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781 INTELLIGENT TRANSPORTATION SYSTEMS–MOTORIST INFORMATION SYSTEMS.

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

SECTION 781
INTELLIGENT TRANSPORTATION SYSTEMS
MOTORIST INFORMATION SYSTEMS

781-1 Description.

Furnish and install Motorist Information Systems meeting the general requirements of 781-2, the specific requirements for each system as defined in 781-3 through 781-6 of this specification, and in accordance with the details specified in the Contract Documents.

781-2 Materials.

Ensure that all materials furnished, assembled, fabricated, or installed are new products and approved by the Engineer.

781-3 Dynamic Message Sign.

781-3.1 Description: Furnish and install a dynamic message sign (DMS) in accordance with the details specified in the Contract Documents.

781-3.1.1 General: Ensure that all exposed material is corrosion resistant. Ensure that the electronic equipment associated with the DMS remains secure from damage and protected from moisture, dust, dirt, and corrosion.

Ensure that ambient magnetic or electromagnetic fields, including those created by any system components, have no negative effects on system performance. Ensure that the system does not conduct or radiate signals that interfere with other electrical or electronic equipment including, but not limited to, other control systems and data processing, audio, radio, and industrial equipment.

Ensure that the DMS housing complies with the fatigue resistance requirements of the fourth edition (2001) AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals with current addendums. Design and construct the DMS unit for continuous usage of at least 20 years and the sign structure for a 50-year design life.

Ensure that the DMS is fabricated, welded, and inspected in accordance with the requirements of the current ANSI/AWS Structural Welding Code-Aluminum. Ensure that all identification markings on the DMS and its components, including but not limited to panels, terminal blocks, and printed circuit boards, are silk-screened and sealed or otherwise indelible using material and methods approved by the Engineer. Ensure that equipment design and manufacturing utilizes the latest available techniques with a minimum number of different parts, subassemblies, circuits, cards, and modules to maximize standardization and commonality. Ensure that the equipment designed includes provisions for access and maintenance without special tools. Ensure that all component parts are readily accessible for inspection and maintenance. Provide labeled test points for checking essential voltages. Ensure that all external connections are terminated using connectors. Key the connectors to preclude improper hookups.

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Provide a clear removable cover measuring 0.125 inch thick to cover all exposed power terminals. Ensure that the covers do not interfere with sign functions or maintenance operations.

781-3.1.2 Sign Housing: Ensure that the external skin of the DMS housing is constructed of aluminum alloy 5052 H32 that is a minimum of 0.125 inch thick. Ensure that the sign housing design and appearance is approved by the Engineer. If cable attachments are used in the sign housing, the cables shall be securely clamped using a method approved by the Engineer. No adhesive attachments shall be allowed.

Ensure that exterior seams and joints, except the finish coated face pieces, are continuously welded using an inert gas welding method. Limit the number of seams on the top of the housing to a maximum of three. Stitch weld the exterior housing panel material to the internal structural members to form a unitized structure.

Ensure that exterior mounting assemblies are fabricated from aluminum alloy 6061 T6 extrusions a minimum of 0.1875 inch thick.

Provide mounting brackets on the sign housing that permit adjustment of the housing's vertical alignment from 0 to 10 degrees down in one-degree increments to optimize the viewing angle. Ensure that these vertical adjustments to the position of the sign housing do not require the removal of the housing from the support structure in order to achieve a different vertical orientation.

Ensure that the bottom panel of the sign housing includes a minimum of four drain holes with replaceable plugs that serve to open and close the drain. Ensure that the drain holes are centered from the front to the back of the housing, and equally spaced across the housing's full length. Ensure that all drain holes and other openings in the sign housing are screened to prevent the entrance of insects and small animals. Ensure that the bottom panels are sloped towards the drain holes to prevent water accumulation on the interior surfaces of the sign bottom.

Ensure that the top of the DMS housing includes multiple steel lifting eyebolts or equivalent hoisting points. Ensure hoist points are attached directly to structural frame members by the DMS manufacturer. Ensure hoist points are positioned such that the DMS remains level when lifted. Ensure that the hoist points and DMS frame allow the DMS to be shipped, handled, and installed without damage.

781-3.1.2.1 Interior Structure: Ensure that framing structural members are constructed of aluminum alloy (6061 T6 or 6063 T5) a minimum of 0.1875 inch thick.

Construct the sign housing with a minimum width of 34 inches Provide an interior walkway with a minimum width of 2 feet. Ensure that the walkway area maintains a minimum of 2 feet of horizontal clear area and 6 feet of clear height along the sign housing's entire length. Fabricate the walkway from diamond tread plate 6061-T6 or 3003-H22 aluminum that is 0.125 inch thick. Finish all edges of the walkway to eliminate sharp edges or protrusions.

781-3.1.2.2 Housing Face: Ensure that housing face consists of internal structural members, external fascia panels, and lens panel assemblies. Do not allow exposed fasteners on the housing face.

781-3.1.2.2.1 Internal Structural Members: Ensure that internal structural members are constructed of extruded aluminum and accommodate both display module mounting and air distribution. Ensure that the internal structural members retain the display modules in a manner that facilitates the easy and rapid removal of each display module from within the sign without disturbing adjacent display modules.

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781-3.1.2.2.2 External Fascia Panels: Ensure that the external fascia panels are constructed using aluminum. Ensure fascia panels incorporate provisions for retaining the modular lens panels. Include a gasket track in the panel for a closed-cell resilient gasket to seal the modular lens panels. Finish each fascia panel with a matte-black coating system that meets or exceeds American Architectural Manufacturers Association (AAMA) Specification No. 2605. Ensure that the external fascia perimeter panels are a minimum of 1 foot wide. Ensure that external fascia interline panels are a minimum of 9 inches wide.

781-3.1.2.2.3 Lens Panel Assembly: Provide lens panel assemblies that are modular in design, interchangeable without misalignment of the lens panel and the LED pixels, and that are removable from within the main sign housing. Ensure that lens panels consist of a mask constructed of 0.080 inch minimum thickness aluminum with a matte black coating that meets or exceeds AAMA Specification No. 2605 with a minimum thickness of 0.04 inch. Ensure that the mask is perforated to provide an aperture for each pixel on the display module. Ensure that the aperture is as small as possible, without blocking the LED output at the required viewing angle.

Ensure that the lens panel includes a clear polycarbonate layer placed behind the mask to protect and seal the LEDs and other internal electronics from the environment. Ensure that the clear polycarbonate is laminated and sealed to the inside surface of the lens panel's aluminum mask using an adhesive joining system to form the lens panel assembly and that the clear polycarbonate used to construct the lens panel is 90% ultraviolet (UV) opaque. The Engineer may approve alternate designs.

781-3.1.2.3 Sign Housing Surface Finish: Ensure that all sign face surfaces are finished with a matte black FP-based coating system that meets or exceeds AAMA Specification No. 2605. Provide certification that the sign face parts are coated with the prescribed thickness. Ensure all other exterior and all interior housing surfaces are a natural aluminum mill finish. No interior painted surfaces will be allowed.

781-3.1.2.4 Sign Housing Access Door: Provide a three-point, lockable, aluminum access door at the end of the housing, as depicted in the plans, to permit easy access to the walk-in housing. The access door shall be a minimum height of 80 inches and a minimum width of 2 feet. Outfit the door with a handle-operated locking mechanism, closed-cell neoprene gasket, and stainless steel hinges.

Furnish a locking mechanism that is a Grade 1 three-point, center-case dead bolt lock conforming to ANSI/BHMA Standard A156.2 and having a zinc finish. Provide a handle on both the inside and outside of the door. These handles shall be heavy duty and industrial strength with a zinc finish on the inside handle and a chrome finish on the outside handle. Include a device in the door assembly to hold the door open at 90 degrees. Ensure that the door is monitored electronically by the sign controller and provides an alert to transportation management center (TMC) personnel whenever the door is opened.

781-3.1.2.5 Sign Housing Ventilation System: Provide a ventilation system that distributes air over all LEDs, power supplies, and communication devices inside the sign housing. Ensure that air circulation is evenly distributed across display modules in each message line, in the cavity between each display module, across lens panels and the back of the display modules. Submit ventilation system design calculations to the Engineer for approval.

Ensure that air drawn into the sign is filtered before reaching the ventilation system fans. Ensure that filters remove airborne particles measuring 500 microns in diameter and larger.

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Ensure that the airflow status for each fan and filter is automatically tested once each day, and that it may be tested on command from the TMC or a laptop computer. Ensure that the sign controller will send an error message to the TMC or a laptop computer when a failure occurs. Ensure that the sign is capable of operating without any decrease in performance over an ambient operating temperature range of -29° to 165°F as per NEMA TS 4, Subsection 2.1.5.1, with a maximum relative humidity of 100%.

Ensure that the DMS includes a fail-safe ventilation subsystem that includes a snap disk thermostat that is independent of the sign controller. Preset the thermostat at 130°F. If the sign housing's interior reaches 130°F, the thermostat will override the normal ventilation system, bypassing the sign controller and turning on all sign ventilation fans. The fans will remain under the control of the thermostat until the internal sign housing temperature falls to 115°F, at which time the fail-safe subsystem will return control of the ventilation system to the sign controller.

Ensure that the sign includes a manual override timer switch located just inside the access door to manually activate the ventilation system. The switch must be adjustable up to four hours.

Ensure that the sign includes a sensor or a sensor assembly to monitor airflow volume to predict the need for a filter change. Ensure that the ventilation system fans possess a 100,000-hour L10 life rating.

