786 INTELLIGENT TRANSPORTATION SYSTEMS – VEHICLE DETECTION AND DATA COLLECTION.

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PAGE 755. The following new Section is added after Section 715:

SECTION 786
VEHICLE DETECTION & DATA COLLECTION

786-1 Description.

Furnish and install a nonintrusive vehicle detection system as shown in the plans and directed by the Engineer that is capable of vehicle presence detection and traffic data collection meeting the general requirements of 786-1 through 786-6 and the specific requirements for each system as defined in 786-7 through 786-10.

786-2 Materials.

786-2.1 Detector: Provide a vehicle detection system that can, at a minimum, produce vehicle presence, volume, speed, and occupancy data for each detected lane. Provide a vehicle detection system utilizing one of the following four technologies, as shown in the plans.

1. A microwave vehicle detection system (MVDS) that uses a Federal Communications Commission (FCC)-certified, low-power microwave radar beam to detect vehicle presence and generate volume, occupancy, and speed data as defined in 786-7.

2. A video vehicle detection system (VVDS) that uses one or more video cameras to collect and analyze video signals for detecting vehicle presence and generating volume, occupancy and speed data as defined in 786-8.

3. A magnetic traffic detection system (MTDS) whose magnetic detector probe is a transducer that detects vehicle presence by converting changes in the vertical component of the earth’s magnetic field to changes in inductance, and which then generates volume, occupancy, and speed data as defined in 786-9.

4. An acoustic vehicle detection system (AVDS) having a passive acoustic detector that responds to vehicle-generated acoustic signals to detect vehicle presence and generate volume, occupancy, and speed data as defined in 786-7.

786-2.2 Communications: Ensure that the vehicle detection system generates and transmits traffic data either in serial format using an Electronic Industries Alliance (EIA) standard EIA-232 communication port or an Internet Protocol (IP) interface. Ensure that the vehicle detection system can generate contact closures emulating the output of a pair of 6-foot by 6-foot loops with leading edges placed 16 feet apart, as detailed in Index No. 17900, Traffic Monitoring Site, of the Design Standards.

Verify that the detection system is IP addressable. Ensure that all device communication addresses are user programmable.

Ensure that the detection system supports Point-to-Point Protocol (PPP), Point to Multi-Point Protocol (PMPP) (i.e., polled protocols), and Ethernet protocols. Ensure that the setup program assigns an IP address to the detection unit. Ensure that the vehicle detection system responds to a polling request from the TMC for traffic data. Verify that the detection unit responds with the accumulated traffic parameter measurements from the period since the last request was issued.

Verify that the detection system stores all system configuration and traffic parameter data within internal nonvolatile memory. Verify that traffic data can be locally and remotely transferred by issuing requests from a personal computer (PC) across the communication network connecting the detector and the TMC operator workstation or other PC.

786-2.3 Configuration and Management: Ensure that the vehicle detection system is provided with computer software that allows an operator to program, operate, and read current status of all system features and functions using a laptop computer or remote TMC workstation. Furnish software that is compatible with the Department's SunGuide[SM] Software System. Ensure that any software-based applications do not interfere with SunGuide[SM] software when the two are installed and used together on a shared hardware platform. Ensure that the software application provides PC desktop display of the detection zones and control of any vehicle detector connected to the network.

Provide software licenses as required in the plans. Ensure that the detection system software offers an open API and software development kit available to the Department at no cost for integration with third party software and systems.

Ensure that an operator using a locally connected laptop computer can conduct system setup, calibration, diagnosis, and data retrieval operations. Ensure that the detection system is capable of having its configuration data saved to a laptop computer or TMC operator workstation, which can later transfer the data back to the detection system for reloading.

Ensure that the detection system operator can use a laptop computer or TMC workstation to edit previously defined detection configurations to permit adjustments to the detection zone's size, placement and sensitivity, and to reprogram the detector's parameters.

Ensure that the laptop computer and the detection system can communicate when connected directly by an EIA-232 cable. Ensure that the laptop computer and detection system can communicate across the ITS system's communication network using the NTCIP standards described in this document. Ensure that the software allows communication between multiple users and multiple field devices concurrently across the same communication network.

Once programmed, ensure that no periodic adjustments are required to the detection zones unless physical roadway conditions change, such as lane shifts or closures.

786-2.4 Electrical Requirements: Ensure that the vehicle detection system field hardware meets the requirements in the FCC's 2005 Code of Federal Regulation (CFR), Title 47, Part 15. The detector shall not interfere with any known equipment.

Ensure the vehicle detection system operates using a nominal input voltage at the field cabinet of 120 volts of alternating current (V_{AC}). Ensure that the system's power supply will operate with an input voltage ranging from 89 to 135 V_{AC}. For any device requiring a source input other than the standard 120 V_{AC}, supply the appropriate means of conversion.

Furnish all equipment with the appropriate power and communication cables. Install the power cable and the communication cables according to the manufacturer's recommendation. Ensure that the cables comply with NEC sizing requirements as presented in NEC Article 210-19(a), Fine Print Note (FPN) No. 4, and meet all other applicable standards, specifications and local code requirements.

Ensure that the power cable running between the detection system and its electrical service is in a separate conduit. Do not install communication cables in the same conduit as power cables carrying voltage greater than 24 V_{DC}/V_{AC} or current in excess of 1.5 amps. Do not install the power and communication cables in the same pull boxes.

Cut all wires to their proper length before assembly. Do not double back any wire to take up slack. Neatly lace wires into cables with nylon lacing or plastic straps. Secure cables with clamps and provide service loops at all connections.

In the event that power to the vehicle detection system or a subcomponent thereof is interrupted, ensure that the equipment automatically recovers after power is restored. Ensure that all programmable system settings return to their previous configurations and the system resumes proper operation.

786-2.4.1 MVDS Electrical: Ensure that the MVDS operator is able to select and use 12 to 24 volts of direct current (V_{DC}) and 115 V_{AC} at 60 Hz.

Ensure that the detector is FCC certified and that the FCC's identification number is displayed on an external label. Ensure that the detector transmits within a frequency band of 10.525 gigahertz, ±25 megahertz, or another FCC approved spectral band.

786-2.4.2 VVDS Electrical: Ensure that the VVDS camera and positioner (if so equipped) have an operating voltage of 24 V_{AC} or 10 to 28 V_{DC}. If the VVDS camera or related ancillary device requires operating voltages other than these, provide an appropriate voltage converter.

Ensure that the VVDS camera and the machine vision processor (MVP) do not exceed a maximum power consumption of 200 watts.

786-2.4.3 AVDS Electrical: Ensure that the AVDS operates at 8 to 24 V_{DC}. If the device requires operating voltages other than these, provide an appropriate voltage converter.

786-2.5 Environmental Requirements: Provide detection systems that meet all specifications during and after being subjected to an ambient operating temperature range of -30 degrees (°) to 165° Fahrenheit (F) with a maximum noncondensing relative humidity as defined in the environmental requirements section of the NEMA TS 2 standard.

Verify that the detection system manufacturer certifies that its device has successfully completed environmental testing as defined in the NEMA TS 2 standard. Verify that vibration and shock resistance meet the requirements of Sections 2.1.9 and 2.1.10, respectively, of NEMA TS 2.

Ensure that no item, component, or subassembly emits a noise level exceeding the peak level of 55 decibels adjusted (dBa) when measured at a distance of 3.3 feet away from its surface.

Ensure that system components comply with the environmental requirements detailed in the NEMA TS 2 standard.

786-2.5.1 Detector Housing: Furnish and install an environmentally resistant and tamper-proof sensor enclosure for any detector assembly exposed to the elements. Ensure that the enclosure is environmentally sealed upon installation and that it is light in color.

