General Requirements

All specifications are defined as mandatory minimum requirements. Vendors may bid items that meet or exceed these requirements. Bidder must submit documentation that clearly describes product details that exceed or comply by an alternate design to these requirements.

1. Dynamic Message Sign Manuals and Reports

The Dynamic Message Sign Manual shall provide comprehensive instruction for the maintenance and operation of the materials procured through the contract, including operation of local sign controller software. Three hard-copies per commodity must be submitted with each order. Copies must also be submitted in an electronic format.

1. Protocol Documentation

The controller sign control and communications software shall be non-proprietary, and shall enable modification of communication and command protocols and formats by the Wisconsin Department of Transportation. Programming source code (including compiler program version and settings used to develop firmware/software and all installation / build scripts), logic diagrams, and other necessary documentation shall be provided fully to support this modification by the Department. Documentation duplication by the Department shall not require additional payment to the vendor or the manufacturer, and shall not require authorization by vendor of the manufacturer. Copies of the controller sign control software and remote communications software shall be provided in an electronic format that is useable by WisDOT. Two copies of the software shall be provided for each dynamic message sign or controller.

1. Warranty and Support

The Vendor shall warrant the accepted dynamic message sign for six years from the date of delivery. The Vendor shall warranty the sign delivered under this project shall be able to accurately perform and comply with all required functionality. The Vendor shall repair or replace within 10 working days, at its option, any component of the sign whose non-compliance is discovered and made known by the Department to the Vendor in writing within one year after acceptance hereunder of the non-compliant item.

The Vendor shall provide telephone support during normal working hours (8am-5pm Monday-Friday) for WisDOT or a designated representative for one year after initial acceptance of the dynamic message sign. Telephone support shall consist of a single number provided to the Department to call and request technical assistance regarding integration and/or operational concerns. The Vendor shall respond to Department initiated support requests within one business day.

1. Materials Submittals and Design and Shop Drawings

Along with the bid, submit one original, one electronic, and four copies of design drawings and shop drawings of all commodities required under this contract. These drawings shall document and demonstrate that the proposed materials meet the requirements of the Standard Specifications.

The materials submitted will be reviewed and evaluated along with the other documentation submitted for these specifications. Issues of non-compliance with the specifications discovered during this review may lead to rejection of the bid.

1. Testing

All equipment and material furnished by the Vendor shall be subject to monitoring and testing to determine conformance with all the applicable requirements specified herein and to ensure proper operations of the DMS components and assemblies. Documentation as required to demonstrate component performance and operation in conformance with the Standard Specifications shall be furnished by the Vendor. The Vendor shall supply all equipment required for conducting tests.

1. Pre-Installation Test

A pre-installation test and check-list shall be developed by the Vendor and conducted for each sign to verify that the equipment conforms to the specifications herein, and provides messages that can be viewed by the public. The Vendor shall conduct the test prior to shipping the sign and include the completed checklist with each sign. WisDOT will re-test the sign following the same procedures after delivery and coordinate resolution of any shortcomings with the Vendor. When applicable, the sign will be tested with the actual controller to be installed in the field, and all functions as described shall be documented as completely tested and functional. Failure of any portion of the tests shall be remedied by the Vendor within 7 days.

1. Maintenance

Maintenance and repair of all DMS signs should not require any special tools. LED display modules should be interchangeable among all signs bid as part of this bid. The Vendor is encouraged to bid optional maintenance and support contracts over and above warranty and support for each sign.

1. Optional Features

Optional features are features and capabilities of the equipment being offered by Vendors that exceed the mandatory minimum written specifications for each sign, which may incur costs in addition to the base bid for each respective commodity. Examples of possible optional features include:

• Radar vehicle detector connection enabled;

• Over height / overweight sensor connection and display functions;

• Environmental / Weather sensor connection, integration, and display functions enabled;

• Spare parts shared across all equipment in this contract;

• Higher resolution display;

• Field maintenance software;

• Extended software warranty and/or service plan;

• Extended service warranty;

• Extended parts and hardware warranty.