781-3.1.2.6 Sign Housing Temperature Sensor: Ensure that the sign controller continuously measures and monitors the temperature sensors. When a temperature is greater than the user-selectable critical temperature, ensure that the sign message will go blank and an error message will be sent to the TMC or a laptop computer when polled. Ensure that the user-selectable, critical temperature may be changed by the TMC or a laptop computer. Ensure that the TMC and laptop computer will read all temperature measurements from the sign controller. When the sign reaches a temperature that is 2°F lower than the critical high temperature, ensure that the sign controller will decrease the LED intensity to half its normal brightness.

781-3.1.2.7 Sign Housing Humidity Sensor: Ensure the sign includes a humidity sensor that detects from 0 to 100% relative humidity in 1% or smaller increments. Ensure that the sensor will operate and survive in 0 to 100% relative humidity, and has an accuracy that is better than ±5% relative humidity. A humidistat is not acceptable.

781-3.1.2.8 Photoelectric Sensor Devices: Ensure the sign electronics monitor ambient light using a minimum of three photocells. Ensure that the photocells are placed so they measure light levels on the front and rear of the sign, and ambient light conditions at the sign location. Ensure that the devices provide accurate ambient light condition information to the sign controller for automatic light intensity adjustment. Ensure that the automatic adjustment of the LED driving waveform duty cycle occurs in small enough increments that the sign's brightness changes smoothly, with no perceivable brightness change between adjacent levels. Ensure that stray headlights shining on the photoelectric sensor at night do not cause LED brightness changes.

Supply the DMS with a brightness-versus-ambient light matrix table with algorithms and/or other means of calculation that enables the sign to automatically adjust LED output according to ambient light level. Ensure the sign controller monitors the photocell circuits in the sign and correlates the readings with the brightness table to convert the measured light intensity into the desired pixel brightness. Ensure that the brightness table has a

minimum of 255 levels. Ensure that the brightness table in each individual sign controller is adjustable from the TMC or a laptop computer, and can be customized according to each installation site's requirements. Ensure that the sign controller automatically controls the pixel brightness to compensate for differences in ambient light levels, such as the differences in day and night. In addition to the automatic mode, ensure that the brightness may be set from 1% to 99% in 1% increments manually from the front panel of the sign controller and remotely from the TMC.

Ensure that the brightness and color of each pixel is uniform over the sign's entire face within a 15-degree viewing angle from 200 to 1,100 feet in all lighting conditions. Non-uniformity of brightness or color over the sign's face shall be cause for rejection of the sign.

781-3.1.2.9 Sign Housing Internal Lighting and Electrical Outlets: Furnish the sign housing with a minimum of four internal fluorescent or incandescent light fixtures. Near the door, locate a 12-hour timer without a hold feature for the lights.

If incandescent lamps are provided, ensure that they are spaced evenly above the walkway and fully enclosed in heavy-duty shatterproof, protective fixtures. Ensure that incandescent fixtures include aluminum housing and base, a porcelain socket, and clear glass inner cover. Ensure that all removable components are secured with set screws.

If fluorescent lamps are provided, ensure that the fixtures are spaced evenly above the walkway and fitted with protective guards.

Ensure that the sign housing includes emergency lighting that automatically illuminates the interior in the event of a power outage.

Ensure that the light produced from internal lighting is not visible from outside the sign during nighttime or other dark conditions and does not interfere with normal visible operation of the sign.

Equip each sign housing with at least three 15-amp, 120-volt rated ground fault interrupter (GFI) outlets that include protected duplex electrical receptacles. Locate one duplex receptacle at each end of the sign housing and one at the center of the sign housing. Space the duplex receptacles evenly on the rear wall of the housing at a maximum height of 3 feet above the walkway.

781-3.1.3 Display Modules: Provide display modules manufactured by one source and fully interchangeable throughout the manufacturer's sign system(s). Ensure that all addressing is automatic upon cable connection and power-up. Ensure that the display modules are connected to the sign controller via a single control cable common to each line of display modules or by an alternate method approved by the Engineer. Ensure that removal or replacement of a complete display module or LED board can be accomplished without the use of any tools.

Ensure that the Engineer approves the design and structural calculations of the spacing between the display module and the DMS lens panel. Ensure display modules contain solid-state electronics needed to control pixel data and read pixel status.

781-3.1.3.1 Line Matrix Display Module: Assemble display modules in a line matrix configuration consisting of three lines of 25 display modules per line. Ensure each line consists of an array, 7 pixels high by 125 pixels wide, allowing an 18-inch-high display of 5 pixel by 7 pixel characters per line with double-column spacing between the characters. Ensure that the line matrix display module includes an LED board containing a minimum of 35 pixels in a 5 pixel by 7 pixel configuration capable of displaying 18-inch dot matrix characters.

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781-3.1.3.2 Full Matrix Display Module: Assemble display modules to form a full matrix configuration consisting of three lines of 25 display modules per line providing an arrangement of 27 pixels by 125 pixels. Ensure that the display will allow an 18-inch-high display per line with 5 pixel by 7 pixel characters and double-column spacing between the characters. Ensure that the full matrix display module includes an LED board containing 45 pixels arranged uniformly in 5 columns of 9 pixels each to form a 5 pixel by 9 pixel array capable of displaying 18-inch dot matrix characters.

781-3.1.3.3 LED and Pixel Specifications: Ensure that the DMS utilizes amber, three-quarter diode LED lamps with a minimum viewing angle of 15 degrees and a peak wavelength of 590 nanometers. Ensure that the LED peak wavelength output varies no more than ±2 nanometers. Ensure that the LED pixel cone of vision is a minimum of 15 degrees (centered around the optical axis, or zero point, of the pixel). The cone perimeter is defined by the point where light output intensity is 50% of the intensity measured at the zero point of the pixel.

Ensure that each pixel has a diameter of 1.5 inches, ±10%, and that the LEDs in each pixel are clustered to maximize long-range visibility. Ensure that all pixels in all signs in a project, including operational support supplies, have equal color and on-axis intensity. Ensure that each pixel's on-axis intensity is a minimum of 40 candelas when operating at 100% intensity. Measure the brightness of each LED in accordance with the International Commission on Illumination's (CIE) requirements as detailed in Test Method A of the CIE 127 (1997) standard. Provide the LED brightness and color bins that are used in each pixel to the Engineer for approval. Provide a letter of certification from the LED manufacturer that demonstrates testing and binning according to the CIE 127 (1997) standard.

Ensure each pixel contains two interlaced circular strings of LEDs powered from a regulated power source providing a maximum of 25 volts of direct current (V_{DC}). Ensure that LED power current is maintained at 25 milliamperes, ±2 milliamperes. Ensure that LED failure in one string within a pixel does not affect the operation of any other string or pixel. Do not exceed 1.5 watts per pixel for power drawn from a direct current (DC) supply, including the driving circuitry.

Provide a pixel test as a form of status feedback to the TMC from the local sign controller. Ensure that the operational status of each pixel in the sign can be automatically tested once a day. The operational status may also be tested when the TMC or a laptop computer prompts a pixel test. Ensure that a log file can be created containing a list of defective pixels as transmitted to the TMC or a laptop computer. Ensure that the log file includes the pixel status, module number, column number, and pixel number. Ensure that the pixel status test determines the functional status of the pixel as stuck-on or stuck-off and does not affect the displayed message for more than half a second.

Ensure that LEDs are individually mounted directly on a PCB, and are individually removable and replaceable using conventional electronic repair methods. Do not use pixels in which the LEDs are encapsulated.

781-3.1.3.4 Optical, Electrical, and Mechanical Specifications for Display Modules: Ensure that each display module contains connectors for power, controls, and data; contains display module control electronics and memory elements; and provides the signals to switch the LED pixels.

Ensure the display modules are rectangular and have an identical vertical and horizontal center-to-center distance (i.e., pitch) between adjacent pixels ranging from 2.6 inches to 2.75 inches. Ensure that the separation between the last column of one display

module and the first column of the next module is equal to the horizontal distance between the columns of a single display module.

Ensure that the LED circuit board is a NEMA FR4-rated, single 0.062-inch, flat black PCB having an extruded aluminum frame and will hold the supporting control electronics. Ensure that alternate LED board configurations are submitted to and pre-approved by the Engineer prior to installation. Ensure that PCBs enable components to be removed and replaced without damage to boards, traces, or tracks. Ensure that the intercomponent wiring is a copper-clad track having a minimum weight of 2 ounces per square foot with an adequate cross section for carrying circuit current. Ensure that a maximum of two PCB jumper wires are used from plated through-holes to the component. Finish all PCBs with a solder mask and a component-identifying silk screen.

Provide all PCBs, except for the LED motherboard and power supply PCBs, with a complete and conformal coating of silicone resin with a minimum thickness of 0.01 inch. Provide the LED motherboards with a complete conformal coating of silicone resin with a minimum thickness of 0.01 inch, except for the pixels on the front of the PCB. Meet the material requirements of MIL-I-46058C Military Standard, United States Department of Defense (USDOD).

Mount all LEDs so that the mechanical axis of the LED is ±1 degree to the sign's face to ensure uniformity of brightness over the sign's face. Each pixel shall have a device attached to the PCB to hold and protect the LEDs. Ensure that the devices hold the LEDs perpendicular to the display module within 0.5 degree and may be easily removed from the display module PCB without tools. Ensure that the devices do not block air flow to the LED leads or block the LED light output at the required viewing angle. Ensure that the devices are black in color.