786-2.5.2 Wind Loads: Verify that the detection system, mounting hardware, and any related material that is exposed to the environment can withstand sustained wind speeds as shown in the Plans Preparation Manual, Volume I, tables 29.1 and 29.2.

Ensure that enclosures are capable of withstanding wind loads as specified in the Plans Preparation Manual, Volume I, Section 29, and designed in accordance with the AASHTO 1994 Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals (25-year reoccurrence).

786-3 Performance.

786-3.1 Detection Accuracy: Provide a vehicle detection system capable of meeting the minimum total roadway segment accuracy levels of 95% for volume, 90% for occupancy, and

90% for speed for all lanes, up to the maximum number of lanes that the device can monitor as specified by the manufacturer.

786-3.2 Calculation of Volume, Occupancy, and Speed Accuracy: To verify conformance with the accuracy requirements in this section, perform evaluations by comparing sample data collected from the vehicle detection system with ground truth data collected during the same time by human observation or by another method approved by the Engineer. Base the vehicle detection system's performance evaluation on sample data taken over several time periods under a variety of traffic conditions. Weight each data sample to represent the predominant conditions over the course of a 24-hour period. Samples will consist of 15- and 30-minute data sets collected at various times of the day. Representative data periods and their assigned weights are provided in Table 1.

Table 1 – Data Collection Periods			
Period	Intended To Represent	Duration	Weight
Early morning (predawn) [EM]	12:30 AM – 6:30 AM	15 minutes	24
Dawn [DA]	6:30 AM – 7:00 AM	30 minutes	2
AM Peak [AMP]	7:00 AM – 8:00 AM	15 minutes	4
Late AM Off-Peak [LAOP]	8:00 AM – 12:00 Noon	15 minutes	16
Noon [NO]	12:00 Noon – 1:00 PM	15 minutes	4
Afternoon Off-Peak [AOP]	1:00 PM – 5:00 PM	15 minutes	16
PM Peak [PMP]	5:00 PM – 6:00 PM	15 minutes	4
Dusk [DU]	6:00 PM - 6:30 PM	30 minutes	2
Night [NI]	6:30 PM - 12:30 AM	15 minutes	24
Total Sum of Weights			96

For instance, the sample gathered for the Late AM Off-Peak period is intended to represent typical traffic conditions between 8:00 AM and 12:00 noon. Since the sample period's duration is 15 minutes and the actual period of time represented is 4 hours, the multiplication factor or weight assigned is 16, the number of 15-minute intervals in a 4-hour period.

786-3.3 Calculation of Volume Accuracy: Compute volume accuracy as described in this subsection.

Determine individual lane volume accuracy per period by calculating the percentage of absolute difference of the total volume measured by the detection system and the true volume computed using the method the Engineer approves, divided by the true volume for the period under consideration.

In Equation 1, EM represents the early morning period. The variable *i* represents a lane in a roadway and could vary from 1,…, N, where N is the maximum number of lanes on the roadway segment. Substitute other lane numbers and periods as necessary to determine the accuracy for each lane during each period (i.e., dawn, AM peak, late AM off-peak, etc.).

Variables used in the following calculations are identified as follows:

VT = Total volume

VD = Vehicle detection data (in this case, count data)

GT = Ground truth measurement utilizing a reliable method approved by the Engineer

VA = Volume accuracy

786-3.3.1 Equation 1 – Early Morning Lane Volume Accuracy Expressed in Percentage:

$$VA_{EM,ln_i} = 100 - \frac{\left| VT_{EM,VD,ln_i} - VT_{EM,GT,ln_i} \right|}{VT_{EM,GT,ln_i}} x100$$

where:

VA_{EM,ln_i} = Volume accuracy for early morning traffic conditions in the i^{th} lane.

VT_{EM,VD,ln_i} = Total volume for the 15-minute early morning period using the vehicle detector in the i^{th} lane.

VT_{EM,GT,ln_i} = Total volume for the 15-minute early morning period in the i^{th} lane using human observation or another method approved by the Engineer.

The period volume accuracy will be the arithmetic mean of the lane volume accuracy over all lanes.

In Equation 2, EM represents the early morning period and *N* is the maximum number of lanes in the roadway segment under test. Substitute other periods as necessary to determine the accuracy for each period (i.e., dawn, AM peak, late AM off-peak, etc.).

786-3.3.2 Equation 2 – Early Morning Period Volume Accuracy Expressed in Percentage:

$$VA_{EM} = \left(\frac{\sum_{i=1}^{N} VA_{EM,\ln_i}}{N} \right)$$

where:

VA_{EM} = Average volume accuracy for early morning traffic conditions for all lanes on the roadway segment.

VA_{EM,ln_i} = Volume accuracy for early morning traffic conditions in the i^{th} lane.

Calculate the roadway segment accuracy over all periods using Equation 3. Calculate the volume accuracy using Equation 2 for each individual period, multiplied by its corresponding weight, as shown in Table 1. Next, add the products for all periods and divide the sum by 96 to obtain the overall system accuracy.

786-3.3.3 Equation 3 – Total Roadway Segment Accuracy Expressed in Percentage:

$$VA_{Total} = \frac{\left[VA_{EM}x24 + VA_{DA}x2 + VA_{AMP}x4 + VA_{LAOP}x16 + VA_{NO}x4 + VA_{AOP}x16 + VA_{PMP}x4 + VA_{DU}x2 + VA_{NI}x24 \right]}{96}$$

where:

VA_{Total} = Volume accuracy for all lanes for all periods discussed in Table 1
VA_{EM} = Volume accuracy for early morning traffic conditions
VA_{DA} = Volume accuracy for dawn traffic conditions
VA_{AMP} = Volume accuracy for AM peak traffic conditions
VA_{LAOP} = Volume accuracy for late AM off-peak traffic conditions
VA_{NO} = Volume accuracy for noon traffic conditions
VA_{AOP} = Volume accuracy for afternoon off-peak traffic conditions
VA_{PMP} = Volume accuracy for PM peak traffic conditions
VA_{DU} = Volume accuracy for dusk traffic conditions
VA_{NI} = Volume accuracy for night traffic conditions

Position the detector and configure the detection zones so that a vehicle is detected when 70% or more of the vehicle width is inside a lane, and not detected when 15% or less of the vehicle width is in the lane. Use the detection zone configuration to minimize the occurrence of a double count for the same vehicle, while ensuring that it will be counted at least once.

786-3.4 Calculation of Speed and Occupancy Accuracy: Calculate speed accuracy as discussed in this subsection. Calculate occupancy in a manner similar to the speed computation methodology described below.

The difference between the volume accuracy and speed accuracy computation is that the volume of a particular lane can be aggregated over a period of time, while speed cannot. For computing the accuracy of the detector speed measurement, the average speed readings obtained from the detection system are compared to ground truth values on a particular roadway segment.

Equation 4 represents the ground truth average speed computation procedure for a particular lane during a specific time period. Equation 5 represents the average speed computation procedure for a particular lane during a specific time period using data gathered from the detection system.

In Equations 4 and 5, the time period described is the early morning period, represented by EM, and the variable k represents a vehicle traveling on the roadway and could vary from 1,…, K, where K is the maximum number of vehicles in lane i during the time period under consideration. The variable i represents a lane in a roadway and could vary from 1,…, N, where N is the maximum number of lanes on the roadway segment. Substitute other lanes and periods as necessary and compute the accuracy for each lane for all time periods.

