an output to traffic controllers or other devices that can generate volume, occupancy, and spot speed data (detection output).

660-2.2.2.1.1 Loop Wire: Use No. 12 AWG or No. 14 AWG stranded copper wire with Type XHHW cross-linked polyethylene insulation and an additional outer sleeve composed of polyvinylchloride or polyethylene insulation that meets the requirements of International Municipal Signal Association (IMSA) 51-7.

660-2.2.2.1.2 Shielded Lead-in Cable: Use No. 14 AWG two conductor, stranded copper wire with shield and polyethylene insulation, meeting the requirements for IMSA 50-2.

660-2.2.2.1.3 Splicing Material: Butt-end connectors may be used for splicing the loop wire to the lead-in cable. Butt-end connectors must be non-insulated. Use resin-core solder for soldered splices. Splicing tape must be self-fusing silicone rubber. Ensure insulated tubing used to cover splice is heat-shrinkable, cross-linked polyethylene with a silicon sealant inside the tubing and an insulation rating of at least 600 V.

660-2.2.2.2 Video: A video vehicle detection system (VVDS) uses one or more cameras approved by the manufacturer or an integrated thermal sensor and video analytics hardware and software to detect vehicle presence, provides a detection output, and generates volume, occupancy, and spot speed data.

660-2.2.2.3 Microwave: A microwave vehicle detection system (MVDS) transmits, receives, and analyzes a FCC-certified, low-power microwave radar signal to detect vehicle passage or presence, provide a detection output, and generate volume, occupancy, and spot speed data.

660-2.2.2.4 Wireless Magnetometer: A wireless magnetometer detection system (WMDS) uses one or more battery-powered wireless sensors embedded in the road surface, which communicates data by radio to a corresponding roadside receiver. Wireless magnetometer systems detect vehicle passage or presence and provide a detection output to traffic controllers or other devices that can generate volume, occupancy, and speed data.

660-2.2.2.5 Automatic Vehicle Identification (AVI): An AVI detection system uses one or more different methods to collect information that can be used to establish a unique identifier for each vehicle detected and the time and location that the vehicle was detected. AVI detection systems collect data using radio-frequency identification (RFID), optical character recognition, magnetic signature analysis, laser profiling, Bluetooth®, or other methods to establish vehicle identifier, time, and location.

660-3 Installation Requirements.

660-3.1 ~~Installation Requirements for all Detectors~~General: Install, configure, and demonstrate a fully functional vehicle detection system as shown in the Plans. Connect all field equipment to the existing communication network, and provide all materials specified in the Contract Documents. Install all equipment ~~according to~~in accordance with this Section and the manufacturer's recommendations.

Ensure that above-ground detectors can be mounted on existing poles or sign structures, or on new poles, as shown in the Plans. Furnish all equipment with the appropriate power and communication cables. Install the power cable and the communication cables ~~according to~~in accordance with the manufacturer's recommendation. Ensure that the cables comply with NEC sizing requirements and meet all other applicable standards, specifications, and local code requirements.

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Approval in a spec conveys some level of authority by agency or industry standard.

Commented [CF(9]: I might be mistaken. I thought AVI is only where a vehicle is equipped with an AVI transponder that provides the vehicle identification, whereas Bluetooth does not provide info about vehicle identification and just that one or more devices with MAC addresses are present.

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applicable standards of what?
Applicable specs of what?
Local code requirements for what?

Do not install communication cables in the same conduit or pull boxes as power cables carrying voltage greater than 24 V_{DC}/V_{AC} or current in excess of 1.5 amps.

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.

660-3.2 Inductive Loop Detector Installation: Install vehicle loops in accordance with the Contract Documents, the manufacturer's instructions, and Standard Plans, Index 660-001.

660-3.2.1 Inductive Loop-Detector Units: Adjust the operating frequency of each detector unit, if required, to prevent crosstalk of the units.

660-3.2.2 Saw Cuts: Use a chalk line or equivalent method to outline the perimeter of the loop on the pavement and routes for lead-in cables. Do not allow the saw cut in the pavement to deviate by more than 1 inch from the chalked line. Ensure that all saw cuts are free of any dust, dirt, or other debris and completely dry prior to installation of the loop wire, loop wire twisted pair lead, or lead-in cable.

Ensure that the top conductor of the loop wire or lead-in cable is a minimum of 1 inch below the final surface of the roadway.

660-3.2.3 Loop Wire: Ensure that all loops are wound in a clockwise manner and the first turn of the loop wire is placed in the bottom of the saw cut, with each subsequent turn placed on top of the preceding turn. Push the loop wire to the bottom of the saw cut with a non-metallic tool which will not damage the insulation.