Ensure that the voltage to the LED modules and their associated electronics does not exceed 25 V_{DC}. Ensure that there are a minimum of two, and a maximum of four, power supplies that are wired in a parallel configuration for redundancy. Ensure that multiple power supplies are used to provide power to each display module. Ensure the voltage measured at the display modules does not vary more than 50 millivolts over all the display modules in the sign with 17 pixels on at 100% intensity in each display module. Ensure that if one supply completely fails, the sign shall still be supplied with enough power to run 40% of all pixels at a 100% duty cycle with an ambient operating temperature of 165°F. Ensure that the supplies have a current sharing capability that allows them to provide equal amounts of current to their portion of the LED display.

Ensure that the sign controller continuously measures and monitors all LED module power supply voltages and provides the voltage readings to the TMC or a laptop computer on command. Ensure that an error message will be sent to the TMC or a laptop computer when it polls the sign controller if voltages measured are outside nominal values.

Ensure that LEDs are protected from external environmental conditions, including moisture, snow, ice, wind, dust, dirt, and UV rays. Do not use hoods, louvers, cylinders or visors that could impede the free flow of air over any surface of each individual LED. Do not use epoxy to encapsulate the LEDs.

781-3.1.4 Character Displays: Ensure that the signs are capable of displaying American Standard Code for Information Interchange (ASCII) characters 32 through 126, including all uppercase and lowercase letters and digits 0 through 9, at any location in the message line.

Ensure that the uppercase alphanumeric characters are displayed over the complete height of the matrix. Submit a list of the character fonts to the Engineer for approval.

Characters must be legible under all light conditions at a distance ranging from 200 to 1,100 feet within the 15-degree cone of vision centered on the pixel's optical axis. Ensure that the operator is able to display compressed (i.e., 4 pixel by 7 pixel), expanded (i.e., 6 pixel by 7 pixel), or double-stroke (i.e., 7 pixel by 7 pixel) character fonts, and to change the default spacing between characters. Ensure that the spacing options include 1-, 2-, or 3-pixel columns between the characters. Have the system supervisor assign font access privileges. Ensure that the sign controller is capable of a self-updating time, temperature, and/or date display on the sign.

Ensure that the sign controller allows a moving arrow to be displayed on one line with a standard message on the other lines. Ensure that the moving arrows may be shown moving from the left or right, and starting from one end or in the middle of the sign and continue to the end of the sign.

781-3.1.5 Main Power Supply and Energy Distribution Specifications:

Provide a nominal single-phase power line voltage of 120/240 V_{AC} protected by one 60-amp, two-pole (i.e., common trip) main circuit breaker for the sign and its controller. Ensure that the system operates within a voltage range of 97 to 135 V_{AC} as specified in NEMA TS 4, Subsection 2.1.3.1.

Ensure that all service lines inside the sign housing are supplied by 120 V_{AC} independently protected by a thermomagnetic circuit breaker at the sign housing's entry point. Locate all 120 V_{AC} wiring in conduit, pull boxes, raceways, or control cabinets as required by the NEC. Ensure that no 120 V_{AC} wiring is exposed to the inside or outside of the sign housing. Do not use the sign housing as a wiring raceway or control cabinet.

Ensure that the sign and its controller have an operating frequency of 60 hertz (Hz), ±3.0 Hz, as stated in NEMA TS 4, Subsection 2.1.3.2. Ensure that the drop in the unit's voltage between no-load and full-load during normal operations does not exceed 10% of the nominal voltage. Provide power protection through the use of a thermomagnetic circuit breaker connected to a 5-milliampere GFI device that protects all service outlets. Provide a 100-amp 120/240 V_{AC} two-pole load center with a 20-circuit capability. Provide separate circuit breakers for each sign circuit.

Provide Type XHHW power cables sized as required by the NEC for acceptable voltage drops while supplying alternating current to the sign. Ensure that the sign power consumption does not exceed 7,000 watts under any circumstance, including operation of the fans, heaters (if provided within the sign), sign controllers and communication equipment, and all pixels illuminated at 100% brightness.

Provide protection devices such as surge suppressors and lightning arrestors installed or incorporated in the DMS by the manufacturer to guard against lightning, transient voltage surges, and induced current. Ensure that the protection devices meet or exceed the device protection requirements as contained in Section 785-2. Use protection devices on all electric power and data communication connections.

Ensure that the DC and AC voltage ratings and dissipation factors of capacitors used in the DMS exceed the worst-case design parameters of the circuitry by 50%. Ensure that capacitors are mechanically supported by a clamp or fastener that is resistant to cracking, peeling, and discoloration.

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Ensure that resistors used in the DMS are within 5% of the tolerance of the specified temperature range and, when operated in excess of 50% of its power rating, have an adequate heat sink.

Ensure all transistors, integrated circuits, and diodes are a standard type, listed by the EIA, and clearly identifiable.

781-3.1.6 Uninterruptible Power Supply: Provide each DMS with an uninterruptible power supply (UPS) capable of maintaining and continuing the operation of the sign and its related communication device for a minimum of two hours. Provide sealed AGM type batteries that are maintenance free.

781-3.1.7 Operational Support Supplies: Furnish the operational support supplies listed in the table below. Promptly replace any of the supplies used to perform a warranty repair.

For every group of 10 or fewer signs provided or required, provide 1 set of supplies as follows:

1 each	Sign Controller
3 each	LED Display Modules
3 each	Uninterruptible Power Supplies
1 each	System Interface Circuit
1 each	Cable for connecting interface circuits to daughter boards
1 each	Display Module Power Cable
2 each	Surge Suppression Sets
1 each	Fan Assembly
1 each	Time Relay for Fan Control
10 each	Every Small Fuse (< 10 amp)
2 each	Every Large Fuse (> 10 amp)
1 each	Sensor for each type of sensor

The Engineer will review and approve the operational support supplies list.

781-3.1.8 Sign Controller: Ensure that the sign is provided with a sign controller that includes operational firmware stored in nonvolatile memory. Program the controller to receive sign control commands from the TMC, to transmit responses (as requested) to the TMC, and to control sign operation and message displays. Ensure that sign controller functions include error logging and reporting, and providing the operational status of the sensors including temperature, photocell, airflow, humidity and LED power supply sensors.

Ensure that the sign controller will read the internal temperature sensors, the external ambient temperature sensors, and the humidity sensors and use the readings in an algorithm that turns on the heat tape and/or the fans at the appropriate times to prevent both frost on the face of the sign, and condensation on the display modules and other electronic circuitry.

Ensure that the sign controller receives and sends messages by way of an Ethernet network using the system's fiber optic cable plant and that the failure of any sign does not affect the operation of any other sign in the system.

Ensure that, at a minimum, the sign controller consists of local control panel status indicators including power on/off, TMC communication status, laptop computer communication status, communication status with the electronics in the walk-in housing, sign

display power supply status, pixel error status, controller address, power supply module, access door alarm, central processor module, and input and output circuits.

Ensure that the controller provides power-up and automatic restart capabilities with automatic sign blanking when recovering from a power-off condition. Utilize a hardware watchdog circuit to provide automatic sign shutdown in the event of power or sign controller failure.

Mount the sign controller within the sign housing using industry standard keyed-type connectors with a retaining mechanism.

781-3.1.9 Display System Hardware: Ensure the DMS utilizes a system interface circuit for communication between the sign controller and display modules consisting of data bus drivers and line address decoders. Mount the following components inside the DMS walk-in housing: sign controller, display system interface circuits, display modules, power supplies, local and remote control switches, LED indicators, an Electronic Industries Alliance (EIA)-232 plug-in connection for laptop computers, EIA-232 null modem cables (minimum of 4 feet long for connecting laptop controller to sign controller), a UPS system, workspace for a laptop computer, and communication equipment and transient voltage surge suppressors.

781-3.1.10 Control Cabinet Specifications: Provide a single-door NEMA 3R control cabinet that meets the requirements of Section 785-4.

Equip the ground control cabinet with the following assemblies and components, as shown in the plans: power-on indicators, surge suppression on both sides of all electronics, waterproof local/remote switches and LED indicators, communication interface devices, EIA-232 connections for laptop computers, EIA-232 cables a minimum of 4 feet long to connect laptop computers, and duplex outlets.

Provide for all telephone, data, control, and confirmation connections between the sign and ground control box, and for any required wiring harnesses and connectors.

781-3.1.11 Sign Controller Communication Interface: Ensure that the sign controller includes two separate EIA-232 serial interfaces inside the sign housing for communication with the TMC or a laptop computer, and one Ethernet 10/100 Base TX port that meets the Category 5 requirements detailed in this section. Ensure that EIA-232 serial interfaces support the following:

Data Bits: 7 or 8 bits

Parity: Even, Odd, None, Mark, or Spare

Number Stop Bits: 1 or 2 bit

Ensure that all Category 5 unshielded twisted pair/shielded twisted pair network cables are compliant with the EIA/TIA-568-A standard.

Configure one EIA-232 serial interface to drive asynchronous modems for full duplex communication with the TMC over point-to-point dial-up lines or a multidrop fiber or copper network. Ensure that switching between dial-up and multidrop operations does not require sign controller software or hardware modifications.

For dial-up operations, acquire and bear the charges of installing and connecting the dial-up telephone line. Provide modems to be retained by the Department at each location. Provide a user-selectable data transmission rate of up to 19.2 kbps for dial-up operations.

Configure the second EIA-232 serial port for local communication with a laptop computer.