Functions and features submitted as Optional Features may incur costs in addition to the base price of each commodity in this contract. Brief and clear descriptions of Optional Features must be submitted as an attachment to the materials submittals and design and shop drawings for each commodity for which it is applicable under an attachment clearly labeled “Optional Features”. Price, unit, and quantity for optional features must be included on Attachment E—Cost Sheet. Additional lines may be added if necessary. The costs for optional features will be used as a basis for establishing the costs for any resulting contract but will not be considered as method of award.

Appendix A

Overhead Freeway Dynamic Message Signs (DMS),

Full Matrix, Walk-In, Color, 6 Feet by 22 Feet

Specification

1. General Information
	1. DMS General Requirements

Furnish overhead freeway full color, full display matrix dynamic message sign (DMS) assemblies. Provide the overhead freeway DMS and housing design; and furnish overhead freeway DMS and housing which meet all requirements herein provided. Submit signed and certified design drawings, calculations, and material specifications for all aspects of the sign assemblies including the electronics, housing, and mounting assemblies. Meet the following general requirements for each DMS provided:

* Design the sign for a minimum life of 20 years.
* Remove all company or vendor logos anywhere on the exterior of the sign housing.
* Comply with all applicable federal and state standards along with NTCIP standards.
	1. General Display Requirements

Meet the following display requirements for each DMS provided:

* Provide a continuous and uniform appearance to the traveling public that consists of Light Emitting Diode (LED) composed of multiple red, green, and blue LEDs.
* Conform to the appropriate National Transportation Communications for ITS Protocol (NTCIP) Standards.
* Display area of with minimum dimensions of 6 feet high and 22 feet wide. A larger display area is allowable within the confines of other requirements in this specification.
* Border around the display area of a minimum of 8 inches and a maximum of 10 inches.
* Display alphanumeric text, punctuation symbols and graphic images across multiple panels.
* Provide documentation that the sign is legible per NEMA TS4 standards at a horizontal distance of 900 feet and a height of 20 feet.
	1. General Dimension and Weight Requirements

Meet the following dimension and weight requirements for each DMS provided:

* Dimensions of the overhead freeway DMS housing equal to or less than 10 feet tall by 26 feet long.
* Front-to-back housing depth equal to or less than 5 feet at its widest point, including any rear ventilation hoods.
* Total weight of the overhead freeway DMS equal to or less than 4,800 lbs.
* Design includes enclosed walk-in housing.
1. Environment
	1. Outside Environmental Requirements

Design the system to conform to all applicable NEMA requirements and to meet the following minimum requirements and characteristics for outside environmental conditions:

* + - * Ensure DMS enclosure, components, heating and ventilation and workmanship are new components, corrosion resistant and adequate to assure full sign functionality and durability in an outdoor environment.
			* Provide field equipment that performs to the minimum environmental and sign hardware requirements of -29°F to 165°F and a humidity range of 0 percent to 95 percent relative non-condensing.
			* All outdoor enclosures must resist water infiltration during hose-directed water per NEMA 250 – Class 3R requirements.
			* All connections, internal or external to the DMS must be watertight.
			* All DMS components will not be damaged by temporary exposure to temperatures of -50°F to +185° F.
	1. Environmental Monitoring Systems

Provide a system with multiple sensors that are mounted on the front, rear, and under side facing the ground of the DMS housing that monitor and report ambient external light level and temperature.

Provide light sensors to continuously monitor and adjust the LED display matrix intensity to a level that ensures a legible message on the DMS face.

Monitor the sensors continuously by the DMS controller and report to the DMS control central software upon request. The DMS controller should only reply to polls from the central software and not send the information without being polled.