Variables used in the following calculations are identified as follows:

SA = Speed accuracy
S = Speed of an individual vehicle
veh = Vehicle

786-3.4.1 Equation 4 – Early Morning Average Ground Truth Vehicle Speed:

$$S_{Avg,EM,GT,\ln_i} = \frac{1}{K}\sum_{k=1}^{K} S_{EM,GT,\ln_i,veh_k}$$

Where:

SA_{Avg,EM,GT,ln_i} represents the average ground truth vehicle speed for the i th lane during the early morning period.

S_{EM,GT,ln_i,veh_k} represents the true speed for the k th vehicle in the I th lane during the early morning period using human observation or another method approved by the Engineer.

786-3.4.2 Equation 5 – Early Morning Average Vehicle Detector Speed Measurement:

$$S_{Avg,EM,VD,ln_i} = \frac{1}{K}\sum_{k=1}^{K} S_{EM,VD,ln_i,veh_k}$$

where:

S_{Avg,EM,VD,ln_i} represents the average speed recorded by the vehicle detector for the i^{th} lane during the early morning period.

S_{EM,VD,ln_i,veh_k} represents the speed for the k th vehicle in the I th lane during the early morning period using the vehicle detector.

The lane speed period accuracy is computed as a percentage of the absolute difference of the average lane speed calculated using detection system data and the average lane true speed calculated in Equation 4 (or using another method approved by the Engineer), divided by average ground truth lane speed for the period.

In Equation 6, EM represents the early morning period. The variable i represents a lane on a roadway and could vary from 1,…,N, where N is the maximum number of lanes on the roadway segment. Substitute other lanes as necessary to determine the accuracy for each period (i.e., dawn, AM peak, late AM off-peak, etc.).

786-3.4.3 Equation 6 – Early Morning Lane Speed Accuracy Expressed in Percentage:

$$SA_{Avg,EM,ln_i} = 100 - \frac{\left|S_{Avg,EM,VD,ln_i} - S_{Avg,EM,GT,ln_i}\right|}{S_{Avg,EM,GT,ln_i}} \times 100$$

where:

SA_{Avg,EM,ln_i} represents the average speed accuracy during early morning traffic conditions for all vehicles that traveled in lane i of the roadway segment.

The period speed accuracy will be the arithmetic mean of the lane speed accuracy, computed using Equation 6, over all lanes.

In Equation 7, EM represents the early morning period. The variable i represents a lane on a roadway and could vary from 1,…, N, where N is the maximum number of lanes on the roadway segment. Substitute data as necessary to determine the accuracy for each period (i.e., dawn, AM peak, late AM off-peak, etc.).

786-3.4.4 Equation 7 – Early Morning Speed Accuracy Expressed in Percentage:

$$SA_{EM} = \left(\frac{\sum_{i=1}^{N} SA_{Avg,EM,ln_i}}{N} \right)$$

where:

SA_{EM} represents the average speed accuracy during early morning traffic conditions for all lanes on the roadway segment.

Calculate the roadway segment accuracy over all periods using the following equation. This equation is a weighted average to account for variations in each of the sample detection periods over the course of a 24-hour period. First, calculate the speed accuracy for each individual period using Equation 7. Next, multiply the individual period by its corresponding weight as shown in Table 1. Add the products for all periods and divide the sum by 96 to obtain the overall system accuracy.

786-3.4.5 Equation 8 – Total Roadway Segment Accuracy Expressed in Percentage:

$$SA_{Total} = \frac{[SA_{EM}x24 + SA_{DA}x2 + SA_{AMP}x4 + SA_{LAOP}x16 + SA_{NO}x4 + SA_{AOP}x16 + SA_{PMP}x4 + SA_{DU}x2 + SA_{NI}x24]}{96}$$

where:

SA_{Total} = Speed accuracy for all lanes for all periods discussed in Table 1
SA_{EM} = Speed accuracy for early morning traffic conditions
SA_{DA} = Speed accuracy for dawn traffic conditions
SA_{AMP} = Speed accuracy for AM peak traffic conditions
SA_{LAOP} = Speed accuracy for late AM off-peak traffic conditions
SA_{NO} = Speed accuracy for noon traffic conditions
SA_{AOP} = Speed accuracy for afternoon off-peak traffic conditions
SA_{PMP} = Speed accuracy for PM peak traffic conditions
SA_{DU} = Speed accuracy for dusk traffic conditions
SA_{NI} = Speed accuracy for night traffic conditions

786-4 Installation.

Install, configure and demonstrate a fully functional vehicle detection system, as shown in the plans. Connect all field hardware and TMC components to the existing communication network, and provide all materials specified in the Contract Documents. Install all equipment according to the manufacturer's recommendations or as directed by the Engineer.

Ensure that the MVDS, the VVDS and AVDS can be mounted on existing poles or sign structures, or on new poles, for a side-fire configuration. Utilize prestressed concrete or steel poles that comply with Section 641, Section 649, and Section 785-2, as appropriate. Ensure that poles can withstand sustained wind loads and gust factors according to the Plans Preparation Manual (PPM) and the Design Standards. The support structure and network communication infrastructure shall be paid for under separate pay items.

786-5 Testing.

786-5.1 General: Subject the equipment covered by these specifications to design approval tests (DATs) and field acceptance tests (FATs). Develop and submit a test plan for DATs and FATs to the Engineer for consideration and approval. Ensure that the test plans demonstrate each and every functional requirement specified for the device or system under test.

786-5.2 Design Approval Test Specifications: Prior to site installation, conduct DATs on one or more sample detectors as detailed below. Perform the DATs at the Contractor's facility or, with the Engineer's approval, at a site in the project area. The Engineer may accept certification by an independent testing laboratory in lieu of the DATs to satisfy the requirement that certain features and functions have been witnessed and documented as performing satisfactorily.

Arrange and conduct the tests and satisfy all inspection requirements prior to submission for the Engineer's inspection and acceptance. Furnish all necessary test equipment. Use a radar gun to calibrate speed detection, following the manufacturer's recommended calibration procedures.

At a minimum, demonstrate the following:

1. Use a laptop computer provided as part of the support equipment to configure the installation.

2. Verify that configuration data is stored in nonvolatile memory.

3. Download previously stored configuration data.

4. Verify that vehicles traveling at the test site can be detected across multiple travel lanes to the accuracy specified herein.

5. Drive a test car of known length and speed through the detection zone. Compare the output from the vehicle detector to this known value to verify the accuracy of detection. Repeat this measurement at least 10 times.

6. Install the detection system sensor at the site for test setup. Place a video camera at the same point along the roadway, above the sensor location, as determined appropriate by the Engineer. Produce a video recording of the test to obtain a manual count, then compare those results with those from the detection system to determine the accuracy of the sensor. Alternative verification methods may be considered by the Engineer.

7. Verify the volume counts and speed measurements for each installed assembly using the test software running on the laptop computer connected locally to the detector's EIA-232/485 communication port. Repeat this test remotely from the TMC's operator workstation. Verify the accuracy of traffic parameters specified herein by using permanent or temporary traffic detection devices of known accuracy.

786-5.3 Field Acceptance Test Specifications: Inspect all vehicle detection system field components to ensure proper installation and cable termination.

Adjust and verify the detector settings by comparing each sensor's recorded traffic volumes and speed with those actually observed. Remotely repeat this test from the TMC. Verify the accuracy of traffic parameters using permanent or temporary traffic detection methods or devices of known accuracy.