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Ensure that the sign controller can be managed remotely from a TMC or locally using a laptop computer. Ensure that the TMC or a laptop computer can be used to remotely reset the sign controller.

Ensure that the sign controller and its software will display static, alternating, and double-brush stroke messages, with mixed fonts and spacing for maximum legibility. Ensure that the alternating frequency of the messages will vary between 0.5 and 5 seconds in 0.1-second increments.

Ensure that the unit's software will report errors and failures, including data transmission errors, receipt of invalid data, communication failure recoveries, alternating current power failures, power recoveries, pixel status reads, fan and filter airflow status, temperature status, power supply status, and information on the operational status of the temperature, photocell, airflow, humidity, and LED power supply sensors. Ensure that airflow and humidity sensor information is reported using the objects from the dmsClimateCtrlStatusTable of the NTCIP 1203 V2 standard.

781-3.1.12 Message and Status Monitoring: Ensure that the DMS provides two modes of operation: (1) master operation, where the TMC determines the appropriate message or test pattern; and (2) local operation, where the sign controller or a laptop computer determines the appropriate message or test pattern.

Keep electronic components away from the access door to protect them from the elements. Ensure that the walk-in housing containing the local control panel has switches that perform the following functions:

1. Control Selection – Ensure that the local/remote switch on the local control panel works in parallel with the local/remote switch located in the ground control box. Provide a LED indicator near the local/remote switch to indicate when either switch has selected the local mode. The operating mode is determined by the position of the mode switch on the local control panel. If the local control panel's switch is set to local, the operating mode is local. Otherwise, the operating mode is master.
2. Message Selection – Ensure that the sign controller's keypad may be used to select a blank message or any one of the messages stored in the sign controller's nonvolatile memory when the control mode is set to local.
3. Message Implementation – Ensure that the sign controller can activate the selected message.

Ensure that the sign controller transmits a return message to the TMC whenever it receives a valid status request. Ensure that return messages contain an Internet Protocol (IP) address for the sign controller, the actual message that is visibly displayed on the sign, the displayed message's transmission origin (i.e., the TMC, laptop computer, manual entry, etc.), the Department master or local control panel switch position, error and failure reports, temperature readings, access door alarm, power supply voltage levels, and the UPS status.

In the event of a power or sign controller failure, ensure that the sign controller blanks any message displayed.

Ensure that the sign controller provides a minimum library of 50 messages complying with the range deviances for objects provided in Table 1.

Ensure that message additions, deletions, and sign controller changes may be made from either the remote TMC or a local laptop computer. Ensure that each font may be customized, and modifications to a font may be downloaded to the sign controller from the TMC

or a laptop computer at any time without any software or hardware modifications. Ensure the sign is capable of displaying a different font and character spacing on each line.

Ensure that the TMC sets the sign to neutral (either a blank display or displaying a predefined default message) when a message's display time has expired. Ensure that there is no perceivable flicker or ghosting of the pixels during sign erasure and writing periods.

Ensure that in the event of an AC power loss all nonvolatile memory is retained for a minimum of 30 calendar days. Ensure that the sign controller monitors the messages downloaded from the TMC or laptop computer to make sure that the message will fit in the display area of the sign. Ensure that the sign controller's internal time clock provides for messages to be taken down at the correct time, even in the event of a communication loss. Ensure that the sign controller maintains its internal clock during power outages and displays the proper message when power is restored within 255 minutes. If electric power is restored to the sign after 255 minutes, no message will be displayed.

781-3.1.13 TMC Communication Specifications: Ensure that the sign controller is addressable by the TMC through the Ethernet communication network using software that complies with the NTCIP 1101 base standard (formerly the NEMA TS 3.2 -1996 standard), including all amendments as published at the time the Request for Proposals is released, and the NTCIP Simple Transportation Management Framework, and conforms to Compliance Level 1. Ensure that the software implements all mandatory objects as defined in the FDOT standard Global MIB v01c in Appendix A, all mandatory objects as defined in the FDOT-standard DMS MIB v01c in Appendix B, and all mandatory objects as defined in the FDOT-specific DMS MIB v01c in Appendix C. Ensure that the DMS complies with the NTCIP 1201 v01, 1203 v01, 2101 v01.19, 2103 v01.13, 2201 v01.14, 2202 v01.05, and 2301 v01.08 standards. Ensure that any additional objects implemented by the software do not interfere with the standard operation of any mandatory objects.

Ensure that each DMS provides full, standardized range support for all objects required by these specifications unless otherwise detailed in the plans. The standardized range is defined by a size, range or enumerated listing indicated in the object's syntax field and/or through descriptive text in the relevant standard object description field. Ensure that the DMS maximum response time for any object or group of objects is 200 milliseconds unless otherwise indicated in the plans, or unless approved by the FDOT Traffic Engineering Research Laboratory (TERL). Deviances from the full ranges for objects are detailed in Table 1.

Table 1 – Range Deviances for Objects

Object	Minimum Project Requirements
FDOT Global MIB v01c	
Maximum Event Log Configurations	50
Event Configuration Mode	2, 3, and 4
Maximum Event Log Size	200
Maximum Event Classes	7
Maximum Group Address	1
FDOT DMS MIB v01c	
Number of Fonts	4
Maximum Font Characters	255
Default Background Color	0
Default Foreground Color	2, 7, 8, or 9

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Default Justification Line	2, 3, 4
Default Justification Page	2, 3, 4
DMS – Number of Permanent Messages	0
DMS – Maximum Changeable Messages	50
DMS – Maximum Volatile Messages	0
Nonvolatile Memory	5 KB
DMS – Control Mode	2, 3, 4, and 5
Number of Action Table Entries	15
Number of Brightness Levels	255

Ensure that the software implements the tags (opening and closing where defined) of MULTI as detailed in Table 2 and as defined in the NTCIP 1203 standard.

Table 2 – NTCIP 1203 Standard Software Tags *****

Opening Tag	Closing Tag	Explanation
cbx		Color – Background – The background color for a message.
cfx		Color – Foreground – The foreground color for a message.
fx,y		Field – The information to embed within a message that is based on data from some device, such as a clock, calendar, temperature sensor, detector, etc. The following field tag values (IDs) are REQUIRED to be supported: 1 – the time in a 12-hour format; 2 – the time in a 24-hour format; 4 – the ambient temperature in degrees Fahrenheit; 7 – the day of the week; 8 – the date of the month; 9 – the month of the year; 10 – the year in two digits; and 11 – the year in four digits.
fltxoy	/fl	Flash – Activate flashing of the text; define the flash-on and flash-off times; and the flash order (i.e., on/off or off/on).
fox		Font – Select a font number (as specified in the font table) for the message display.
jlx		Justification – Line – Specify line justification: left, center, right, or full. However, full justification is not required.
jpx		Justification – Page –Specify page justification: top, middle, or bottom.
mvtdw,s,r,text		Moving – Text – Specify the parameters of a horizontal moving (scrolling) text.
nlx		New – Line – Specify the start of a new line.
np		New – Page – Specify the start of a new page.
ptxoy		Page – Time – Specify the page times (t = on, o = off).
scx	/sc	Spacing – Character – Specify the spacing between characters.

* The letters “x” and “y” are character placeholders, usually for numbers, that specify the tag parameter(s). See the NTCIP 1203 standard and its amendments for further definitions.

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Provide each sign controller with error detection and reporting features that will be used to guard against incomplete or inaccurate transmissions including cyclic redundancy checking of all data received from the TMC, with positive acknowledgment for all valid transmissions; status monitoring for communication line malfunctions or breakages; and content validation for all transmissions received for logic or data errors.

Provide communication line circuits that are point-to-point or multipoint, and that provide full duplex asynchronous data transmissions at the rate directed by the Engineer.

Assign each sign controller a unique address in the circuit that the sign is connected to. Where applicable, encode all data transmitted between the TMC and the sign controller using 1 start bit, 8 data bits, and 1 stop bit.

781-3.1.14 Electronic Components: Ensure that all electronic components, with the exception of PCBs, are commercially available, easily accessible and replaceable, and individually removable using conventional electronic repair methods.

Ensure that all workmanship complies with the ANSI International Policy Committee (IPC) requirements as defined in the ANSI/IPC-A-610B, ANSI/IPC-7711, and ANSI/IPC-7721 Standards.

781-3.1.15 Mechanical Components: Ensure that the DMS is fabricated using only stainless steel external screws, nuts, and locking washers. Do not use self-tapping screws unless specifically approved by the Engineer. Ensure that all parts are fabricated from corrosion-resistant materials, such as plastic, stainless steel, aluminum, or brass. Ensure that construction materials are resistant to fungus growth and moisture deterioration. Ensure that all dissimilar metals are separated with an inert, dielectric material.

781-3.2 Sign Control Software: Ensure that the DMS is provided with computer software that allows an operator to program, operate, exercise, diagnose, and read current status of all sign features and functions using a laptop computer. Ensure that sign control software provides a graphical representation that visibly depicts the sign face and the current ON/OFF state of all pixels as well as allows messages to be created and displayed on the sign. Ensure that the laptop computer and sign can communicate when connected directly by an EIA-232 cable. Ensure that the laptop computer and DMS can communicate across the ITS system's communication network using the NTCIP standards described in this document. Ensure that the software will allow communication between multiple users and multiple signs across the same communication network.

781-3.3 Sign Support Structure: Meet the requirements of 700-2.5.

781-3.4 Installation Requirements: Do not install the DMS prior to the availability of electric power. Verify that the ventilation system operates in each DMS within 72 hours of sign mounting.

