devices supplied as system components shall accept, as a primary power source, 120VAC at an input of 60Hz. Any device that requires source input other than 120VAC at 60hz, such as cameras, PTUs, receiver/drives and dome heaters/blowers that operate at 24V or other, shall be furnished with the appropriate means of conversion.

26.2.9 Coaxial Cabling

The minimum coaxial interconnect cable requirements include:

1. The coaxial cable from the FLIR Camera System to the equipment cabinet shall be Belden 8281 or approved equivalent.
2. RG 59/U, 20AWG, bare copper conductor, polyethylene insulation.
3. 98% tinned copper, double braid shield, black polyethylene jacket.
4. Characteristic Impedance: 75 ohms (Ω), nominal.
5. Capacitance (conductor to shield): 21pF/ft; Inductance: 0.131uH/ft, nominal.

26.2.10 Surge Protection

All FLIR Camera System electrical interconnects shall be protected from voltage surges caused by lightning and external electromagnetic fields. The minimum surge protection requirements include:

1. Surge protectors shall be furnished for all non-dielectric cable and conductors (video, data/signal, and device/assembly power) between the FLIR Camera System and the equipment cabinet.
2. The surge protectors shall have leads that are kept to a minimum length as recommended by the surge device manufacturer.
3. All surge protection devices shall be designed to meet the temperature and humidity requirements expected in this type of outdoor application.
4. All Surge protectors shall be UL listed (UL 1449, UL 497, 497A, 497B, etc., as appropriate) and bonded to the same single-point ground point.

5. Coaxial Cable Surge protectors for coaxial cable shall meet/provide the following functionality:

    a. Attenuation: 0.1dB @10 MHz, typical
    b. Input / Output Impedance: 75 ohms nominal
    c. Operating Voltage of the surge protector shall match characteristics of the ITS device/assembly
    d. Peak Surge Current: 5,000-amperes for an 8x20 microsecond waveform
    e. Response Time: 1 nanosecond or less

6. Low Voltage/Signal Cable Surge protectors for data/signal/control cable shall meet/provide the following functionality:

    a. Peak Surge Current: 10,000A for an 8x20 microsecond waveform
    b. Response Time: 1 nanosecond or less
    c. Life Expectancy: Capable of surviving at a minimum of 25 occurrences at 2000A

7. FLIR power surge protectors for power from equipment cabinet power distribution to the FLIR Camera System shall meet/provide the following functionality:

    a. Frequency: DC to 10MHz
    b. Clamping Voltage: < 30VAC (rms) or 42VDC
    c. Insertion Loss: < 0.2dB
    d. Input / Output Impedance: 75 ohms, typical
    e. Peak Surge Current: 3000-amperes
    f. Response Time: 1 nanosecond or less

26.3 Installation Requirements

Contractor shall abide by the installation requirements in the following sections. All equipment shall be installed according to the manufacturer's recommendations, the Plans and as follows:

1. Materials and associated accessories/adapters shall not be applied contrary to the manufacturer's recommendations and standard practices.

2. Shall include all materials needed to permanently mount the FLIR camera to the support structure as indicated on the Plans.

3. Furnish and install power, video, and data cables, and any and all ancillary equipment required to provide a complete and fully operational FLIR system site.

4. Verify all wiring meets NEC requirements where applicable.

5. All above requirements apply to both new FLIR sites as well as sites where an existing FLIR is being replaced under the contract.

6. Cameras shall be mounted in positions which allow 360-degree continuous rotation and mounting arm position shall be as indicated on the Plans and approved by the Engineer prior to pole placement.

7. Furnish and install all appropriate field surge protection devices and ensure proper ground per manufacturer recommendations.

8. Coordinate with TDOT Regional TMC IT for IP addresses, and video encoding settings for all CCTV camera sites prior to turn-on/installation and site testing.

26.4 Testing Requirements

26.4.1 General Requirements

1. The Contractor shall conduct a project testing program for all materials specified in this section and as required in Section 2.5 of this SP725.
2. All test results shall confirm physical and performance compliance with this SP725.
3. The Contractor shall submit all test results documentation to the Engineer within 7 calendar days of completion of the tests. The Engineer will review test documentation in accordance with the Submittal Review Process in Section 2.7.
4. Payment for all testing is included in the cost of the FLIR Camera System.

26.4.2 Factory Acceptance Test

FAT may be performed in the presence of the Engineer. FAT shall include the following tests and inspections:

1. Test all completed and assembled Cameras at the point of manufacture for performance and functionality and provide an electronic copy of the manufacturer test documentation.

26.4.3 Bench Test Component

BTC shall be performed in the presence of the Engineer. The BTC shall include the following tests and inspections:

1. Verify the Camera has no internal or external damage.
2. Test all Camera functionality including iris and focus to verify functionality.

26.4.4 Bench Test System

BTS shall be performed in the presence of the Engineer. The BTS shall include the following tests and inspections:

1. Verify Camera attachment compatibility with the camera lowering device.
2. Verify that the Camera is compatible and supports operational interoperability with the communication equipment, TDOT ATMS software, and any existing equipment at the camera site.