Conduct the acceptance tests detailed below in conjunction with the detector support structure testing. Notify the Engineer at least 14 calendar days prior to the proposed test date. The Contractor shall:

1. Furnish all equipment, appliances, and labor necessary to test the installed vehicle detection system and the network communication device, and to perform the following tests before any connections are made:

a. Perform a continuity test on the detector cables to ensure that anomalies, such as openings, shorts, crimps or defects, are not present.

b. Perform continuity tests on the detector's stranded conductors element using a meter having a minimum input resistance of 20,000 Ω per volt and show that each conductor has a resistance of not more than that specified by the wire/cable manufacturer.

c. Measure the insulation resistance between isolated conductors and between each conductor, ground, and shield using a meter designed for measuring insulation resistance. The resistance must be greater than 100 MΩ. Perform all resistance testing after final termination and cable installation, but prior to the connection of any electronic or field devices.

d. Replace any cable that fails to meet these parameters, or if any testing reveals defects in the cable, and retest new cable as specified in this section.

2. Furnish and calibrate all test equipment.

3. Demonstrate the following after installation of the vehicle detection system, other hardware, power supplies, and connecting cables:

a. Verify that physical construction has been completed as specified in the plans.

b. Inspect the quality and tightness of ground and surge protector connections.

c. Check power supply voltages and outputs.

d. Verify that device connections to power sources are as specified in the plans.

e. Verify that the installation of specified cables and connections between all detectors and the field cabinet are as specified in the plans.

f. Demonstrate that the remote system is fully operational and performing all specified types of detection, including data storage functions, with a laptop computer.

g. Verify that the network interface device is receiving and transmitting data from the remote site to the ITS network.

786-6 System Acceptance Criteria.

Upon request, furnish independent laboratory testing documentation certifying adherence to the standards and specifications required herein, along with adherence to the stated wind force criteria using a minimum effective projected area (EPA), the actual EPA, or an EPA greater than that of the detection assembly to be attached.

Within three calendar days of successful test completion, deliver to the Engineer a written completion notice and a copy of all test results. Include in this completion notice the documentation of any discrepancies found during testing. Also include assembly installation locations and successful test completion dates. If any component fails to pass required testing, replace the part and retest according to the requirements above, then resubmit the test results to the Engineer.

Within 10 calendar days of receipt of the completion notice and all test results, the Engineer shall either accept or reject the work. If rejected, the Engineer shall specify the defect or failure in the work. Notification of acceptance or rejection of the work shall be by delivery of written notice to the Contractor.

786-7 Microwave Vehicle Detection System.

786-7.1 Description: Furnish and install a microwave vehicle detection system (MVDS) as shown in the plans and directed by the Engineer.

786-7.2 Materials: Ensure that the MVDS is a true-presence microwave radar that uses the frequency modulated continuous wave (FMCW) principle. Ensure that the detector transmits a low-power, frequency modulated microwave signal in a fixed beam. Ensure that any nonbackground targets reflect the signal back to the microwave radar detector, where the targets are detected and their range measured.

Provide an MVDS assembly for the project site that consists of microwave radar sensor(s) in enclosed housing(s) (i.e., the detectors), as shown in the plans and directed by the Engineer. Provide an installation kit with mounting brackets; home run cable for the transmission and receipt of data and communications between the field detector and the communication system hardware; and all required power and data cables, as detailed in the plans.

786-7.2.1 MVDS Detector: Furnish a microwave vehicle detector that determines vehicle presence by the return or reflection of radar output waves, and that upon this return the MVDS generates data and/or a contact closure signal that corresponds to vehicle presence.

Ensure that the contact pairs are able to connect directly to the traffic controllers. Ensure that the detector accumulates and transmits short-term statistical data on each zone using a serial communication port or an IP connection. Ensure that the MVDS is capable of logging and storing traffic data for all programmed detection zones for a minimum of 7 days in 10-second data intervals.

Provide a detector that is capable of resolving closely spaced vehicles. Ensure that the MVDS setup program enables the operator to select whether data is output as contact closures emulating standard loop detector outputs, and/or as accumulated statistical data using detector serial ports. Verify that the sensor holds a vehicle’s presence in the specified detection zone until the vehicle is clear of the zone. Ensure that the sensor does not tune out stationary vehicles within a detection zone and thereby give a false clear status to the lane, even if a vehicle has stopped for a period exceeding 30 minutes.

Provide an assembly manufactured in such a way as to prevent reversed or improper installation. Ensure that the MVDS design provides high-voltage exposure protection to personnel during equipment operation, adjustments, and maintenance.

Ensure that the MVDS provides speed-trap emulation and has the ability to automatically detect sensor settings, baud rates, loop spacing, and communication port settings to select an operational mode.

Ensure that the detector has the ability to self-tune and allow manual calibration via supplied vendor software. Ensure that the MVDS is capable of autocalibration and autoconfiguration, and that it does not transmit any signals outside its FCC-approved frequency. Provide a setup program that allows the operator to define detection zones within the detector’s field of view. Ensure that the detector automatically configures zones, requiring minimal external tuning. Verify that the unit is not adversely affected by varied weather conditions, such as rain, fog, heat, or wind.

Ensure that the MVDS can compute, store, and provide all required traffic parameter measurements per detection zone in user-selected time intervals from 0 to 60 minutes, including, but not limited to, 10 seconds, 20 seconds, 30 seconds, 60 seconds, 5 minutes, 10 minutes, 15 minutes, 30 minutes, and 60 minutes. The MVDS shall log and store vehicle volume, occupancy, and speed data for a minimum of seven days regardless of collection interval. Data storage within the MVDS shall utilize a first in/first out architecture such that the oldest stored data record is overwritten with the newest data record when the storage device is at full capacity.

786-7.3 Installation of MVDS: Mount the MVDS' detector as detailed in the plans. In either configuration, mount the detector level from side to side. Ensure that the vertical and horizontal clearance of the installed detection device complies with Vol. I, Chapter 2 of the PPM.

Ensure that the MVDS sensor has a 200-foot range, and that the viewing angle is a minimum of 40 degrees vertical and a maximum of 15 degrees horizontal. Verify that all detection zones are contained within the specified elevation angle according to the manufacturer's recommendations and that the MVDS is capable of fully detecting all vehicles in a maximum of eight lanes. Ensure that the configuration also provides accurate collection of all data types as detailed in this specification.

Mount the detector in a NEMA 4X polycarbonate box, and verify that the electrical connection is located on the bottom of the box.

Provide a housing that can be pole- or wall-mounted, as indicated in the plans. Supply a universal mounting bracket that is adjustable on two axes for optimum alignment.

Attach the mounting bracket with approved stainless steel bands that are 0.75 inch wide and 0.025 inch thick, or mount to a concrete structure using two stainless steel expansion bolts of sufficient length and diameter to support 100 pounds.

When installing a detector near metal structures, such as buildings, bridges or sign supports, mount the sensor and aim it so that the detection zone is not under and does not pass through any structure to avoid distortion and reflection. In forward-looking configurations, the detector shall be mounted over the center of each lane.

Ensure that the detector is factory calibrated to comply with all applicable standards, specifications, and requirements. Ensure that the detector does not require further adjustment after initial setup, and that no periodic calibration is required.

Provide an interface to external equipment with a single connector. Ensure that the connector provides power to the unit and allows generation of contact closure output pairs for interface with traffic controller inputs. Ensure that the connector includes serial communication lines for programming, testing, and interfacing with the modem at a minimum 9,600-baud rate and that it has at least 26 pins. Ensure that the serial port's data format is standard binary non-return to zero (NRZ) modulation with 8-bit data, 1-stop bit, and no parity.

Ensure that the home run cable is a polyurethane-jacketed cable approved by the Engineer, with polyvinyl chloride (PVC) insulated conductors. The home run cable shall have a 300-volt rating and a temperature rating of 200° F. Ensure that the cable is equipped with #20 or #22 American Wire Gauge (AWG) conductors.