Set the sign housing's vertical angular alignment as shown in the plans or as directed by the Engineer. Ensure that lifting eyebolts are removed and any remaining holes in the top surface of the DMS are sealed to prevent water entry after installation.

Load the initial message libraries on both the TMC and the sign controller. The Engineer will furnish the messages to be placed in these libraries.

781-3.5 Documentation: Provide documentation as noted below, reflecting the as-built conditions necessary to facilitate the operation, maintenance, modification, and expansion of the DMS system or any of its individual components. Manufacturer-supplied documentation that covers the intent of these specifications may be used, subject to the approval of the Engineer.

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Provide the Engineer with two paper copies and one electronic copy of all documentation. Print the paper copies on 8 1/2-by-11-inch paper and place in three-ring binders. Format the electronic copy in portable document format and submit on CD-ROM. Ensure that electronic submittals are compatible with the Department's own software and CADD programs at the time submittals are made. In addition, place one paper copy of an operations and maintenance manual and as-built drawings, wiring diagrams, and schematics at each DMS location. Ensure that the drawings are printed on 11-by-17-inch sheets and include structural member and attachment support details. Provide each of the following items in the operations and maintenance manual:

1. A general description of the equipment's basic use and function. Provide a general block diagram of the DMS equipment, including the nomenclature, physical and electrical characteristics, and the functions of any auxiliary devices utilized.

2. Sections describing the DMS using block diagrams and schematic drawings. Furnish layout drawings showing the location of all components, along with a complete components list. Use a logical development starting with a system block level and proceeding to a circuit analysis. Detail the circuit analysis whenever circuits are not normally found in standard textbooks. Fully describe the application of new theoretical concepts. Where the design allows operation in a number of different modes, provide an operational description of each mode.

3. The standard routine of operation for the DMS, from necessary preparations for placing the equipment into operation to securing the equipment after the beginning of operation. Include appropriate illustrations with the sequence of operations presented in tabular form wherever feasible. Provide a list of applicable test instruments, aids, and tools required in the performance of necessary measurements and techniques for each system component. Describe setup tests and calibration procedures.

4. Information required to maintain, diagnose, and repair the sign and its controller to the component level, including the manufacturer's recommended procedures for preventive maintenance performed weekly, monthly, quarterly, semi-annually, and annually, and any other required maintenance checks necessary to assure reliable equipment operation. Fully describe all adjustments and alignment procedures and provide descriptions of expected signals at all test points and outputs. List all requirements, including tolerances for all electrical, mechanical, and other applicable measurements and adjustments. Provide a repair and troubleshooting decision tree that describes each function, the tests of each function, and any process that defines faulty elements that require repair, replacement, or adjustment to restore operation of a malfunctioning sign or system element.

5. General instructions for the disassembly, overhaul, and reassembly of the DMS, including shop specifications and operating performance specifications.

6. Detailed instructions and specifications for maintenance that must be accomplished by specialized technicians and engineers in a modern electromechanical shop. Include instructions that describe special test setups, component fabrications, and the use of special tools, jigs, and test equipment.

7. A detailed physical description of size, weight, special mounting requirements, electrical connections, and all other pertinent information necessary for proper installation and use of the equipment.

8. A parts list containing all equipment within a group, and a list of all assemblies, subassemblies, and unit replacement parts. Arrange the list in alphanumerical order

of the schematic reference symbols and shall give the associated description, manufacturer's name, and part number. Provide a table of contents or some other appropriate grouping method for the purpose of identifying major components, assemblies, etc.

9. Complete and accurate schematic diagrams as required to supplement the text material and to allow the books to be self-contained technical information sources. Include part reference symbols, test voltages, waveforms, and other aids to understanding the circuit's functions on the diagrams.

Include drawings of conduit layouts, cable diagrams, wiring lists, control cabinet layouts, wiring diagrams, and schematics for all elements of the communication system in the final documentation. Include detailed drawings identifying the routing of all conductor pairs in the communication system by cable type, color code, and function. Upon completion of the installation, submit these plans, maps, drawings, and/or diagrams to reflect an as-built condition, incorporating all changes made during installation, such as in-pair identification and routing.

Provide software and documentation for the TMC software system and its components including, but not limited to all documentation concerning the sign controller communication protocol, including information needed to define the interface design, software codes, message definitions, and message sequences for DMS control and feedback; and one complete copy of the manufacturer's documentation for plug-in circuit cards used in the microcomputer chassis.

Provide documentation that reflects all field changes and software modifications and revisions prior to the power-on test period for the DMS. Modify the documentation with any final corrections or adjustments made during the test period. Submit the documentation to the Engineer within seven days of the successful completion of the operational testing.

781-3.6 Licensing: Ensure that the manufacturer grants the Department a nonexclusive, unrestricted license that allows the Department to use, modify, and/or distribute any and all of the stated communication protocols, sign operating systems, drivers, and documentation.

781-3.7 Technical Assistance: Ensure that a manufacturer's representative is available (preferably on site) to assist the Contractor's technical personnel at each sign installation site for sign-to-sign structure installation, sign controller cabinet installation, and sign-to-controller cabling.

Do not proceed with the initial powering up of the sign(s) without the permission of the manufacturer's representative.

781-3.8 Testing: Conduct performance testing of materials and equipment not previously tested and approved. If the technical data is not considered adequate for approval, samples may be requested for testing by the Engineer. The contract period will not be extended for time lost or delays caused by testing prior to the Engineer's final approval of any items.

Subject the equipment covered by these specifications to design approval tests (DATs) and factory demonstration tests (FDTs). The Engineer may accept certification by an independent testing laboratory in lieu of the DATs to verify that the tests have been previously completed satisfactorily. Arrange and conduct the tests in accordance with the testing specifications stated in this section. Unless otherwise specified, the Contractor is responsible for satisfying all inspection requirements prior to submission for the Engineer's inspection and acceptance.

The Engineer reserves the right to witness all DATs and FDTs. The tests on all or one type of equipment must be completed within five calendar days. The Contractor shall be financially responsible for testing each DMS.

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Provide five copies of all design approvals, FDTs, stand-alone and subsystem test procedures, and data forms for the Engineer's approval at least 60 calendar days prior to the beginning of testing. Include in the test procedures the sequence in which the tests will be conducted. Obtain the Engineer's approval of the test procedures prior to testing the equipment.

Furnish data forms, certified and signed by the manufacturer, containing all of the data taken, and the quantitative results for all tests. Send one copy of the data forms to the Engineer.

Provide the test fixtures and test instruments for all the tests.

781-3.8.1 Design Approval and Preshipment Factory Demonstration Testing: Conduct DATs on one or more samples of each type of equipment, as approved by the Engineer, to determine whether the equipment design meets the DMS specification's requirements. Conduct the test in accordance with the approved test procedures as described in this section. All requirements listed below take precedence over the applicable NEMA TS 4 standard.

Notify the Engineer a minimum of 30 calendar days in advance of the time these tests are to be conducted.

781-3.8.1.1 Temperature and Condensation: Provide results of the DMS and sign controller FDTs to the Engineer or his representative prior to shipment of any DMS equipment. Test requirements include the following:

1. Stabilize the equipment at -29°F. After temperature stabilization, operate the equipment without degradation for two hours.
2. Cause moisture to condense on the equipment by allowing it to warm to room temperature in an atmosphere having a relative humidity of at least 40% and satisfactorily operate the equipment for two hours while wet.
3. Stabilize the equipment at 165°F. After stabilization, satisfactorily operate the equipment for two hours without degradation or failure.

781-3.8.1.2 Primary Power Variation: The equipment shall meet the defined performance specifications when the nominal input voltage is 120 volts, ±11.5 volts. Operate the equipment at extreme limits for at least 15 minutes, successfully performing FDTs.

781-3.8.1.3 Relative Humidity: The equipment shall meet its performance specifications when subjected to an ambient operating temperature of 165°F and a relative humidity of 90%. Maintain the equipment at the above condition for 48 hours. At the conclusion of the 48 hour soak, the equipment shall meet FDT requirements within 30 minutes of beginning the test.

781-3.8.1.4 Vibration: The equipment, excluding cabinets, shall show no degradation of mechanical structure, soldered components, or plug-in components, and shall operate in accordance with the manufacturer's equipment specifications after being subjected to the vibration tests required in Section 2.2.5 of the NEMA TS 4 standard.

781-3.8.1.5 Water Spray Hose Test: Test the fully assembled DMS by way of a directed water spray hose test. The test shall consist of a 10-minute soaking of the DMS by way of two constant streams of water. The water spray shall be delivered by two hoses, 0.625 inch in diameter, with a water throughput of 6 gallons per minute at 45 pounds per square inch. One hose with a medium spray nozzle shall be directed at the sign face. The hose setup for the sign face shall be placed 15 feet from the sign face, be 12 feet in height, and be set at a 45-degree down angle. The second hose with a heavy spray nozzle shall be directed at the top of the sign cabinet in the form of heavy spray. This top hose setup shall be set at 10 feet directly above the sign cabinet pointing directly down on top of the cabinet. The water shall run

continuously for 10 minutes. At the end of the test period, the interior of the sign shall be inspected for leaks, water/moisture contamination of the electronics, standing water in the base of the sign, and any other abnormal water/moisture issues. Note any leaks and have them permanently repaired. Retest until all leaks are stopped. Note all repairs on the as-built documentation.