26.4.5 Stand Alone Site Test

SAT shall be performed in the presence of the Engineer. The SAT shall include the following tests and inspections:

1. Verify all components have been installed per manufacturer requirements.
2. Verify all items have been attached properly (as per manufacturer recommendations and the Plans) to each other and to the Pole Structure.
3. Verify the Camera has no internal or external damage.
4. Verify the Camera has been properly connected to the UPS for continuous, conditioned power.
5. Verify the Camera and cabinet equipment are protected by surge suppression.

6. Verify local iris and focus control.
7. Verify iris and focus control through the Network Switch.

26.5 Warranty

All materials specified in this section shall carry a minimum three-year manufacturer's warranty from the date of Final Acceptance against any imperfections in workmanship or materials. Warranties shall cover complete replacement at no charge for the equipment. Warranties shall be transferred to TDOT upon Final Acceptance of the project as per the requirements in Section 2.6 of this specification.

26.6 Method of Measurement

26.6.1 FLIR Camera System

FLIR Camera System will be measured in units of each and paid for at the contract price per each. The bid price shall include furnishing, installing, device integration, documentation, and testing of a complete FLIR Camera System including the FLIR Camera Assembly, PT unit, zoom lens, enclosure, camera controller/receiver, coaxial cable, control/signal cable, power cable, surge suppressors and conduit between the camera and the cabinet, connections to support structures, attachment hardware and brackets and all incidental items to provide and install the FLIR Camera System as intended, removal of existing equipment (FLIR, cables, cabinet interface equipment, etc.) at locations where an existing FLIR is being replaced, satisfactory completion of all testing requirements and all work, equipment and appurtenances as required for a full FLIR Camera System. The bid price shall also include all system documentation including shop drawings, operations and maintenance manuals, wiring diagrams, block diagrams, and other materials necessary to document the operation of the FLIR Camera System. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

26.7 Payment

The contract unit price shall be full compensation for all work specified in this section.

Payment will be made under:

Item No.	Description	Unit
725-20.93	CCTV CAMERA SYSTEM (INFRARED)	EA

The FLIR Camera System will be paid per each as follows:

1. 50% of the contract unit price upon approval of Bench Test Component, Bench Test System, and Pre-Installation test results.
2. Additional 20% of the contract unit price upon approval of Stand Alone Site Test results.
3. Additional 20% of the contract unit price upon approval of Conditional System Acceptance Test results.
4. Final 10% of the contract unit price upon Final System Acceptance.

27 FIELD VIDEO ENCODER UNIT

27.1 Description

This section specifies the minimum requirements for Field Video Encoder Units furnished and installed on this project. The Field Video Encoder Unit will provide for the encoding and transmission of digital video signals from new CCTV units to the TDOT Regional TMC installed at locations shown on the Plans.

The Contractor shall provide a complete Field Video Encoder Unit including all cabling, conduits, sensors, mounts, electrical service, surge suppression, and all hardware associated with a complete installation as required by this SP725.

27.2 Materials

Contractor shall provide all materials according to the requirements in the following sections.

All equipment shall be new and constructed using the highest quality, commercially available components and techniques to assure high reliability and minimum maintenance. The Contractor shall submit, prior to installation, a complete set of shop drawings of all the equipment and components listed within this Special Provision and included as part of the installation.

27.2.1 General Capabilities and Performance Requirements

Furnish a field-hardened video encoder designed for unheated/uncooled “outdoor” applications such as road side control cabinets. The video encoder shall be installed in traffic signal controller cabinets and shall allow for the encoding and transmission of digital video signals from new CCTV units that will be provided under this Project.

The unit shall be shelf-mountable and shall allow for converting digital video signals from new CCTV units into 2 digital video streams; 1 in H.264 format (high-resolution) and 1 in MPEG-4 format (low-resolution), that can be transported over Ethernet. High resolution streams shall allow video bit rates from 1 to 3 Mbps and the low-resolution stream shall allow video bit rates from 64 kbps to 2 Mbps. The Contractor shall initially configure these formats for 2 Mbps and 64kbps, respectively. The video encoder shall also transmit pan-tilt-zoom control data from all CCTV control points to the CCTV camera via a serial connection to the CCTV camera resident on the CODEC.

The video encoder shall support the following digital transport standards at a minimum: RTP/IP, UDP/IP, TCP/IP, and unicast/multicast IP. The Contractor shall initially use UDP/IP for video transport and TCP/IP for camera control transport unless otherwise approved by the Engineer.

The video shall support resolutions of CIF (352 (H) x 240 (V)), ½ D1 (352 (H) x 480 (V)), and D1 (720 (H) x 480 (V)) at a minimum. The video encoder units shall provide a display showing diagnostic data such as data rate, quality level, frame rate, and video status on the front panel. All supporting user interface software shall be provided with each encoder unit.