Supply a test cable and converter to connect the detector to a laptop computer for testing and configuration. Verify that the test cable and converter are compliant with current EIA-232 and Universal Serial Bus specification standards for protocol converters. The male DB-9 and USB connectors for laptop computers equipped with only a USB port shall support the automatic handshake mode, transmission rates of 230 kilobits per second (kbps), and remote wakeup and power management features. Verify that the test cable and converter are compatible with the operating systems recommended for SunGuide^{SM} software, and are USB powered.

Crimp or solder the detector connector pins to the cable conductors. Assemble and test the cable prior to onsite installation and pulling. Cut all wires to their proper length before installation. Do not doubled back wire to take up slack. Neatly lace wires into cable with nylon lacing or plastic straps, and secure cables with clamps. Provide service loops at all connections.

Perform continuity tests on the detector's stranded conductors using a meter having a minimum input resistance of 20,000 Ω per volt and show that each conductor has a resistance of not more than 16 Ω per 984.25 feet of conductor.

Measure the insulation resistance between isolated conductors and between each conductor, ground, and shield using a meter designed for measuring insulation resistance. The resistance must be infinity. Perform all resistance testing after final termination and cable installation, but prior to the connection of any electronic or field devices.

786-8 Video Vehicle Detection System.

786-8.1 Description: Furnish and install a video vehicle detection system (VVDS) as shown in the plans and directed by the Engineer.

786-8.2 Materials: Provide a VVDS consisting of one or more cameras together with a machine vision processor (MVP), necessary cabling, installation hardware, and central monitoring equipment.

786-8.2.1 Detection-only VVDS: Ensure that the VVDS performs vehicle detection and data collection functions by analyzing video signals in order to detect moving and stopped vehicles within the video image.

786-8.2.2 Dual-use VVDS: For VVDS where surveillance capability is also desired, provide dual-use equipment that is suited for both detection of vehicles and surveillance of the roadway.

During surveillance, provide a mechanism that automatically suspends the VVDS' vehicle detection functions. Should the system be configured to provide real-time traffic data to the TMC at regular intervals, any responses to TMC polling requests during periods when the camera is in motion or otherwise not viewing the area designated for vehicle detection shall indicate that the system is being used in a surveillance capacity, and that traffic data is either unavailable or should be disregarded. The intent of this requirement is to prevent the inclusion of erroneous data in real-time TMC systems due to the fact that the camera may not be resting in a position that allows preconfigured detection zones to produce valid data.

786-8.2.3 Video Vehicle Detection Camera: Ensure that the camera is compatible with the current version of the Department's SunGuide^{SM} Software System.

Use a camera that produces National Television System Committee (NTSC) composite video output of 1 volt peak-to-peak (Vp-p) at 75 Ω. Use either a dome-type or external positioner-type camera assembly. Ensure that the VVDS camera can transmit images directly to the MVP.

Ensure that VVDS cameras, as well as any MVPs integrated in camera housings, meet the environmental requirements as detailed in Section 782-1.2.8.

Ensure that the VVDS camera conforms to one of the two options described below, as shown in the plans.

786-8.2.3.1 Dual-use Camera: Provide a VVDS camera that also functions as a closed-circuit television (CCTV) roadway surveillance system through the use of pan-tilt-zoom (PTZ) control by the operator. If utilized in this dual manner, ensure that the VVDS meets the following requirements:

1. Perform video vehicle detection and collect traffic data as its primary function, with surveillance as the secondary function.
2. Allow the VVDS operator to move the camera using PTZ control to view traffic conditions.
3. Return the VVDS camera to its preconfigured detection state when switched back from surveillance mode. Ensure that the positioner has a preset position return accuracy of ±0.36 degree, or less than 0.10% or better, as required in 782-1.2.3.

Ensure that dual-use cameras are either dome-type or external positioner-type cameras as shown in the plans, and that they meet the requirements detailed in Section 782-1.2.1.

Ensure that the lens meets the requirements of 782-1.2.2.

Use camera housings that meet the requirements of 782-1.2.7. Provide mounting hardware as required in 782-1.3.

Use PTZ mechanisms that meet the requirements of 782-1.2.3 for dome type cameras and 782-1.2.4 for external positioner type cameras.

Ensure that the camera meets the mechanical specifications in 782-1.2.7 and the electrical specifications in 782-1.2.6.

786-8.2.3.2 Detection-only Camera: Provide a fixed-mount camera that is either black-and-white or, alternately, color with automatic switchover from monochrome to color and vice versa, as shown in the plans.

Ensure that any detection-only camera provides the following features and capabilities:

1. Minimum resolution of 470 horizontal and 350 vertical TV lines.
2. User-selectable automatic gain control (AGC) that is peak-average adjustable to 30 decibels (dB).
3. A minimum signal-to-noise ratio of 50 dB.
4. User-selectable gamma settings of 0.45 and 1.0.
5. Automatic electronic shutter that is user selectable from 1/60 to 1/10,000 of a second.

Ensure that the detection-only camera has a minimum 10x motorized optical zoom lens with automatic iris. Ensure that the lens is capable of automatic and manual focus and iris control and has a minimum focal length of 0.14 to 3.2 inches. Ensure that the lens depth of field provides a clear image of roadside areas under all lighting conditions and has a maximum aperture of at least f/1.6.

Use camera housings that meet the requirements of 782-1.2.7. Provide mounting hardware as required in 782-1.3.

Ensure that the camera meets the mechanical specifications in 782-1.2.7 and the electrical specifications in 782-1.2.6.

786-8.2.4 Machine Vision Processor: Include with the field hardware an MVP for analyzing the video input and for computing, storing, and reporting the collected vehicle detection data. Use an MVP that also supports the installation at the TMC by providing video feeds transmitted from field locations over the communications network infrastructure, as shown in the plans.

786-8.2.4.1 Detection: Ensure that the MVP emulates standard in-pavement loops by producing vehicle volume, occupancy, and speed data for every detection zone.

Ensure that the MVP resolves closely spaced vehicles and rejects adjacent lane vehicles.

Ensure that the MVP is able to process images of approaching or receding traffic, or both, in the same field of view.

Ensure that the MVP can provide presence and pulse detection modes for each detection zone. In presence mode, the detection zone shall be active as long as a vehicle occupies the zone. In pulse mode, ensure that the detection zone provides a momentary, on/off detection that does not remain active, even if the vehicle stays within the zone.

Ensure that the MVP can compute, store, and provide all required traffic parameter measurements per detection zone in user-selected time intervals from 0 to 60 minutes, including, but not limited to, 10 seconds, 20 seconds, 30 seconds, 60 seconds, 5 minutes, 10 minutes, 15 minutes, 30 minutes, and 60 minutes. Ensure that the MVP logs and stores vehicle volume, occupancy, and speed data for a minimum of one day, regardless of the collection interval. Data storage within the MVP shall utilize a first in/first out architecture such that the oldest stored data record is overwritten with the newest data record when the storage device is at full capacity.

786-8.2.4.2 Remote Monitoring: Ensure that the VVDS operator can observe real-time detection activity by viewing the video output from the cameras, with the detection zones depicted as flashing overlays indicating the current detection status (on/off). Ensure that this real-time output also includes display of each zone's cumulative volume statistics, as dictated by operator preferences.

Ensure that the MVP can be polled for vehicle volume, occupancy, speed, and event alarm data. Ensure that the MVP can collect and store data locally at timed intervals and report the data to the TMC. During normal operation, ensure that the MVP can respond to each polling request by transmitting the most recently collected interval of traffic data to the device or application that initiated the request.