* 1. Inside Environment

Meet the following minimum requirements and characteristics for environmental conditions maintained inside the sign enclosure:

* Install a ventilation system designed to keep the internal DMS air temperature lower than +140°F, when the outdoor ambient temperature is +115°F or less.
* Eliminate condensation within the sign enclosure to ensure longevity of the LEDs and electronic components.
* Install a thermostat near the top of the overhead freeway DMS interior that will automatically activate the housing exhaust system whenever the internal air temperature exceeds +100°F.
* Design the sign to meet or exceed all International Mechanical (IM) standards (formally BOCA, ICBO and SBCCI) for human occupation. This standard can be best described as follows; in regards to the high temperature requirement of the DMS housing, the sign housing interior temperature must be maintained at a maximum of 25°F above the outside air temperature.

The vendor must submit the ventilation calculations that verify that the DMS meets all IM standards for human habitation.

Fans and air filters must be removable and replaceable from inside the DMS housing. To ease serviceability, mount the fans at a pre-approved optimum locations not obstructed by other subsystems while meeting all the ventilation requirements.

Locate an adjustable manual override timer (from 0 to 4 hours) switch just inside the access door to manually activate the ventilation system.

Filters must be removable without the need for special tools and must remove airborne particles measuring 5 microns in diameter and larger. The intake air filter media must be readily available from three sources. The manufacturer recommended minimum filter replacement cycle must be a minimum of once every two months to a maximum of once every six months.

Install two electronic temperature monitoring devices and one humidity sensor to assure a failsafe monitoring of the interior temperature. The temperature monitoring devices will be wired independently and upon failure of either an alarm message must be transmitted through the DMS controller to the central sign control software. The system shall be configurable such that the DMS will automatically shut down the LED modules to prevent damage if the internal temperature exceeds a minimum threshold temperature.

Monitor the sensors continuously by the DMS controller and report to the DMS control software upon request.

Cover each intake and exhaust port on its front, and sides by an aluminum hood that is riveted to the rear overhead freeway DMS wall. Screen openings to prevent the entrance of insects and small animals. Fabricate hoods from 0.090-inch or thicker aluminum sheeting. Seal all hood-to-housing contact edges to prevent water from entering the housing.

Design the system to defog/defrost the front face panel whenever the internal air temperature falls below +40° F automatically.

At a minimum install one 4-foot, 40-watt fluorescent lamp fixture for every five feet of housing length. Space lamps evenly across the housing ceiling in order to provide uniform light distribution for maintenance purposes. Use lamp ballasts rated for operation at 0° F. Protect lamps with wire cages. Control lamp circuits with a manual timer switch having an adjustable timer of two hours. Locate one light switch within easy reach of the access door.

1. DMS Display
	1. LED Display Modules

The DMS shall contain LED display modules that include an LED pixel array and LED driver circuitry. Mount modules adjacently in a two-dimensional array to form a continuous LED pixel matrix. Construct each LED display module as follows:

* Each LED display module may consist of one or two circuit boards. If two boards are used, physically mount them to each other using durable non-corrosive hardware and electrically connect them via one or more header-type connectors. Key the header connectors such that the boards cannot be connected incorrectly.
* Manufacture all LED modules using laminated fiberglass printed circuit boards.
* Mount each LED display module using durable non-corrosive hardware. No special tools shall be required to remove and replace the module. Mount the modules such that the face panel does not block any part of the viewing cone of any of the LEDs in any pixels. Do not use light enhancing lenses to achieve defined viewing cone.
* Use quick-disconnect locking connector type for LED display module power and signal connections. Removal of a display module from the DMS, or a pixel board or driver circuit board from its display module, shall not require a soldering operation.
* Protect all exposed metal on both sides of each printed circuit board, except connector contacts, from water and humidity exposure by a thorough application of conformal coating. Allow bench level repair of individual components, including discrete LED replacement and conformal coating repair.
* Configure individual addressing of the each LED display module via the communication wiring harness and connector. Do not use on-board addressing jumpers or switches.
* Removal or failure of any LED module shall not affect the operation of any other LED module or sign component. Removal of one or more LED modules shall not affect the structural integrity of any part of the sign.
* It shall not be possible to mount an LED display module upside-down or in an otherwise incorrect position within the DMS display matrix.
* All LED display modules, as well as the LED pixel boards and driver circuit boards, shall be identical and interchangeable throughout the DMS.
	1. LED Pixels

Manufacture LED modules on a printed circuit board to which LED pixels are soldered. The LED pixel matrix shall conform to the following specifications:

The distance from the center of one pixel to the center of all adjacent pixels, both horizontally and vertically, shall be 0.787 inches (20 mm).