The video encoder shall be equipped with at least 1 NTSC video input, 2 RS-232/422 serial ports and 1 10/100BaseTX Ethernet port. The 10/100BaseTX port shall support half-duplex or full-duplex and provide auto negotiation and shall be initially configured for full-duplex.

The video encoder shall be remotely manageable using standard network applications such as telnet, SNMP monitors, and/or web interface administration. The video encoder shall be equipped with LED or other approved indicators for the following functions:

1. Power
2. Link
3. Activity
4. Port Speed (10/100 Mbps)

27.2.2 Electrical Requirements

The video encoder shall operate from 115 VAC (+/-10%) input power at 60 Hz. The Contractor shall furnish any external step down transformers, power converters, and/or regulation equipment needed to operate the video encoder.

27.2.3 Physical and Environmental Requirements

The video encoder enclosure shall be constructed of non-corrosive materials (galvanized steel or an approved equal). For Contractor-supplied cameras, the video encoder shall be installed in equipment t cabinets and secured to the cabinet in a manner that is approved by the Engineer. The video encoder enclosure, including adapters/connectors, shall fit neatly within the confines of the equipment cabinet. All necessary mounting hardware shall be provided by the Contractor.

The video encoder shall meet or exceed NEMA TS-2 requirements for shock, temperature, humidity, and vibration. The video encoder shall operate at ambient temperatures from -40° to 158° F (-40° to 70° C) and ambient relative humidity from 0% to 90% (non-condensing). No cooling airflow shall be required.

27.2.4 Communication Interface Requirements

The video encoder shall comply with the 10/100BaseTX standard and have at least 1 standard RJ-45 interface. The 10/100BaseTX port shall operate as half-duplex or full-duplex and provide auto negotiation.

The video encoder shall have at least 2 serial ports – 1 for pan-tilt-zoom camera control and 1 for local maintenance or other data transport. The 2 serial ports shall support RS-232 and RS-422 data transmission and shall be transparent to the TDOT ATMS software using TCP/IP network access methods. Interconnection with camera control receivers with or without adapters or converters (i.e., RS-422/232 for compatibility with CCTVs) shall provide opto-isolated surge suppression. The optical isolation shall provide an isolation of no greater than 2000 VAC for data signals and ground.

27.2.5 Cables and Connectors

The Contractor shall furnish and install all cables and connectors necessary for video encoder installation. This shall include at a minimum Category 6 cables with RJ-45 connectors to connect the Video Encoder to the Field Ethernet Switch in the equipment cabinet or traffic controller cabinet and standard serial data cables to connect the Video Encoder to the CCTV camera for pan-tilt-zoom functions and local configuration administration.

27.3 Installation Requirements

Contractor shall abide by the installation requirements in the following sections.

27.3.1 General Requirements

All equipment shall be installed according to the manufacturer's recommendations, the Plans and as follows:

1. Materials and associated accessories/adapters shall not be applied contrary to the manufacturer's recommendations and standard practices.
2. All components shall be grounded in accordance with manufacturers' recommendations and the Standard Specifications.
3. Surge protection shall be provided between the sensors and cabinet components.
4. All like cabling shall be bundled to minimize crosstalk and electrical interference. Wiring shall be routed to prevent conductors from being in contact with devices in the cabinet and metal edges. Wiring shall also be arranged so that any removable assembly may be removed without disturbing or unhooking conductors.
5. All power and communications wiring shall be 1 continuous run from cabinet to Sensor. No splicing of wiring will be permitted unless approved by the Engineer.
6. Electronic devices in the sensor cabinet shall not be installed until electrical service has been installed and activated, and the cabinet ventilation fan is operational.
7. Prior to installation, all equipment must be stored in a location and manner approved by TDOT.
8. The Contractor is responsible for coordinating with TDOT Regional TMC IT for IP addresses and integrating the new sensors into the TDOT ATMS software.
9. Field Video Encoders shall be configured for transmitting video to the Ethernet switch at the data rates listed above in Section 27.2.1. MPEG-4 video resolution parameters shall be configured for 720x480 pixels unless otherwise approved by the Engineer.

27.3.2 Documentation

The documentation for the Field Video Encoder Unit shall consist of the following: Communications Protocol, Operator's Manual, Maintenance Procedure Manual, Equipment Drawings, and Electrical Schematic Diagrams.

1. Operator's Manual:

   This document shall fully describe the operation of the Field Video Encoder Unit using the Windows based software that runs on a notebook computer. This document shall clearly define all functions that are supported by the sensors/software. The manual shall define the normal operation of the sensors and the software including resetting and restarting the software package. A word-searchable electronic copy of this document shall be provided.

2. Maintenance Procedure Manual:

   This manual shall document the preventive and corrective maintenance procedures that should be followed to maintain the Field Video Encoder Unit at the highest level of operational efficiency. The manual shall include step-by-step field and bench trouble-shooting procedures to isolate and repair faults. The document shall include descriptions of normative waveforms and test voltages. A detailed parts list shall be included. For each part or assembly, a circuit diagram or pictorial shall be provided. A word-searchable electronic copy shall be provided.