Should the communication link to the TMC be damaged or otherwise disconnected, ensure that the MVP stores collected data in its internal nonvolatile memory. Ensure that the data collected during the communication outage is made available for retrieval by TMC software once the link is restored.

Ensure that all MVP configuration settings and user preferences are savable in electronic format for storage on a PC.

786-8.2.4.3 Video Inputs and Outputs: Use an MVP that accepts input of NTSC composite video output of 1 Vp-p by way of BNC connectors.

Ensure that the MVP can transmit streaming video from the field site to the TMC based on the Joint Photographic Experts Group (JPEG) video compression standard, Moving Picture Experts Group-2 (MPEG-2), or another video compression standard acceptable to the Engineer. Ensure that the streaming video is recordable as a data file on a PC for later playback and editing, and is capable of transmission at a minimum communication link speed of 9.6 kbps.

786-8.2.4.4 Contact Closure Inputs and Outputs: Ensure that the MVP produces detection information both as contact closures emulating standard loop detector outputs and as accumulated statistical data output that is transmitted via the MVP's data port.

Ensure that contact closure emulation provides multiple programmable electrical outputs that change state when a vehicle is present within a detection zone (i.e., emulating the output of standard loop detector amplifiers). Ensure that the MVP can be configured to associate multiple detection zones to a single output and multiple outputs to a single zone.

786-8.2.4.5 Serial Interface: Ensure that the unit can transfer traffic parameter data from nonvolatile memory to the TMC using a standard EIA-232 communication port with a DB-9 connector.

786-8.2.4.6 Network Interface: Ensure that the MVP has an Ethernet communications interface that allows connection to multiple MVPs and remote network access to perform all functions normally accomplished through direction connection to the MVP.

Provide an RJ-45 connector on the MVP's front panel for network connection.

Ensure that the MVP is addressable, with the operator able to assign a unique address to the device during setup. Ensure that a MVP that shares a data connection with other MVPs responds only to data requests and commands that contain its unique address.

786-8.2.4.7 Configuration and Management:

786-8.2.4.7.1 Programming: Ensure that the MVP utilizes nonvolatile memory for storage of configuration information, collected traffic data, and MVP firmware. Configuration information consists of all user-definable parameters, including, but not limited to, detection zone placement; data acquisition and logging parameters; baud rate settings; data collection intervals; input and output configurations; and calibration settings. Ensure that the MVP retains its programming indefinitely in nonvolatile memory. Ensure that, once programmed, no periodic adjustments are required to the MVP unless physical roadway conditions are changed, as with lane shifts or closures.

Ensure that the MVP supports firmware updates through the serial port or by network download. Ensure that the firmware updates do not require the physical removal of hardware or disassembly of the MVP.

786-8.2.4.7.2 Monitoring: Ensure that the MVP can provide at least eight assignable outputs. Ensure that the MVP supports the number of camera inputs shown in the plans. Ensure that the MVP is able to provide at least eight detection zones for each VVDS camera. Ensure that the MVP contact closure outputs can mimic the operation of the zone to which they are associated.

786-8.2.5 Mechanical Specifications: Use an MVP that is shelf- and rack-mountable, or is contained in the camera's environmental enclosure.

Ensure that the shelf- and rack-mountable MVP fits in a standard EIA 19-inch rack and does not exceed 7 inches in height. Ensure that the MVP does not require shielding from other electronic devices, such as power supplies and communication equipment.

786-8.2.6 Central Monitoring Equipment: Ensure that the VVDS provides the capability for operator control and detection zone designation through the use of a PC having a keyboard and mouse.

Provide the VVDS operator with the ability to position the detection zones from the TMC or by using a laptop computer at the field site. Ensure that the detection zones can be drawn on the video image from the VVDS camera and rendered in varying sizes and shapes to allow for the best coverage of viewable roadway lanes, ramps, and shoulders. Ensure that it is possible to download, upload, save, and edit a particular camera's detection zone configurations from the TMC.

Ensure that a VGA computer monitor is able to display the video from the VVDS camera and the detection zones superimposed on the video image, along with individual vehicle actuations, in real time, as they occur.

Furnish the system with software that allows configuration, setup, data logging, and retrieval via direct and remote connection of a PC to the MVP. Ensure that the software allows the operator to perform any calibration necessary; set detector count periods; adjust detection sensitivity, communication addresses, baud rates, operational modes (i.e., pulse, presence, etc.), and output pulses; retrieve data; and utilize, operate, and adjust all features and functions of the VVDS. Ensure that the VVDS has the capability to provide long-loop, delay, and directional detection.

786-8.3 Installation of VVDS: Adjust the cameras and program the MVPs so all lanes have detection zones that generate data to the specified accuracy requirements. Ensure that the position, size and sensitivity of each detection zone are fully programmable from onsite or remote locations, and that the vehicle detection system retains its programming in nonvolatile memory for an indefinite time.

In cases where the proposed site for the MVP is more than 500 feet from the VVDS camera (i.e., a field cabinet housing that is not installed on the same structure as the camera), use fiber optic cable as specified in the plans as the communication medium. Select the type of interface device between the VVDS camera and fiber optic cable, and between the fiber optic cable and the MVP, depending on the specific camera output (i.e., video or serial data, or both).

Alternate communication media, such as wireless and cellular networks, may be considered by the Engineer on a project-by-project basis.

786-8.3.1 Camera Placement and Aiming: Install the VVDS camera at the minimum mounting heights described below. Verify that detection quality is not degraded due to excess movement and vibration of the assembly. Ensure that the cameras furnished are factory calibrated to conform to the performance specifications herein. Verify that any existing cameras utilized are compatible and properly configured. Do not use cameras that require further adjustment after initial setup, or that require periodic calibration.

Ensure that the VVDS manufacturer's representative is present to assist in the installation and setup process for each individual VVDS field site.

786-8.3.2 Roadside Camera Placement: Mount roadside VVDS cameras at a prescribed height, with the camera facing at an angle that will enable the cone of view to include the upstream and/or downstream traffic flow.

Verify that the height ratio to the closest point in the detection zone is 2 feet away for every 1 foot of camera mounting height; therefore, the preferred camera mounting height of 70 feet requires a minimum 140-foot distance to the closest detection area. The maximum distance from the camera is 5 feet to every 1 foot in height, or 350 feet away from the camera. Due to the use of the zoom feature for detection zone definition, the maximum mounting height of a camera is not limited as it relates to the field of view.

During installation, tilt the VVDS camera well below the horizon, then zoom to the detection area to eliminate environmentally generated glare and improve the camera's image.

Submit a graphical depiction of each camera site, its pole location, mounting height, the ratio of distance away from the camera versus the mounting height, the camera's mounting type (i.e., pole or structure), camera aiming procedures, and the placement of the proposed detection zone for each lane.

786-8.3.3 Over-the-Road Camera Placement: For mounts over the travel lane, place the camera at the preferable horizontal distance-to-mounting height ratio between 2:1 and 5:1 to count vehicles, and at a maximum ratio of 10:1 to detect the presence of vehicles only. The preferred mounting height over the travel lane shall be a minimum of 30 feet. The Engineer may consider alternate heights as recommended by the manufacturer.

Ensure that the VVDS cameras mounted over the road on mast arms or similar structures electronically dampen vibration so as to allow this type of installation.

786-9 Magnetic Traffic Detection System.

786-9.1 Description: Furnish and install a magnetic traffic detection system (MTDS) as shown in the plans and directed by the Engineer.

786-9.2 Materials: Provide a magnetic detector that is able to resolve closely spaced vehicles and reject adjacent lane vehicles. Ensure that the operator is able to select whether data is output as contact closures, mimicking standard loop detector outputs, or as accumulated statistical data using the detector's serial port.