Each pixel shall consist of a minimum of one independent string of discrete LEDs for each color. All pixels shall contain an equal quantity of LED strings.

The failure of an LED string or pixel shall not cause the failure of any other LED string or pixel in the DMS.

Each pixel shall contain the quantity of discrete LEDs needed to output white colored light at a minimum luminous intensity of 12,400 candelas per square meter when measured using a photometric meter through the DMS front face panel assembly. Failure to conform to the requirements will be cause for rejection.

Each pixel shall also be capable of displaying amber colored light with a minimum luminous intensity of 7,440 candelas per square meter when measured using a photometric meter through the DMS front face panel assembly. Failure to conform to the requirements will be cause for rejection.

Construct DMS pixels with discrete LEDs manufactured by a reputable manufacturer such as Avago Technologies (formerly Agilent Technologies), Toshiba Corporation, Nichia Corporation, OSRAM, Cree, Inc., or EOI. Discrete LEDs shall conform to the following specifications.

All LEDs shall have a nominal viewing cone of 30 degrees with a half-power angle of 15 degrees measured from the longitudinal axis of the LED. Viewing cone tolerances shall be as specified in the LED manufacturer’s product specifications and shall not exceed +/- 5 degrees. Using optical enhancing lenses with 15 degree LED’s will not conform to 30 degree half-power viewing cone specifications and will be cause for rejection.

Red LEDs shall utilize AlInGaP semiconductor technology and shall emit red light that has a peak wavelength of 615-635nm

Green LEDs shall utilize InGaN semiconductor technology and shall emit green light that has a peak wavelength of 520-535nm

Blue LEDs shall utilize InGaN semiconductor technology and shall emit blue light that has a peak wavelength of 464-470nm

Fabricate the LED packages from UV light resistant epoxy.

The LED manufacturer shall perform color sorting of the bins. Obtain each color of LEDs from no more than two consecutive color “bins” as defined by the LED manufacturer.

The LED manufacturer shall perform intensity sorting of the bins. Obtain LEDs from no more than two consecutive luminous intensity “bins” as defined by the LED manufacturer.

Evenly distribute the various LED color and intensity bins throughout the sign and shall be consistent from pixel to pixel. Random distribution of the LED bins shall not be accepted.

The LED manufacturer shall assure color uniformity and consistency on the LED display face within the 30 degree cone of vision. Inconsistent color shifts or intensity will be cause for rejection.

All LEDs used in all DMS provided for this contract shall be from the same manufacturer and of the same part number, except for the variations in the part number due to the intensity and color.

The LEDs shall be rated by the LED manufacturer to have a minimum lifetime of 100,000 hours of continuous operation while maintaining a minimum of 70% of the original brightness.

1. Housing Characteristics
	1. General Housing

Fabricate, weld, and inspect the overhead freeway DMS housing in accordance with AWS D1.2/D1.2M:2003 *Structural Welding Code-Aluminum* (2003). Perform welding according to documented in-house welding procedures, and certify personnel who perform welding on the overhead freeway DMS housing to AWS D1.2/D1.2M:2003 for all weld types required.

Design and construct the housing to follow the AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals, 5th Edition*.

Housing shall protect internal components from rain, ice, dust, and corrosion in accordance with NEMA enclosure Type 3R standards, as described in *NEMA Standards Publication 250-1997, Enclosures for Electrical Equipment (1000 Volts Maximum)*.

Construct the housing and modules so that all maintenance is performed from within the sign.