3. Equipment Drawings and Diagrams:

A pictorial drawing showing the physical location and identification of each component shall be provided for each different electronic assembly and each different subassembly. An electronic copy of these drawings shall be provided in either PDF or CAD file type.

4. Electrical Schematic Diagrams:

   An electrical schematic, wiring diagram, and a logic diagram shall be provided for each different type of equipment. A stage-by-stage explanation of the circuit theory shall be provided with the circuit wiring diagrams. Connection diagrams for each sensor including block diagrams, terminal numbers, and conductor color codes shall be provided. An electronic copy of these diagrams shall be provided in either PDF or CAD file type.

27.3.3 Training

If the Field Video Encoder Unit model and generation proposed by the Contractor is not identical to a Field Video Encoder Unit model and generation that is already deployed within the TDOT Region of the project, training will be required. Prior to the acceptance of the first ESS, training shall be provided for TDOT's engineering, maintenance, and operations staff, at a facility provided by TDOT. The training shall include all material and manuals required for each participant.

The training shall be provided for 2 identical non-consecutive 1 day sessions for at least 10 engineering and operations personnel each. These hours of training are inclusive of those required in Section 2.4. The training shall include a complete demonstration of the operation and capabilities of the Field Video Encoder Unit. This session shall include a complete review of any field adjustments or calibration that may be required for any component. The training shall include operation instructions, theory of operation, circuit description, field adjustments, preventive maintenance procedures, troubleshooting, and repair of all components. Particular attention shall be given to the operation of the software packages to be provided.

27.4 Testing Requirements

27.4.1 General Requirements

1. The Contractor shall conduct a project testing program for all materials specified in this section and as required in Section 2.5 of this SP725.
2. The Contractor shall demonstrate CCTV command/control using vendor software upon completion of each Video Encoder installation.
3. All test results shall confirm physical and performance compliance with this SP725.
4. Payment for all testing is included in the cost of the Field Video Encoder Unit.
5. All Field Video Encoder Unit Cables under test shall be removed from all wiring termination devices until testing is completed. All Field Video Encoder Unit Cable conductors shall be connected to ground immediately after testing to ensure elimination of all capacitive charges and potentials.
6. Submit all test results documentation to the Engineer within 7 days of completion of the tests. The Engineer will review test documentation in accordance with the Project Submittal Program Requirements in Section 2.7. Test documentation shall include:
   a. Cable Identification:

i. Cable ID and Location – physical location (device ID and station number of equipment cabinet) and conductor/pair/shield ID for both the beginning and ending point

ii. Operator Name

iii. Engineer's Representative

iv. Date & Time

b. Setup and Test Conditions Parameters:

i. Battery charge and proper operation of ohmmeter

ii. Battery charge and proper operation of insulation resistance tester

iii. Ambient Temperature

c. Test Results for Continuity Test:

i. Conductor continuity

ii. Resistance (ohms)

iii. Measured Length (Cable Marking)

d. Test Results for Insulation Resistance Test:

i. Measured Cable Length

ii. Insulation resistance (exceeds manufacturer's specifications for at least 60 seconds.)

27.4.2 Factory Acceptance Test

FAT is not required for Field Video Encoder Unit.

27.4.3 Bench Test Component

BTC shall be performed in the presence of the Engineer. The BTC shall include the following tests and inspections:

1. Verify the Field Video Encoder Unit has no internal or external damage.
2. Test all Field Video Encoder Unit functionality using vendor software.
3. Perform continuity test on all conductors and shield in the Field Video Encoder Unit Cable.

27.4.4 Bench Test System

BTS shall be performed in the presence of the Engineer. The BTS must be performed utilizing the maximum total length of the Field Video Encoder Unit Cable required in this project. The BTS shall include the following tests and inspections:

1. Verify Field Video Encoder Unit attachment compatibility with the mounting brackets.
2. Verify that the Field Video Encoder Unit is compatible and supports operational interoperability with the communication equipment, TDOT ATMS software, and any existing equipment at the site.

3. Verify that the Field Video Encoder Unit can be configured and calibrated using the vendor software.
4. Verify that the required operational characteristics of the device are valid.

27.4.5 Stand Alone Site Test

SAT shall be performed in the presence of the Engineer. The SAT shall include the following tests and inspections:

1. Verify all components have been installed per manufacturer requirements.
2. Verify all items have been attached properly (as per manufacturer recommendations and the Plans) to each other and to the Pole Structure.
3. Verify the Field Video Encoder Unit has no internal or external damage.
4. Verify the Field Video Encoder Unit has been properly connected to the UPS for continuous, conditioned power.
5. Verify the Field Video Encoder Unit and cabinet equipment are protected by surge suppression.
6. Perform continuity test and insulation resistance test on all conductors and shield in the Field Video Encoder Unit Cable.