Tag and identify the clockwise "lead" of each loop.

Use alternate polarity on adjacent loops.

Ensure that the hold down material is non-metallic, is placed in the saw slot using segments 1 to 2 inches long, spaced 12 inches apart, and that the distance from the top of the hold down material to the final surface of the roadway is not less than 1-1/2 inches.

660-3.2.4 Loop Wire Twisted Pair Lead: Create a loop wire twisted pair lead by twisting the loop wire pair a minimum of 10 turns per foot to form a loop wire twisted pair lead from the edge of the loop to the pull box located adjacent to the roadway. Place only one loop wire twisted pair lead in a saw cut. Ensure that the distance between a twisted loop wire pair lead within the roadway is a minimum of 6 inches from any other twisted loop wire pair lead or loop, until they are within 1 foot of the edge of pavement or curb, at which point they may be placed closer together.

Provide a minimum of 3 feet of twisted loop wire pair lead in the pull box located adjacent to the roadway. Do not route twisted loop wire pair lead directly through conduits to the cabinet, unless otherwise shown in the Plans.

660-3.2.5 Loop Sealant: Do not use expired products. Prepare and apply loop sealant in accordance with the manufacturer's instructions. Ensure that the loop sealant has cured completely before allowing vehicular traffic to travel over the sealant.

660-3.2.6 Shielded Lead-in Cable: Place the lead-in cable in the bottom of the saw cut. Do not damage the insulation.

Install no more than four lead-in cables in a saw cut. Ensure that the hold down material is not longer than 1 inch and that the distance from the top of the hold down material to the final surface of the roadway is not less than 1-1/2 inches.

660-3.2.7 Splicing: Perform the splicing in a pull box located off the roadway, not in the roadway itself.

Splice the black conductor of the lead-in cable to the clockwise "lead" of the loop.

Ensure that the ends of the cable jackets, twisted pair, and lead-in are encased in the loop splice material.

Ensure that each loop has an individual return to the cabinet and series splicing is performed on a separate terminal block in the cabinet.

660-3.2.8 Terminations: Using insulated terminal lugs, terminate lead-in cables or twisted pair loop wire on a terminal strip, which is located in the controller or detector cabinet. Use a calibrated ratchet type crimping tool to attach the lugs to the conductors of the lead-in cable or twisted loop wire.

660-3.2.9 Loop Assembly Identification: Identify and tag each loop assembly in the controller or detector cabinet by lane and movement number.

660-3.2.10 Inductive Loop Detector Testing and Turn-on:

660-3.2.10.1 Series Resistance: Obtain Department of Transportation Traffic Signal Resistance Measurement Data Sheets from the Engineer. Measure and record the series resistance of each loop assembly on these data sheets. Leave a copy in the controller cabinet.

If the series resistance of a loop assembly is greater than 10 Ω, inspect the loop assembly to find the cause of the excessive resistance. Correct the cause of the excessive resistance at no additional cost to the Department.

660-3.2.10.2 Insulation Resistance: Measure and record the insulation resistance of each loop assembly and verify that the resistance is greater than 100 MΩ. Use a 500 V_{DC} insulation tester to measure the resistance. Reference all measurements to a good earth ground (ground rod, metallic water pipe, etc.). Disconnect the transient suppression devices from the loop assemblies before taking any measurements. If the insulation resistance is less than 100 MΩ, determine if the lead-in cable or the loop wire is causing the problem, and replace the defective cable or loop wire at no additional cost to the Department.

660-3.2.10.3 Loop Detector Turn-on: Connect the loop assemblies to the appropriate inductive loop vehicle detectors and tune the detectors in accordance with the manufacturer's instructions. Separate the operating frequencies of vehicle detectors, in adjacent lanes, by at least 2 kHz. Verify operation in accordance with 660-2.2.1.

660-3.3 Video Detector Installation: Install cameras and configure detection zones and settings in accordance with the Contract Documents, manufacturer's recommendations, and as directed by the Engineer. Submit configuration settings (including, but not limited to, detector names, communication settings, and output assignments) and configuration file backups to the Engineer. 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.

Do not use coaxial cable runs in excess of 500 feet. Mount and aim cameras in a manner that eliminates as much environmentally generated glare as possible.

660-3.4 Microwave Detector Installation: Install detector and configure detection zones and settings in accordance with the Contract Documents, manufacturer's recommendations, and as directed by the Engineer. Submit configuration settings (including, but not limited to, detector names, communication settings, and output assignments) and configuration file backups to the Engineer.