781-3.8.2 Preshipment Factory Demonstration Testing: Conduct FDTs on all units at a Contractor-provided facility. Notify the Engineer a minimum of 30 calendar days before the start of tests. Conduct all tests in accordance with the approved test procedure contained in this section. All equipment shall have passed the following individual tests.

781-3.8.2.1 Product Examination Test: Examine each piece of equipment carefully to verify that the materials, design, construction, markings, and workmanship comply with the requirements of these specifications.

781-3.8.2.2 Continuity Test: Check the wiring to determine conformance with the requirements of the appropriate paragraphs in these specifications.

781-3.8.2.3 Operational Test: Operate each piece of equipment long enough to permit equipment temperature stabilization, and to check and record an adequate number of performance characteristics to ensure compliance with the requirements of these specifications.

Have factory personnel make necessary changes and repairs, making notations of the repairs on the as-built documentation. Retest the DMS to verify the proper operation of the now-repaired components. Upon satisfactory completion of all pre-shipment testing, the Engineer will release the sign for shipment.

If a failure pattern develops, the Engineer may direct that design and construction modifications be made to all units without additional cost to the Department and/or without an extension of the contract period.

781-3.8.3 Pre-installation Field Testing: Conduct pre-installation tests on all units at a Contractor-provided facility within the appropriate District. Perform the tests on each unit supplied to verify that no damage was done to any sign during the shipment and delivery process. Notify the Engineer a minimum of 10 calendar days before the start of any tests. Conduct all tests according to the approved test procedures detailed in this section. Each DMS shall pass the individual tests detailed below prior to installation.

781-3.8.3.1 Product Examination Test: Examine each DMS carefully to verify that the materials, design, construction, markings, and workmanship comply with all applicable standards, specifications, and requirements.

781-3.8.3.2 Continuity Test Specifications: Check the wiring to determine conformance with the applicable standards, specifications, and requirements.

781-3.8.3.3 Operational Test Specifications: Operate each DMS long enough to permit equipment temperature stabilization, and to check and record an adequate number of performance characteristics to ensure compliance with applicable standards, specifications, and requirements.

781-3.8.3.4 Pre-installation Test Failure Consequence: If any unit fails to pass an FDT, the unit shall be corrected or another unit substituted in its place, and the test successfully repeated.

If a unit has been modified as a result of an FDT failure, a report shall be prepared and delivered to the Engineer prior to the unit's shipment. The report shall describe the nature of the failure and the corrective action taken.

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If a failure pattern develops, the Engineer may direct that design and construction modifications be made to all units without additional cost to the Department or an extension of the contract period.

781-3.8.4 Installed Site Tests: Conduct an approved, stand-alone equipment installation test at the field site. Test all stand-alone (i.e., non-network) functions of the field equipment using equipment installed as detailed in the plans, or as directed by the Engineer.

Complete approved data forms and turn them over to the Engineer for review, and as a basis for rejection or acceptance. Provide a minimum notice of 30 calendar days prior to all tests to permit the Engineer or his representative to observe each test.

If any unit fails to pass its stand-alone test, correct the unit or substitute another unit in its place, then repeat the test.

If a unit has been modified as a result of a stand-alone test failure, prepare a report describing the nature of the failure and the corrective action taken and deliver it to the Engineer prior to re-testing the unit. If a failure pattern develops, the Engineer may direct that design and construction modifications be made to all units without additional cost to the Department or an extension of the contract period.

781-3.8.5 System Testing: Conduct approved DMS system tests on the field equipment with the master equipment including, at a minimum, all remote control functions. Display the return status codes from the sign controller for a minimum of 72 hours. Complete approved data forms and turn them over to the Engineer for review, and as a basis for rejection or acceptance.

Demonstrate the sign's ability to display the proper predefined message or remain blank when power is restored following an AC power interruption.

If the system test fails because of any subsystem component, repair that component or substitute another in its place, then repeat the test. If a component has been modified as a result of a system test failure, prepare a report and deliver it to the Engineer prior to retesting.

781-3.8.6 Operational Testing: After the DMS system installation and system testing are successfully completed, conduct one continuous 72-hour, full-operating test prior to conducting the 60-day test period. The Engineer will approve the type of tests to be conducted. Include in the tests all control, monitoring, and communication functions of the field equipment by the master equipment.

Commence the 60-day test period on the first day after the successful completion of the approved continuous 72-hour, full-operating test period.

During the 60-day test period, limit downtime due to mechanical, electrical, or other malfunctions to a maximum of 5 calendar days. The Engineer may extend the 60-day test period by the number of days equal to the downtime in excess of 5 calendar days.

The Engineer will furnish the Contractor with a letter of approval and completion stating the first and last day of the 60-day test period.

Final system acceptance is defined as the time when all work and materials described in the plans have been furnished and completely installed by the Contractor; all parts of the work have been approved and accepted by the Engineer; and the DMS system has been operated continuously and successfully for 60 calendar days with no more than a total of 5 calendar days non-operation due to mechanical, electrical, or other malfunctions. If the equipment fails to operate for more than 5 calendar days during final system acceptance testing, testing will be restarted.

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781-4 Highway Advisory Radio.

781-4.1 Description: Furnish and install a highway advisory radio (HAR) system having all equipment necessary to record verbal messages from onsite or remote locations, and to continually broadcast live, prerecorded, or synthesized messages.

781-4.2 Materials:

781-4.2.1 General: Provide an HAR system with remotely operated flashing lights and highway signs to notify motorists of active HAR broadcasts. Ensure that all components are modular and fit in a rack-mounted chassis. Use HAR subsystems and components that are programmable remotely or onsite.

Ensure that the HAR system includes software, hardware and any other component required to fully configure, operate and monitor the HAR field equipment locally and remotely using a personal computer.

781-4.2.2 Transmitter: Ensure that the transmitter complies with the requirements of Code of Federal Regulations (CFR) Title 47, Section 90.242, “Travelers’ Information Stations”, and 47 CFR Section 2.901 et seqq. (Part 2, Subpart J), of the Federal Communications Commission (FCC) Rules and Regulations.

Use a transmitter with a power efficiency of 80% or greater. Ensure that the transmitter is adjustable from 0 to 10 watts. Ensure that the transmitter frequency is set at the factory. Ensure that the transmitter parameters can be monitored locally and remotely.

Ensure that the radio frequency (RF) output impedance is 50 ohms and unbalanced.

Ensure that the audio input impedance is 600 ohms and balanced. Ensure that the transmitter module has audio distortion of less than 1.5% for a audio frequency response of 200 Hz to 3.5 kHz.

Provide a transmitter module with indicators or displays for power status, RF power output, and audio modulation level.

781-4.2.3 Digital Recorder and Playback Unit: Ensure that the digital recorder and playback unit can locally and remotely record, store, transmit, and receive digital messages or audio files. Ensure that the digital recorder and playback unit allows operator control by dual tone multi-frequency (DTMF) tones over standard public switched telephone networks (PSTNs) and digital cellular telephone, and digital commands via serial modem. Ensure that the digital recorder and playback unit is FCC certified under Part 68 for dial-up operations.

Ensure that the digital recorder and playback unit can schedule broadcasts, which shall be programmable by the day of the week, month, date, and time. Ensure that the digital recorder and playback unit uses solid state electronics. Do not use floppy disks or magnetic tapes. Use a digital recorder and playback unit with the ability to record and store a minimum of 250 distinct, variable-length messages, and provide a minimum of 14 minutes of recorded message time.

Ensure that the digital recorder and playback unit has access to, and command and control of, the remote flashing beacon controller.

Ensure that the digital recorder and playback unit is password protected and has an input source indicator. Ensure that the digital recorder and playback unit can simultaneously record and playback messages. Ensure that the digital recorder and playback unit can retain messages indefinitely, in the event of a power loss, and not require a battery. Ensure that the digital recorder and playback unit has built-in voice prompts.

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781-4.2.4 National Weather Service Receiver: Provide a National Weather Service (NWS) receiver that is capable of automatically broadcasting alerts from the NWS. Allow the alert feature to be switched on or off and the duration to be set.

781-4.2.5 Transmitter Synchronizer: Ensure that multiple HAR transmitters broadcasting the same message are synchronized. Ensure that the synchronization eliminates interference and audio distortion within possible overlapping areas. Provide a transmitter synchronizer module of modular design.

Provide a global positioning system (GPS) receiver for audio synchronization and frequency synchronization. Provide a minimum of eight channels in the transmitter synchronizer module. Ensure that the accuracy of the module is within 45 nanoseconds at 10 MHz reference.

781-4.2.6 Antenna Assembly: Provide an antenna assembly with hardware and cables to mount the antenna as shown in the plans. Use either a vertical monopole, which propagates omnidirectional radio waves in a circular pattern, or a directional array that propagates radio waves in a noncircular shape, according to the plans.

Use an antenna that can be tuned to the transmission frequency either mechanically or electronically. Tune the antenna to the same frequency as the transmitter.

781-4.2.7 Ground Plane: Install system grounding components in accordance with 785-1 or as shown in the plans. Use a minimum of American Wire Gauge (AWG) #20 wire for any radial ground planes. Install these wires extending outward from the base of the antenna, at a minimum of 6 inches below ground, forming a circular pattern with a radius of 30 to 100 feet.

781-4.2.8 Surge Suppressor: Install transient voltage surge suppressors between the transmitter and the antenna as required in 785-2.

781-4.2.9 HAR Sign and Flashing Beacons: Provide roadside signs with flashing beacons that are activated when the associated HAR system is transmitting. Ensure that the HAR sign conforms to the FDOT Standard Index for Special Sign Details pertaining to highway advisory radio.