27.5 Warranty

All materials specified in this section shall carry a minimum three-year manufacturer's warranty from the date of Final Acceptance against any imperfections in workmanship or materials. Warranties shall cover complete replacement at no charge for the equipment. Warranties shall be transferred to TDOT upon Final Acceptance of the project as per the requirements in Section 2.6 of this specification.

27.6 Method of Measurement

27.6.1 Field Video Encoder Unit

Field Video Encoder Units will be measured in units of each and paid for at the contract price per each. The bid price shall include furnishing, installing, device integration, documentation, and testing of a complete Field Video Encoder Unit including the video encoder, power supply, power cable, attachment hardware and brackets and all incidental items to provide and install the Field Video Encoder as intended, satisfactory completion of all testing requirements and all work, equipment and appurtenances as required for a full Field Video Encoder installation. The bid price shall also include all system documentation including shop drawings, operations and maintenance manuals, wiring diagrams, block diagrams, and other materials necessary to document the operation of the Field Video Encoder Units. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

27.7 Payment

The contract unit price shall be full compensation for all the work specified in this section. Payment will be made under:

Item No.	Description	Unit
725-20.99	VIDEO ENCODER	EA

The Field Video Encoder Unit will be paid per each as follows:

1. 50% of the contract unit price upon approval of Bench Test Component, Bench Test System, and Pre-Installation test results.
2. Additional 20% of the contract unit price upon approval of Stand Alone Site Test results.
3. Additional 20% of the contract unit price upon approval of Conditional System Acceptance Test results.
4. Final 10% of the contract unit price upon Final System Acceptance

28 TERMINAL SERVERS

28.1 Description

This section specifies the minimum requirements for Terminal Servers furnished and installed on this project. The work shall consist of providing all labor, materials, equipment, and incidentals necessary to furnish, install, and test Terminal Servers.

The Terminal Server device, also commonly referred to as a Port Server device, will be used to communicate bi-directionally between IP-based Ethernet network systems and field devices that communicate or are controlled via a full-duplex serial interface.

28.2 Materials

Contractor shall provide all materials according to the requirements in the following sections.

All equipment shall be new and constructed using the highest quality, commercially available components and techniques to assure high reliability and minimum maintenance. Prior to installation, the Contractor shall submit and receive approval from TDOT on a complete set of shop drawings of all the equipment and components listed within these Special Provisions and included as part of the installation.

The firmware pre-installed on the device shall meet the minimum version listed in APPENDIX D at the time of device installation in the field.

28.2.1 General Capabilities and Performance Requirements

The Terminal Server shall meet the following general requirements:

1. 10/100 Base-TX Ethernet port connection
2. RS-232/485 selectable or programmable serial connections
3. Baud rates up to 230 Kbps
4. TCP/IP protocol
5. SNMP protocol
6. HTTP protocol
7. Remote TELNET connection
8. ARP-Ping for IP address assignment
9. LED status for link and power
10. All terminal servers shall be mechanically and electrically interchangeable within the network.

28.2.2 Data Interface Requirements

The minimum data interface requirements include the following:

1. The Terminal Server shall support a minimum of 2 bi-directional serial communication channels over an Ethernet 10/100 Base-TX uplink.

2. Each Terminal Server shall have a minimum of 2 EIA-232/485 Serial interface ports. These ports shall be individually and independently configurable, directly by switching or over the network, to EIA-232/485 mode of operation as defined by the EIA for data format, data rate, and data structure (e.g., the number of bits, parity, stop bits, etc.). Each serial port shall support up to 230 Kbps.
3. Each serial port shall support IP addressing, and shall not use proprietary encapsulation methods, which would restrict the use of standards-based virtual COM port connectivity software.
4. The equipment shall provide the capability to establish an IP connection directly from a workstation to any device IP address.
5. Each Terminal Server shall have an Ethernet Interface (10/100Base-TX protocol, Full/Half-Duplex, Auto Sense (802.3), RJ-45).

28.2.3 Physical and Environmental Specifications

The minimum physical and environmental requirements include:

1. Each Terminal Server shall have the following ports:
   a. Network Ethernet Port: Minimum 1-10/100 Mbps RJ-45.
   b. Serial Data Interfaces: 2-232/485 9 pin ports.
2. Operate in a temperature range of -35°C to 74°C.
3. Operate in relative humidity of 5% to 95% non-condensing.
4. Maximum Dimensions: 8”W x 6”D x 3”H.
5. Provide external markings:
   a. All connectors, indicators, and replaceable components shall be permanently marked and traceable to the supplied documentation, including schematics and parts list.
   b. The external markings shall include the product function name, model number, serial number, and manufacturer’s name.
6. Terminal Servers shall be shelf mountable or rack mountable. Shelf for the cabinet shall be provided if needed. Other mounting options may be submitted for review and approval by the Engineer.

28.2.4 Management Capabilities

The minimum management system requirements shall include:

1. Remote Management and Port Configurable.
2. SNMP compatible.
3. Local Configuration Port.
4. Port Configurable via Telnet.