660-3.5 Wireless Magnetometer Installation: Install in accordance with the Contract Documents, manufacturer's recommendations, and as directed by the Engineer. Ensure that materials used for the installation of magnetometers in the road surface have cured completely before allowing vehicular traffic to travel over them.

660-3.6 AVI Detector Installation: Install in accordance with the Contract Documents, manufacturer's recommendations, and as directed by the Engineer.

660-3.7 Wrong Way Vehicle Detection Systems (WWVDS) Installation: Install in accordance with the Contract Documents, manufacturer's recommendations, and as directed by the Engineer.

660-4 Acceptance Testing.

660-4.1 Vehicle Presence Detection System:

660-4.1.1 Performance Requirements: Ensure presence detectors provide a minimum detection accuracy of 98%.

660-4.1.2 Field Acceptance Testing: Verify presence detection accuracy at installed field sites using a reduced method in accordance with 995-2.8.1. Compare sample data collected from the detection system with ground truth data collected by human observation. For site acceptance tests, collect samples and ground truth data for each site for a minimum of five minutes during a peak period and five minutes during an off-peak period. For presence detection at signalized intersections, ensure there are a minimum of three detections for each signal phase. Perform site acceptance tests in the presence of the Engineer.

660-4.2 Traffic Data Detection System:

660-4.2.1 Performance Requirements: 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.

660-4.2.2 Field Acceptance Testing: Verify detector data accuracy at installed field sites using a reduced method similar to those described in 995-2.9.1. Compare sample data collected from the detection system with ground truth data collected by human observation. For site acceptance tests, collect samples and ground truth data for each site for a minimum of five minutes during a peak period and five minutes during an off-peak period. Perform site acceptance tests in the presence of the Engineer.

660-4.3 Probe Data Detection System:

660-4.3.1 Performance Requirements: Ensure that probe data detectors establish a unique and consistent identifier for each vehicle detected and the time and location that the vehicle was detected. Ensure that probe detectors provide a minimum penetration rate of 75%. Ensure probe data detection systems that match upstream and downstream detection of the same vehicle provide a minimum match rate of 5%. Ensure probe data detection systems meet a minimum total roadway segment speed and travel time accuracy level of 90%. Verify system performance over several time periods under a variety of traffic conditions as described in 995-2.9.1.

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660-4.3.2 Calculation of Speed and Travel Time Accuracy: Verify detector accuracy at installed field sites using a reduced method in accordance with 995-2.10. Calculate speed and travel time accuracy by comparing the speeds and travel times reported by the system against ground truth collected through human observation or another method approved by the Engineer.

660-4.4 Wrong Way Vehicle (WWVDS) Detection System: Submit a test plan for the field acceptance test (FAT) to the Engineer for approval. The test plan must include a detection accuracy test and false positive test for each location in the project. The Engineer reserves the right to witness all FATs.

660-5 Warranty.

Ensure that the detection system has a manufacturer's warranty covering defects for a minimum of 2 years from the date of final acceptance by the Engineer in accordance with 5-11 and Section 608.

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Ensure the warranty includes providing replacements, within 10 calendar days of notification, for defective parts and equipment during the warranty period at no cost to the Department or the maintaining agency.

660-6 Method of Measurement.

The Contract unit price for each inductive loop detector and per assembly for loop assembly will include all equipment, materials as specified in the Contract Documents, and all labor, equipment, and miscellaneous materials necessary for a complete and accepted installation.

The Contract unit price for each component of an MVDS, VVDS, WMDS, AVI or WWVDS will include furnishing, placement, and testing of all materials and equipment, and for all tools, labor, equipment, hardware, operational software packages and firmware, supplies, support, personnel training, shop drawings, warranty documentation, and incidentals necessary to complete the work.

Activation of highlighted signs installed as a component of an WWVDS will be included in the cost of the detection system. The highlighted sign and incidentals related to the sign will be paid for separately. Only one WWVDS will be paid per exit ramp, regardless of the number of signs or components used.

660-7 Basis of Payment.

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

Item No. 660-1	Inductive Loop Detector – each.
Item No. 660-2	Loop Assembly – per assembly.
Item No. 660-3	Vehicle Detection System - Microwave – each.
Item No. 660-4	Vehicle Detection System – Video – each.
Item No. 660-5	Vehicle Detection System – Wireless Magnetometer – each.
Item No. 660-6	Vehicle Detection System - AVI – each.
Item No. 660-7	Vehicle Detection System - WWVDS – each.

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