At a 9,600-baud rate, the MTDS should meet the stated accuracy requirements applicable to data collected from each of four travel lanes in a given direction of travel in all prevalent traffic, weather, and lighting conditions. In addition, ensure that the MTDS also meets the following performance specifications:

1. The MTDS shall have a magnetic field of 0.2 to 0.8 oersted (Oe).
2. The unit's inductance (i.e., red to green wires) shall be 50 to 63 microHenries (μH) per probe, plus a nominal inductance of 16.5 μH per 100 feet of lead-in cable and 23 μH per 100 feet of home run cable.
3. The DC resistance between sensor leads (i.e., red to green wires) shall be 1.2 to 1.8 Ω per probe, plus a nominal resistance of 3 Ω per 100 feet of lead-in cable and 1.7 Ω per 100 feet of home run cable.
4. The DC resistance of each sensor lead to the earth at 500 V_{DC} shall be greater than 100 megohms (MΩ).
5. The transducer's gain (i.e., sensitivity) shall be 5 nanoHenries (nH) per millioersted (mOe) per probe at 0.4 Oe ambient field intensity.
6. The system's peak-to-peak drive current shall be 14 and 80 milliamperes (mA).

Ensure that the detector system is equipped with channel detect outputs and status output, plus fault and status light emitting diode (LED) indicators for each input channel.

Equip the detector system with a front panel that conforms to the EIA-232 communication port and 44 contact rear-edge connectors (i.e., 22 double-sided contacts). Ensure that the front of the detector is equipped with the appropriate switches, including a frequency selector switch, a reset switch, and mode/sensitivity switches.

Provide detector units that match the selected probes as part of the manufacturer's recommended detection assembly and that are compatible with the SunGuide[SM] software. Ensure that each detector has four detector inputs and has the ability to accommodate up to four probes per channel.

Ensure that the detector can self-tune to its detection zone with no external adjustments other than physical alignment. There shall be no external tuning controls of any kind.

Ensure that the system operator is able to view real-time traffic activity data from the TMC and is able to set the parameters for count periods, probe sensitivities, communication addresses, bit rates, modes of operation (i.e., pulse, presence, long loop, delay, or directional detection), output pulses, and enable power line filtering through use of the MTDS software.

Ensure that the detector system has a transceiver monitoring circuit that will change the output relay to the fail-safe position in the event of a component failure.

Ensure that the detector system can be rack-mounted and is compatible with requirements in the NEMA TS 1 and TS 2 standards for card racks, and with Model 170 and 2070 input files. Ensure that the MTDS has 44 contact edge connectors. Provide a detector with a separate rack-mounted card rack from the detector's manufacturer.

786-9.2.1 Detector Probe and Carrier: Ensure that the magnetic detector probe is a transducer that detects vehicles by converting changes in the vertical component of the earth's magnetic field to changes in inductance. One probe centered under each monitored lane shall be sufficient to provide the accuracy specified herein, except in projects where motorcycles must be detected. In these cases, determine the number of required probes according to the manufacturer's recommendations.

Ensure that the carriers hold the magnetic probes firmly under a lane in a fixed, vertical alignment and lateral position as they are inserted into conduits installed beneath the pavement. Ensure that the carrier's interlocking mechanism maintains the probe's alignment within ±20 degrees from vertical alignment. Install the probes within 3 inches of the desired carrier position.

Verify that probes may be easily repositioned or readjusted to improve vehicle-sensing accuracy or to reflect changing traffic characteristics in permanent installations or work zones. Determine the proper configuration for the probe sets based on the number of probes used, their depth, and the traffic or roadway characteristics.

786-9.2.2 Carrier, Conduit and Pull Box: Install the magnetic probes and carriers in a 3-inch nonferrous conduit. Provide the conduits under a separate pay item. Ensure that the conduit is polyvinyl chloride (PVC) Schedule 80 conduit, or its structural and dimensional equivalent in high density polyethylene (HDPE) pipe. Mechanical joints are allowed only if the carrier sections can slide freely over the joints.

Ensure that the pull box, provided for under a separate pay item, conforms to Section 635. Ensure that the pull box is a minimum of 2 feet in diameter, or a minimum of 2 feet square. The nominal depth for either square or round pull boxes shall be 3 feet.

Provide the home run and lead-in cables according to the MTDS manufacturer's recommendations. Equip the probes with a lead-in cable assembled by the manufacturer. Ensure that the lead-in cable's length is adequate to connect the probe to a splice at the pull box.

Ensure that up to four probes can be connected to the same lead. The lead-in cable shall be a maximum of 1,000 feet in length.

Connect the lead-in cables to the field cabinet with a four-conductor home run cable. Provide the kits to splice the probe's lead-in cables to the home run cables according to the MTDS manufacturer's recommendations. Ensure that each sensor's lead-in cable length allows sufficient, but not excessive, slack for splicing connections to the shielded home run cable at the pull box. Solder, insulate, and waterproof the splices using underground-rated splice kits with an encapsulation compound. Ensure that a combined home run and lead-in cable can have a length of up to 2,500 feet.

786-9.2.3 MTDS Cabling: Ensure that the lead-in cable is a polyurethane-jacketed cable with two PVC-insulated conductors and includes #22 AWG conductors.

786-9.3 Installation of MTDS: Install the magnetic traffic detector below the road's surface, employing horizontal directional drilling or other methods approved by the Engineer. Prior to drilling, furnish a sufficient number of bore logs at 5-foot intervals across the installation site to characterize the soils, sediments, clays, groundwater, and related subsurface conditions.

Install and maintain the MTDS probes as detailed in the plans without the need to close traffic lanes. Do not damage the road's surface or disturb the pavement in any way. Trenching may be utilized during installation in non-paved areas.

Prepare shop drawings that detail the complete MTDS, and all other components to be supplied and constructed. Provide detailed drawings with the exact location and placement of system components, and include the installation details for required cables. Install all cabling according to the manufacturer's recommendations.

Adjust and program the system components so that all lanes generate data meeting the required accuracy specifications. Follow the manufacturer's recommendations for setting the sensitivity, depending on the expected vehicle mix. Install all electrical and communication conduits as specified in the plans. Install the 3-inch conduit at a depth of 21 inches, ±3 inches, extending from under the road's surface to the roadside pull box as described herein. Provide the conduit separately, according to the manufacturer's recommendations. Extend the installed conduit 2 to 3.5 inches into the terminating roadside pull box to facilitate installation of the probes in their carriers.

Ensure that the conduit's vertical alignment does not vary more than 0.25 inch per 1 foot of the horizontal length. Ensure that the conduit slopes downward slightly to drain any accumulated water from the conduit. Install a removable cap on the conduit at the far end of the pull box. Drill a weep hole measuring 0.1875 inch in the cap's bottom, facing downward. After all connections are completed, enclose the conduit's end in the pull box with a filter material that will let water enter and escape while preventing soil sediment intrusion. Provide details of the spacing of the probes in the plans and adapted to any local conditions.

Ensure that the field cabinet's wiring is in accordance with the functions assigned to the vehicle detector module pins. Ensure that all conductor pairs in the field cabinet between the home run cable conductor pair terminations and the traffic detector card sensor input are twisted at six or more turns per 1 foot.

Neatly bundle, tie-wrap and label all cables. Label each lead-in cable, as well as its detector, with the lane number.