Provide 12-inch beacons that comply with Section 650, along with controller, communications, power and material needed to provide a fully functioning flashing beacon system. Ensure that the flashing beacons use a NEMA-rated flasher circuit. Ensure that the flashing beacons can be operated locally and remotely.

781-4.2.10 Power Distribution: Provide a power distribution system with automatic charging circuitry to prevent overcharging and with the capability of low-voltage battery disconnection and isolation.

Provide external AC power supply module with backup batteries as shown in the plans. Ensure that the power supply module is a nominal 120 volts of alternating current (V_{AC}). Ensure that the power supply module operates at 50 to 60 Hz and a maximum of 150 watts. Provide batteries that can continuously operate the HAR system at full power for a minimum period of three days without an external power source. Ensure that the system has an automatic charging unit and automatic power changeover with no interruption to HAR transmissions.

Provide a solar power supply module, as shown in the plans, with photovoltaic array and battery storage system to operate the HAR system continuously at full power for a minimum period of three days without sunlight. Verify that the system's solar panels are compliant with the International Electrotechnical Commission (IEC) requirements detailed in

the IEC 61215 standard. Verify that the DC output power specifications are a nominal 13.6 volts of direct current (V_{DC}) at 5 amps, with a maximum of 15 V_{DC} and a maximum of 10 amps.

Provide batteries capable of 180 amps per hour, are deep cycle, and maintenance-free.

Provide an accessible attachment point that allows connection of a portable generator for emergency power.

781-4.2.11 Control Cabinet: Provide a control cabinet for housing the transmitter, digital recorder and playback unit, NWS receiver, transmitter synchronizer, power, surge suppressors, and flashing beacon controller, as shown in the plans. Ensure that cabinets meet NEMA 3R requirements for aluminum enclosures and conform to Section 676. Use a cabinet that is constructed of aluminum alloy 5052-H32 measuring 0.125 inch thick.

781-4.2.12 Performance Requirements: Furnish an HAR system that is compatible with the current version of the Department's SunGuide℠ Software System.

Ensure that the system has a text-to-speech capability for converting typed words to audio files. Ensure that the system logs the status of all devices. Ensure that the operator is able to record, edit, and delete messages, and to select desired messages for broadcast. Ensure that the system maintains event schedules, diagnostic information, and logs of messages that have been downloaded and played, along with the date and time that a message was activated for each HAR. Ensure that the HAR system provides system failure remote alarms and indicates system status in the user interface.

781-4.2.13 Environmental Specifications: Ensure that the HAR system installed at the field site is able to withstand temperatures between -29° and 165°F as per the NEMA TS 2 standard at 95% noncondensing humidity. Ensure that the HAR system meets the requirements specified in the Plans Preparation Manual for wind loading.

781-4.3 Installation Requirements: Install all HAR equipment according to the manufacturer's recommendations or as directed by the Engineer.

Obtain all required licenses to operate the HAR as per FCC requirements using the services of the HAR manufacturer. Perform all necessary on-site testing to select the clearest and most appropriate operating frequency for all HAR transmitters at the proposed locations. Submit the results of the frequency search, testing, and the recommended frequency selection to the Engineer for approval prior to application for FCC licenses.

Provide all utility coordination, power design and power service installations to obtain power for the HAR and flashing beacon sites.

Ensure that any public network connections (PSTN, cellular, or other connections) used for system interconnect are approved by the Engineer.

781-4.4 Testing: 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.

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.

The Engineer reserves the right to witness all DATs and FATs. Complete the tests within five calendar days.

Ensure that the test plans demonstrate each and every feature available in the device or system under test and includes the tests discussed below.

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781-4.4.1 Stand-Alone Tests: Perform the following stand-alone tests on the HAR, after all equipment has been installed and initial adjustment is complete at the field site.

781-4.4.1.1 Ground Plane Resistivity: Conduct ground plane resistivity measurements as required in 785-1.

781-4.4.1.2 Transmitter: Perform field measurements to verify compliance with 47 CFR Part 90.242. Document the location and results of field measurements and submit them to the Engineer.

781-4.4.1.3 Digital Recorder and Playback Unit: Demonstrate the correct operation of each function of the digital recorder and playback unit at the field site using the display screen. Verify the test message is received on a vehicle radio set to the approved transmitter frequency and located within the coverage area of the HAR transmission.

781-4.4.1.4 Battery System: Verify that the charged batteries can run the HAR system for the number of days as advertised by the manufacturer.

781-4.4.2 System Tests: Conduct approved HAR system tests on at least one HAR system, including the operations center, one sign and flashing beacon, and one transmitter. Perform, at a minimum, all remote control functions. Complete approved data forms and turn them over to the Engineer for review, and as a basis for rejection or acceptance.

If the system test fails because of any subsystem component, correct that component or substitute another in its place, then repeat the test. If a component has been modified as a result of a system test failure, prepare a report and deliver it to the Engineer prior to retesting.

781-4.4.2.1 Digital Recorder and Playback Unit: Test the remote loading of the messages on digital recorder and playback unit and verify the quality of voice broadcasted. Load 14 minutes of messages and demonstrate different sequences of playback. Test the message loading from a remote location using cellular telephone, standard analog telephone line and digital commands via serial modem.

781-4.4.2.2 Transmitter Synchronization: If multiple HARs are deployed, test that a clear signal is obtained in the signal influence region that is free of interference caused by synchronization faults.

781-5 Road Weather Information System.

781-5.1 Description: Furnish and install a road weather information system (RWIS) as shown in the plans and as directed by the Engineer.

781-5.2 Materials: Provide an RWIS consisting of environmental sensor stations (ESS) installed at specified locations. Provide an ESS that includes environmental sensors mounted on an aluminum tripod tower, other sensors mounted in the roadway and in the soil, and a remote processing unit (RPU) at the tower's base, if required for that location. Ensure that the RPU can collect, store, and process sensor data to describe current weather conditions.

Provide any ancillary equipment or incidental items required, including mounting hardware, power supplies, grounding, surge suppression devices, and communication equipment, at each ESS location to make a complete and fully operational RWIS. Ensure that the system provides real-time, accurate, reliable data on all system parameters to the degree of precision defined in this specification.

781-5.2.1 Sensors: Provide an RWIS that can collect and store data from various sensors, which are divided into the following three categories:

1. Roadway sensors located in or under the pavement.

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2. Atmospheric sensors mounted on towers that are installed along the roadway or on bridges.

3. Subsoil sensors located in soil adjacent to the ESS.

Ensure that all RWIS sensors and other field equipment are made of materials able to withstand wet, corrosive, dusty and humid weather conditions characteristic of the Florida climate.

Provide hardware and fasteners that meet the requirements of 603-2.

Provide ultrasonic anemometers and other sensors that are electronic devices which do not rely on moving parts to create electrical signals for processing.

781-5.2.2 Sensor Performance: Each environmental sensor and its associated transducers shall record the following attributes to the listed degree of accuracy:

Roadway Data		
Surface Temperature	±0.36° F between -40° and 176° F	
Subsurface Temperature	±0.36° F between -40 and 176° F	
Precipitation	Type:	Dry, wet at >32° F; wet at <32° F; frozen, frost and dew
	Percent of Ice:	From 0 to 100%
	Depth/Amount:	From 0 to 0.5 inch
Atmospheric Data		
Temperature	±1° F between -40° and 176° F; resolution of 0.1 degree	
Relative Humidity at 70° F	±5% between 10 and 100%	
Barometric Pressure	Accurate to ±0.02 inch of mercury (in. Hg) between 27.2 and 31.9 in. Hg; resolution of 0.005 inches Hg	
Precipitation	Type:	Light rain, rain and ice
	Intensity:	±20% between 0.02 to 200 inches per hour
	Visibility:	±10% from 0.005 to 1 mile
Wind	Direction:	±3 degrees between 0 and 360 degrees
	Speed:	±1 mph between 0 and 150 mph, with gusts up to 180 mph
Solar Radiation	±5% between 0 and 1,400 watts per square meter	
Subsoil Data		
Temperature	±0.36° F between -40° and 176° F	
Moisture	±5% water moisture content between 0 and 100%	

Ensure that pavement sensors function as specified above when installed at a maximum of 2,000 feet from the RPU.

781-5.2.3 ESS: Install an ESS having the sensors necessary to collect, store, and transmit the following data:

1. Roadway data, including:

A) Temperature

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B) Subsurface temperature

C) Precipitation data that includes precipitation type, percent of ice, and precipitation depth/amount.

2. Atmospheric data, including:

A) Temperature

B) Relative humidity

C) Barometric pressure

D) Precipitation data that includes type and intensity

E) Visibility as affected by fog, smoke, or a combination thereof

F) Wind data, including direction and average speed

G) Solar radiation (optional)

3. Subsoil data, including:

A) Temperature

B) Moisture (optional)

4. High water data

781-5.2.4 Communications: Use an RPU capable of transmitting all collected data to the transportation management center (TMC) using the National Transportation Communications for ITS Protocol (NTCIP) over any of the following media, as detailed in the plans:

1. Microwave communications, specifically, Florida's statewide Motorist Aid System (MAS) microwave communication infrastructure.

2. Ethernet communications over single-mode fiber optic cable that transfers data at a minimum rate of 10 megabits per second (Mbps).