28.2.5 Electrical

The minimum electrical/power requirements include:

1. 120 VAC.
2. External power supply unit is acceptable.

28.3 Installation Requirements

All equipment shall be installed according to the manufacturer’s recommendations, the Plans, this SP725, and as follows:

1. Materials and associated accessories/adapters shall not be applied contrary to the manufacturer’s recommendations and standard practices.
2. The Contractor shall furnish all tools, equipment, materials, supplies and manufactured hardware, and shall perform all operations and equipment integration necessary to provide complete, fully operational communications equipment as specified in this SP725, on the Plans, and/or in the contract documents. It is the responsibility of the Contractor to ensure DCE/DTE conflicts are addressed and that the equipment performs its required function when installed.
3. The terminal server power supply shall be connected to the UPS within the cabinet.
4. The Contractor shall provide TDOT with a written inventory of items received and the condition in which they were received. Once received, the equipment becomes the Contractor’s responsibility. The Contractor shall provide all labor and equipment necessary to move inventory out of the designated storage facility and to transport it to the installation location. All equipment shall be installed according to the manufacturer’s recommendations or as directed by the Engineer.

28.4 Testing Requirements

28.4.1 General Requirements

1. The Contractor shall conduct a project testing program for all materials specified in this section and as required in Section 2.5 of this SP.
2. All test results shall confirm physical and performance compliance with this SP.
3. The Contractor shall submit all test results documentation to the Engineer within 7 calendar days of completion of the tests. The Engineer will review test documentation in accordance with the Submittal Review Process in Section 2.7.
4. Payment for all testing is included in the cost of the Terminal Server.

28.4.2 Factory Acceptance Test

FAT is not required for Terminal Server.

28.4.3 Bench Test Component

BTC is not required for Terminal Server

28.4.4 Bench Test System

BTS shall be performed in the presence of the Engineer. The BTS shall include the following tests and inspections:

1. Demonstrate the ability of the Terminal Server to communicate with the attached RDS's through the serial port.
2. Verify that the Terminal Server is compatible and supports operational interoperability with the communication equipment and TDOT ATMS software.

28.4.5 Stand Alone Site Test

SAT shall be performed in the presence of the Engineer. The SAT shall include the following tests and inspections:

1. Verify all components have been installed per manufacturer requirements.
2. Verify all items have been attached properly (as per manufacturer recommendations and the Plans) to each other.
3. Verify the Terminal Server has no internal or external damage.
4. Verify the Terminal Server has been properly connected to the UPS for continuous, conditioned power.
5. Verify the Terminal Server is protected by surge suppression.

28.5 Warranty

All materials specified in this section shall carry a minimum one-year manufacturer's warranty from the date of Final Acceptance against any imperfections in workmanship or materials. Warranties shall cover complete replacement at no charge for the equipment. Warranties shall be transferred to TDOT upon Final Acceptance of the project as per the requirements in Section 2.6 of this specification.

28.6 Measurement

The Terminal Servers will be measured in units of each and paid for at the contract price per each. The bid price shall include furnishing, installing, testing, warranties, full operation and configuring the Terminal Server in accordance with applicable Standards, Specifications, and requirements. The bid price shall also include the mounting hardware, Category 6 ethernet patch cord, serial port cables or connectors, power cable, power adapters, user manuals, and any and all other equipment required to complete installation of the unit. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

28.7 Payment

The contract unit price shall be full compensation for all work specified in this section.

Payment will be made under:

Item No.	Description	Unit
725-21.21	TERMINAL SERVER	EA

The Terminal Servers will be paid per each as follows:

1. 50% of the contract unit price upon approval of Bench Test Component, Bench Test System, and Pre-Installation Test results.

2. Additional 20% of the contract unit price upon approval of Stand Alone Site Test results.
3. Additional 20% of the contract unit price upon approval of Conditional System Acceptance Test results.
4. Final 10% of the contract unit price upon Final System Acceptance.

29 FORWARD FIRING RADAR DETECTION

29.1 Description

This Section specifies the minimum requirements for the Forward Firing Radar Detection System furnished and installed. The Forward Firing Radar Detection System will provide XXXXXX as specified on the Plans, including but not limited to XXXXXXX. It is the Contractor's responsibility to furnish, program, install, and integrate all devices in the field and at the TDOT Regional TMC.

The Contractor shall provide a complete system including all cabling, conduits, sensors, mounts, electrical service, surge suppression, and all hardware associated with a complete installation as required by this SP725.

29.2 Materials

Contractor shall provide all materials according to the requirements in the following sections.

All equipment shall be new and constructed using the highest quality, commercially available components and techniques to assure high reliability and minimum maintenance. The Contractor shall submit, prior to installation, a complete set of shop drawings of all the equipment and components listed within this Special Provision and included as part of the installation.