Use the installation kits required for inserting and removing the probes, labeling probe cables, and closing off conduit ends according to the manufacturer's recommendations. At the splice box, splice the home run cables to the detector probe lead-in cables, as specified in Subsection 786-9.2.2 herein and according to the probe manufacturer's recommended practices. Mechanically connect the spliced wires together by soldering. Seal the soldered cable assemblies with an encapsulating compound from the splice kit. Permanently label the lead-in and home run cables at both the splice and in the field cabinet. Splice the lead-in cable to the home run cable according to the manufacturer's recommendations to ensure a reliable connection in the environmental conditions encountered by the MTDS.

Mount and install the detector assembly so that movement and vibration of the assembly does not degrade detection quality. Ensure that the detectors are well calibrated to ensure that they perform as required. Ensure that no further adjustments or calibration will be required after the initial setup. During installation, measure the MTDS loop resistance, loop inductance, crosstalk, and inductance change for each probe array. Record these results for each set of sensors. Verify that the resistance between sensor leads does not exceed the following limits: leads shall have resistance of less than 2 Ω per probe; lead-ins shall have resistance of less than 3 Ω per 100 feet; and home run cables shall have resistance of less than 1.7 Ω per 100 feet. After verifying that each detector probe's loop resistance is within these acceptable limits, seal and encapsulate the splices using the manufacturer's recommended splicing kit and procedures. Check each probe set for continuity using an ohmmeter according to the probe manufacturer's recommendations.

786-10 Acoustic Vehicle Detection System.

786-10.1 Description: Furnish and install an acoustic vehicle detection system (AVDS) as shown in the plans and directed by the Engineer.

786-10.2 Materials: Ensure that a single AVDS acoustic detector is able to measure traffic flow parameters for five adjacent lanes on a lane-by-lane basis. Ensure that the acoustic detector works in both a side-fire (roadside) mounted configuration and in an overhead-mounted configuration.

Ensure that the detector can identify and distinguish acoustic signals from multiple approaching vehicles with a different signal level and a different wave front, or arrival angle.

Ensure that the acoustic detector can process in real time every received acoustic signal generated by passing or stationary (i.e., idling) vehicles. Ensure that the system produces detection information both as contact closures emulating standard loop detector outputs and as accumulated statistical data output that is transmitted via the AVDS' data port.

Provide an AVDS that emulates a dual-loop speed trap configuration for speed measurement. Ensure that the AVDS assembly includes relay contacts that close when a vehicle is present within the defined detection zone, and whose relay contacts can be connected to traffic controllers.

Ensure that the AVDS can accumulate short-term statistical data for each detected lane and transmit the data to the TMC after each data collection interval. Ensure that the AVDS can compute, store, and provide all required traffic parameter measurements per detection zone in user-selected time intervals from 2 to 180 seconds, including, but not limited to, 10 seconds, 20 seconds, 30 seconds, 60 seconds, 90 seconds and 120 seconds.

Ensure the acoustic detector resolves closely spaced vehicles and rejects adjacent lane vehicles.

Ensure that the AVDS is able to log and save data for up to 7 days, regardless of the data collection interval.

Ensure that detection quality is not degraded due to vibration or movement of the detector assembly due to wind or other factors.

Ensure that the acoustic detector is factory calibrated and able to perform as required herein. The unit shall not require periodic adjustment after initial setup and configuration.

Ensure that the AVDS equipment connections prevent reversed assembly or improper installations. Ensure that the AVDS does not produce false detection due to in-lane non-vehicle generated noise, or out-of-lane and off-road noise.

Ensure that the AVDS assembly meets the accuracy requirements detailed herein whether the sensor is mounted on a pole, mast arm, sign structure, bridge or overpass. Accuracy requirements are applicable to data collected from each of five lanes in a given direction of travel in all prevalent weather and traffic conditions, from free-flow to stop-and-go operations.

Verify that the AVDS is equipped with presence and passage detection modes.

Ensure that the AVDS has a minimum designed mean time between failures (MTBF) of 10 years, or 87,600 hours, while operating continuously in its application.

Ensure that the AVDS does not produce false detection due to in-lane non-vehicle generated noise, or out-of-lane and off-road noise.

786-10.3 Installation of AVDS: Ensure that the AVDS can be mounted on existing poles or sign structures, or on new poles, for a side-fire configuration. Utilize prestressed concrete or steel poles that comply with Section 641 and Section 649, respectively, and that can withstand sustained wind loads and gust factors according to the PPM and the Design Standards. The support structure and network communication infrastructure shall be paid for under separate pay items.

Verify that the acoustic detector setback distance and mounting height for the side-fire mounted configuration is set to produce the required detection accuracy from the lanes that need to be covered, according to the manufacturer’s recommendations. A 25- to 40-foot mounting height shall produce the degree of accuracy these specifications require. From a side-fire mounted position, taking into account the necessary clear zone, the detector’s required location for the production of data to the specified accuracy shall not exceed 40 feet.

Ensure that the acoustic detector is programmed so all lanes have detection zones generating data that meets the accuracy specifications.

786-11 Guaranty Provisions.

Ensure that the MVDS, including, but not limited to, the microwave detection sensor, the network interface devices, and all required cables, have a manufacturer’s warranty covering defects in assembly, fabrication and materials of two years from the date of final acceptance by the Engineer in accordance with 5-11 of all work to be performed under the Contract.

Ensure that the VVDS, including, but not limited to, the camera, mounting equipment and MVP, have a manufacturer’s warranty of five years from the date of final acceptance by the Engineer, in accordance with 5-11, of all the work to be performed under the Contract.

Ensure that the MTDS, including, but not limited to, the underpavement probes, carriers and detectors, have a manufacturer’s warranty of five years from the date of final acceptance by the Engineer in accordance with 5-11 of all work to be performed under the Contract.

Ensure that the AVDS has a manufacturer’s warranty covering defects in assembly, fabrication, and materials for a minimum of three years from the date of final acceptance by the Engineer in accordance with 5-11 of all work to be performed under the Contract.

If the manufacturers’ warranties for the detection systems and components are for longer periods, then those longer period warranties will apply.

Ensure that the manufacturer's warranty is fully transferable from the Contractor to the Department. Ensure that these warranties require the manufacturer to furnish replacements for any part or equipment found to be defective during the warranty period at no cost to the Department within 10 calendar days of notification by the Department.

786-12 Method of Measurement.

The detection system shall be measured for payment in accordance with the following tasks.

786-12.1 Furnish and Install: The Contract unit price for an MVDS, VVDS, MTDS or AVDS at each detection site, furnished and installed, will include furnishing, placement, and testing of all materials and equipment, and for all tools, labor, equipment, hardware, operational software package(s) and firmware(s), supplies, support, personnel training, shop drawings, warranty documentation, and incidentals necessary to complete the work.

786-12.2 Furnish: The Contract unit price for an MVDS, VVDS, MTDS or AVDS at each detection site, furnished, will include providing all equipment specified in the Contract Documents, plus all shipping and handling costs involved in delivery as specified in the Contract Documents.

786-12.3 Install: The Contract unit price for an MVDS, VVDS, MTDS or AVDS at each detection site, installed, will include placement and testing of all materials and equipment, and for all tools, labor, equipment, hardware, operational software package(s) and firmware(s), supplies, support, personnel training, shop drawings, warranty documentation, and incidentals necessary to complete the work. The Engineer will supply the equipment specified in the Contract Documents.

786-13 Basis of Payment.

Price and payment will be full compensation for all work specified in this Section. Payment will be made under:

Item No. 786-1	Microwave Vehicle Detection System (MVDS) – each.
Item No. 786-2	Video Vehicle Detection System (VVDS) – each.
Item No. 786-3	Magnetic Traffic Detection System (MTDS) – each.
Item No. 786-4	Acoustic Vehicle Detection System (AVDS) – each.