3. Twisted-pair copper wire capable of transferring data at a rate of up to 128 kilobits per second (kbps).

4. Cellular mobile telephone service with data transmission rates of up to 56 kbps.

Ensure that all communications, including those between sensors and the RPU, are nonproprietary and compatible with the Department's SunGuide℠ Software System. In certain cases, provide peer-to-peer wireless communication between RPUs at a maximum distance of 5 miles. Ensure that the RPU is capable of, or adaptable to, providing this type of communication.

781-5.2.5 Remote Processing Unit: Furnish an RPU that supports a minimum of four pavement sensors, four subsoil sensors, and eight atmospheric sensors. Use an RPU that supports EIA 232/488 serial protocols, as well as TCP/IP output. Ensure that the RPU is programmable and based on an open architecture.

Provide a unit having a minimum of 28 analog inputs and 2 EIA-232 serial ports. Ensure that the RPU has a maximum serial data transmission rate of 128 kbps. Ensure that the unit's mean time between failures (MTBF) is 15,000 hours or 625 days.

Ensure that the RPU issues and communicates an alarm whenever a user-defined threshold is exceeded. Ensure that the RPU is also capable of producing an output through contact closure or a digital output that imitates a contact closure.

At minimum, the RPU shall be able to store internally the last 24 readings over a user-defined time interval of up to 5 minutes.

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With additional hardware and software, the RPU shall be capable of collecting, storing, and transmitting single-frame, black-and-white images from a closed-circuit television (CCTV) camera mounted on the RWIS tower.

Ensure that the RPU operates using a nominal input voltage at the cabinet of 110 to 120 V_{AC}, and also be capable of operating on 12 V_{DC} of solar battery power. The RPU shall issue an alarm to the TMC if the AC power supply is low or if there has been a complete power loss. Ensure that the system sends a message when the unit returns to normal conditions.

All components within the RPU shall operate throughout an ambient operating temperature range of 0° to 140°F, with a maximum relative humidity of 90%.

781-5.2.6 RPU Enclosure: Furnish a NEMA Type 4-rated RPU enclosure that is designed specifically for RWIS applications. Attach the control cabinet to the tower according to the manufacturer's recommendations.

781-5.2.7 RWIS Software: Ensure that the RWIS software enables the system operator to derive environmental measurements, such as the dew point, wind chill, and heat index, from sensor data received. Ensure that the RWIS software can be used to report minimums, maximums, averages, cumulative values, and standard deviations for all data over a prescribed time period.

Ensure that the RWIS software provides English-to-metric unit conversions, when applicable, and lets the operator choose which unit of measure to report if more than one unit is common for a particular measurement.

When the software supplied with the RWIS is installed on a laptop computer or a remote workstation, ensure that the operator is able to access, either remotely through the workstation or at the site with the laptop computer, all user-defined parameters and stored data within the RPU, including the ability to view, download, and delete stored data.

781-5.2.8 Electrical Specifications: Provide RWIS equipment and components installed at the ESS that operate at 110 to 120 V_{AC} from a commercial utility company or, alternatively, 12 V_{DC} from a solar-powered or battery-powered system. In cases where the ESS are mounted on the Department's MAS towers, ensure that the devices can utilize the towers' 48 V_{DC} power supply.

Ensure that solar- and battery-powered units operate continuously for 14 days without requiring battery recharging. Provide an appropriate means of conversion for any device that requires a different power source.

Equip each ESS installation with provisions for emergency backup power in the event of primary power loss. Ensure that backup power is capable of continuing the ESS' operations for a minimum of 12 hours.

As a power-saving option during hurricanes, ensure that the RWIS allows the system operator to curtail temperature and relative humidity measurements in favor of collecting wind direction and speed measurements.

781-5.2.9 Foundation and Tower Specifications: Provide a supporting tower or pole that provides a mounting platform for atmospheric sensors free of influences from topography, buildings, and vehicles. Ensure that the tower also supports any lightning protection devices (e.g., grounding rods) for the site. Mount the atmospheric sensors on a hinged, 33-foot tower. Use a tower having a hinge approximately 10 feet above ground for access to the atmospheric sensors.

Provide a support structure that is self-supporting without guy wires, using a 50-year design life, and in accordance with the current Structures Manual. Ensure that the

structure is made of 6061-T6 corrosion-resistant aluminum or an equivalent. Ensure that all hardware and fasteners are stainless steel.

If the field site is solar powered, ensure that the structure provides the mounting platform for the solar array and the control cabinet that houses the battery bank and charger.

Place a concrete work pad measuring 4 feet wide by 3 feet long by 4 inches deep in front of the RPU control cabinet if the cabinet is ground mounted. The pad shall conform to specifications for nonstructural Portland cement as detailed in Section 347.

781-5.3 Applicable Standards: Ensure that the RWIS complies with the Electronic Industries Alliance (EIA) requirements as detailed in the EIA-170 standard, as well as all applicable standards from the National Weather Service.

Ensure that the RWIS complies with the latest revisions of all applicable NTCIP standards, including NTCIP-1201 and NTCIP-1204. Ensure that the National Television System Committee requirements are met if the RWIS includes CCTV capability.

ESS installations utilizing wireless communications shall conform to the requirements of the standard IEEE 802.15.4, Wireless Media Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (LR-WPANs).

781-5.4 Installation Requirements: Ensure that all equipment and materials furnished, assembled, fabricated, or installed are commercial off-the-shelf products.

Unless detailed otherwise in the plans, mount all atmospheric sensors except anemometers at cabinet-top height, approximately 10 feet above grade. Mount anemometers at the top of the tower. If local restrictions prevent installing the anemometers at the top, install them no less than 20 feet above the ground. Locate pavement and subsoil sensors as specified in the plans.

Install all wiring so that it is either internal to a pole, in conduit attached to truss members, or contained in underground conduit.

Install all buried lead-in cable to subsoil or pavement sensors according to the trenched conduit requirements detailed in Section 630.

Mount all roadway sensors flush with the roadway surface.

781-5.5 Testing: Utilize a testing procedure that includes a remote field sensor and RPU test, a remote-to-central communication test, and a systems operational test. Conduct the following tests and submit the results to the Engineer:

1. Perform and document laboratory tests verifying proper sensor calibration.
2. Calibrate instrument alignment with true north.
3. Furnish sensor calibration protocols and adjustment procedures.
4. Verify and ensure that sensors are reporting proper field data.
5. Detail regular site maintenance procedures and calibration training.
6. Provide block diagrams, schematics, catalogs, and line drawings.
7. Program source codes in both printed and digital form.
8. Verify proper orientation of wiring and cabling.
9. Ensure that the conduit is straight, neat, and properly secured.
10. Verify that the grounding component is installed as required in 785-2 and produces a voltage standing wave ratio (VSWR) of 1.5 or less.

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Subject the RWIS to a 30-day observation period, during which time the Contractor shall perform any and all maintenance, recalibration, and data verification required by the Engineer.

Certify anemometers by wind tunnel tests. Submit test results to the Engineer for review and approval. Upon request, furnish independent laboratory testing documentation certifying 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 device to be attached.

Perform local field operational testing at each RWIS field site according to the test plans detailed in this section. After the environmental sensor and RPUs, and other RWIS hardware, power supplies, and connecting cables have been installed, perform the following:

1. Verify that physical construction has been completed as specified in the plans.
2. Inspect the quality and tightness of ground and surge protector connections.
3. Check power supply voltages and outputs.
4. Connect devices to the power sources.
5. Verify installation of specified cables and connections between the environmental sensor and RPUs, and the control cabinet.
6. Test local operation of all environmental sensor and RPU components.

Within three days of successful test completion, deliver to the Engineer a written completion notice and a copy of all test results. Include in the completion notice the documentation of any discrepancies found during testing, along with environmental sensor and RPU serial numbers. Include assembly installation locations and successful test completion dates.

Within 10 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.

If the Engineer rejects the work, promptly remedy the defect or failure specified in the Engineer's notice. Upon completion of the remedy, again provide the Engineer with a completion notice. The Engineer may identify an independent third party to specify what defects must be addressed in order for the work to meet the specifications.

781-6 Guaranty Provisions.

Ensure that the DMS and HAR systems and equipment furnished have a manufacturer's warranty covering defects in assembly, fabrication, and materials for a minimum 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 RWIS equipment and components furnished have a manufacturer's warranty covering defects in assembly, fabrication, and materials for three 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.

If the manufacturer's warranties for these systems and components are for a longer period, those longer period warranties will apply.

Ensure that the manufacturers' warranties on DMS, RWIS, and HAR systems are 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.

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781-7 Method of Measurement.

Measurement for payment will be in accordance with the following work tasks.

781-7.1 Furnish and Install: For DMS, the quantity to be paid for will be each sign and associated support structure furnished, installed, warranted, made fully operational, and tested in accordance with the specifications in this section.

The Contract unit price for each HAR system, 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, documentation, and incidentals necessary to complete the work.

The Contract unit price for an RWIS at each field location, 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.

781-7.2 Furnish: The Contract unit price per each DMS, HAR or RWIS system, furnished, will include all equipment specified in the Contract Documents, plus all shipping and handling costs involved in delivery as specified in the Contract Documents.

781-7.3 Install: The Contract unit price per each DMS, HAR or RWIS system, 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, documentation, and incidentals necessary to complete the work. The Engineer will supply the equipment specified in the Contract Documents.

781-8 Basis of Payment.

Price and payment will be full compensation for furnishing all materials and completing all work as specified in this section or shown in the plans.

Payment will be made under:

Item No. 781-1	Dynamic Message Sign – each.
Item No. 781-2	Highway Advisory Radio System – each.
Item No. 781-3	Road Weather Information System – each.