29.2.1 General

1. RDS in forward-looking configuration shall monitor traffic in 1 lane and be capable of providing the following data:
    a. Volume, occupancy, and average speed
    b. Per vehicle speed and direction
2. Communications:
    a. The Forward Firing Radar Detection System must be capable of transmitting all collected data via IP communications.
3. Software:
    a. All software required to configure and operate the System shall be provided.
4. ATMS Compatibility:
    a. The Forward Firing Radar Detection System must be compatible with the TDOT ATMS software. The devices must be able to be integrated into the software such that the data processed by the sensors is available for monitoring within the TDOT ATMS software.

29.3 Installation Requirements

Contractor shall abide by the installation requirements in the following sections.

29.3.1 General Requirements

All equipment shall be installed according to the manufacturer's recommendations, the Plans and as follows:

1. Materials and associated accessories/adapters shall not be applied contrary to the manufacturer's recommendations and standard practices.
2. All components shall be grounded in accordance with manufacturers' recommendations and the Standard Specifications.
3. Surge protection shall be provided between the sensors and cabinet components.
4. All like cabling shall be bundled to minimize crosstalk and electrical interference. Wiring shall be routed to prevent conductors from being in contact with devices in the cabinet and metal edges. Wiring shall also be arranged so that any removable assembly may be removed without disturbing or unhooking conductors.
5. All power and communications wiring shall be 1 continuous run from cabinet to Sensor. No splicing of wiring will be permitted unless approved by the Engineer.
6. Electronic devices in the sensor cabinet shall not be installed until electrical service has been installed and activated, and the cabinet ventilation fan is operational.
7. The Forward Firing Radar Detection System power supply shall be connected to the UPS within the cabinet.
8. Prior to installation, all equipment must be stored in a location and manner approved by TDOT.
9. The Contractor is responsible for coordinating with TDOT Regional TMC IT for IP addresses and integrating the new sensors into the TDOT ATMS software.

29.3.2 Documentation

The documentation for the Forward Firing Radar Detection System shall consist of the following: Communications Protocol, Operator's Manual, Maintenance Procedure Manual, Equipment Drawings, and Electrical Schematic Diagrams.

1. Operator's Manual:

   This document shall fully describe the operation of the ESS using the Windows based software that runs on a notebook computer. This document shall clearly define all functions that are supported by the sensors/software. The manual shall define the normal operation of the sensors and the software including resetting and restarting the software package. A word-searchable electronic copy of this document shall be provided.

2. Maintenance Procedure Manual:

   This manual shall document the preventive and corrective maintenance procedures that should be followed to maintain the ESS at the highest level of operational efficiency. The manual shall include step-by-step field and bench trouble-shooting procedures to isolate and repair faults. The document shall include descriptions of normative waveforms and test voltages. A detailed parts list shall be included. For each part or assembly, a circuit diagram or pictorial shall be provided. A word-searchable electronic copy shall be provided.

3. Equipment Drawings and Diagrams:

   A pictorial drawing showing the physical location and identification of each component shall be provided for each different electronic assembly and each different subassembly. An electronic copy of these drawings shall be provided in either PDF or CAD file type.

4. Electrical Schematic Diagrams:

An electrical schematic, wiring diagram, and a logic diagram shall be provided for each different type of equipment. A stage-by-stage explanation of the circuit theory shall be provided with the circuit wiring diagrams. Connection diagrams for each sensor including block diagrams, terminal numbers, and conductor color codes shall be provided. An electronic copy of these diagrams shall be provided in either PDF or CAD file type.

29.3.3 Training

If the Forward Firing Radar Detection System model and generation proposed by the Contractor is not identical to an ESS model and generation that is already deployed within the TDOT Region of the project, training will be required. Prior to the acceptance of the first ESS, training shall be provided for TDOT's engineering, maintenance, and operations staff, at a facility provided by TDOT. The training shall include all material and manuals required for each participant.

The training shall be provided for 2 identical non-consecutive 1 day sessions for at least 10 engineering and operations personnel each. These hours of training are inclusive of those required in Section 2.4. The training shall include a complete demonstration of the operation and capabilities of the ESS. This session shall include a complete review of any field adjustments or calibration that may be required for any component. The training shall include operation instructions, theory of operation, circuit description, field adjustments, preventive maintenance procedures, troubleshooting, and repair of all components. Particular attention shall be given to the operation of the software packages to be provided.

29.4 Testing Requirements

29.4.1 General Requirements

1. The Contractor shall conduct a project testing program for all materials specified in this section and as required in Section 2.5 of this SP725.
2. All test results shall confirm physical and performance compliance with this SP725.
3. Payment for all testing is included in the cost of the Forward Firing Radar Detection System.
4. All Forward Firing Radar Detection System Cables under test shall be removed from all wiring termination devices until testing is completed. All Forward Firing Radar Detection System Cable conductors shall be connected to ground immediately after testing to ensure elimination of all capacitive charges and potentials.
5. Submit all test results documentation to the Engineer within 7 days of completion of the tests. The Engineer will review test documentation in accordance with the Project Submittal Program Requirements in Section 2.7. Test documentation shall include:
    a. Forward Firing Radar Detection System Cable Identification:
        i. Cable ID and Location – physical location (device ID and station number of equipment cabinet) and conductor/pair/shield ID for both the beginning and ending point
        ii. Operator Name
        iii. Engineer's Representative
        iv. Date & Time
    b. Setup and Test Conditions Parameters:

    i. Battery charge and proper operation of ohmmeter
    ii. Battery charge and proper operation of insulation resistance tester
    iii. Ambient Temperature

c. Test Results for Continuity Test:
    i. Conductor continuity
    ii. Resistance (ohms)
    iii. Measured Length (Cable Marking)

d. Test Results for Insulation Resistance Test:
    i. Measured Cable Length
    ii. Insulation resistance (exceeds manufacturer's specifications for at least 60 seconds.)

29.4.2 Factory Acceptance Test

FAT is not required for Forward Firing Radar Detection System.

29.4.3 Bench Test Component

BTC shall be performed in the presence of the Engineer. The BTC shall include the following tests and inspections:

1. Verify the Forward Firing Radar Detection System has no internal or external damage.
2. Test all Forward Firing Radar Detection System functionality using vendor software.
3. Perform continuity test on all conductors and shield in the Forward Firing Radar Detection System Cable.

29.4.4 Bench Test System

BTS shall be performed in the presence of the Engineer. The BTS must be performed utilizing the maximum total length of the Forward Firing Radar Detection System Cable required in this project. The BTS shall include the following tests and inspections:

1. Verify Forward Firing Radar Detection System attachment compatibility with the mounting brackets.
2. Verify that the Forward Firing Radar Detection System is compatible and supports operational interoperability with the communication equipment, TDOT ATMS software, and any existing equipment at the Forward Firing Radar Detection System site.
3. Verify that the Forward Firing Radar Detection System can be configured and calibrated using the vendor software.
4. Verify that the required operational characteristics of the device are valid including the measurement of environmental conditions required in Section 13.2.

29.4.5 Stand Alone Site Test

SAT shall be performed in the presence of the Engineer. The SAT shall include the following tests and inspections:

1. Verify all components have been installed per manufacturer requirements.
2. Verify all items have been attached properly (as per manufacturer recommendations and the Plans) to each other and to the Pole Structure.
3. Verify the Forward Firing Radar Detection System has no internal or external damage.
4. Verify the Forward Firing Radar Detection System has been properly connected to the UPS for continuous, conditioned power.
5. Verify the Forward Firing Radar Detection System and cabinet equipment are protected by surge suppression.
6. Verify the measurement of environmental conditions required in Section 13.2 can be observed through the direct local connection.
7. Verify the measurement of environmental conditions required in Section 13.2 can be observed through the Network Switch.
8. Test the accuracy of the Forward Firing Radar Detection System in accordance with the accuracy requirements specified in Section 13.2.
9. Perform continuity test and insulation resistance test on all conductors and shield in the Forward Firing Radar Detection System Cable.

29.5 Warranty

All materials specified in this section shall carry a minimum three-year manufacturer's warranty from the date of Final Acceptance against any imperfections in workmanship or materials. Warranties shall cover complete replacement at no charge for the equipment. Warranties shall be transferred to TDOT upon Final Acceptance of the project as per the requirements in Section 2.6 of this specification.

29.6 Method of Measurement

29.6.1 Forward Firing Radar Detection System

The Forward Firing Radar Detection System shall be measured in units of each and paid for at the contract unit price per each. The price shall include furnishing, installing, device integration, and testing of the complete Forward Firing Radar Detection System including the data processor, power supply, pavement temperature sensor, wiring, controller, communications interface, fittings, and junction boxes, satisfactory completion of testing requirements, and all work, equipment, and appurtenances as required to effect the full operation of the sensors, complete in place and ready for use. The bid price shall also include all system documentation including shop drawings, operations and maintenance manuals, wiring diagrams, block diagrams, and other material necessary to document the operation of the Forward Firing Radar Detection System. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

29.7 Payment

The contract unit price shall be full compensation for all work specified in this section. Payment will be made under:

Item No.	Description	Unit
	Forward Firing Radar Detector	

Forward Firing Radar Detection System will be paid per each as follows:

1. 50% of the contract unit price upon approval of Bench Test Component and Bench Test System test results.
2. Additional 20% of the contract unit price upon approval of Stand Alone Site Test results.
3. Additional 20% of the contract unit price upon approval of Conditional System Acceptance Test results.
4. Final 10% of the contract unit price upon Final System Acceptance.

Forward Firing Radar Detection System Cable will be paid per linear foot as follows:

1. 25% of the contract unit price upon delivery and reel test.
2. Additional 35% of the contract unit price for complete installation of cables.
3. Additional 30% of the contract unit price for successful completion of Stand Alone Site Test results of the complete cable in any lineal foot between terminations in equipment cabinets and Stand Alone Site Testing of all ESS units communicating through this section of cable.
4. Final 10% of the contract unit price upon Final System Acceptance.