Fabricate the housing from 0.125-inch (minimum) thick 3003-H14 or 5052-H32 aluminum alloy. Round all edges and corners.

Construct the housing to have a neat, professional appearance. Securely clamp or tie all cables in the sign housing.

Drain any water that accumulates due to condensation with small weep holes on the bottom side. Screen weep holes and ventilation/exhaust hoods to prevent the entrance of insects and small animals.

Mount the display elements on interior non-corrosive metal cage support frames. Design the cage support frame to withstand and minimize vibration when the sign is mounted with any number of display elements.

Provide a 20-Amp utility outlet circuit consisting of a minimum of three (3) NEMA 20-R, 120 VAC duplex outlets, with ground-fault circuit interrupters. Locate one outlet near each end of housing interior, and the third outlet near the housing’s center.

Include a fire-retardant flooring system in the housing. Construct the flooring system at a fixed elevation with removable panels. Equip the housing with a fire extinguisher capable of extinguishing class A, B, and C fires, be USCG and OSHA approved and that meets the following additional requirements:

* + - * Nominal Capacity: 5 LBS
			* U/L Rating: 3A-40B:C
			* Valve Material: Aluminum
			* Shell Material: Steel
			* Operating Pressure: +195 PSI
			* Temperature Range: -401 to 1201° F
			* Discharge Time: 14.0 seconds
			* Range: 12 – 18 feet
			* USCG Certified Bracket

* 1. Housing Frame

Construct the housing’s right, left, and rear walls vertical. Construct the housing’s top and bottom sides horizontal. Use aluminum extrusions made from alloy number 6061-T6 or 6063-T5 for the structural frame.

* 1. Mounting Brackets

Provide two lifting eyes with a minimum one inch diameter on the housing to be used when placing the housing on the sign structure. The Engineer will position the lifting eyes. Fully assembled signs will be lifted into place using both lifting eyes. However, each eye shall have sufficient structural strength to allow the sign be lifted or moved without structural damage or permanent deformation to the sign.

Provide multiple mounting brackets in the form of I-beams or Z-extrusions bolted to the housing exterior rear wall, to facilitate attachment of the overhead freeway DMS to its support structure. Use mounting brackets made from extruded aluminum alloy number 6061-T6. Attach the mounting brackets to the overhead freeway DMS structural frame members, not just the exterior sheet metal. Attach the mounting brackets to the overhead freeway DMS using galvanized A 105 grade high-strength steel bolts. Design and fabricate the mounting brackets such that the installing Vendor can drill into them without penetrating the overhead freeway DMS housing and comprising the housing’s ability to shed water.

Overhead freeway DMS structural hardware and mounting brackets hardware (nuts, bolts, washers, and direct tension indicators) shall be stainless steel or galvanized high-strength steel appropriately sized for the application.

* 1. Front Face Construction

Construct the front face with multiple rigid panels, each of which support and protect a full height section of the LED display matrix. Panel exteriors shall be fabricated from 0.090-inch aluminum sheeting and panel interiors shall be 0.125-inch polycarbonate sheeting. All sides, except the front, shall be covered with 0.125-inch thick aluminum sheets made from alloy number 5050-H34 or 3003-H14.

Bolt face panels to the overhead freeway DMS housing and to each other using stainless steel hardware. Seal seams that separate adjacent panels. Stitch weld the interior side of each sheet to the frame members. All exterior sheet seams shall be continuously seam welded to the frame, in order to form a unitized structure.

Panels shall be removable and shall not be welded to the overhead freeway DMS housing.

Weight of a single face panel shall not exceed 150 lbs.

Provide a high-contrast background on the front face. Paint aluminum portions of each panel black. Front face shall employ a flat black anti-glare sheeting substance. To maximize display contrast and legibility paint the overhead freeway DMS front face borders (top, bottom, left side, and right side), which surround the front face panels and LED display matrix, black.

Front panel shall be mounted securely as to withstand a 100 mph wind load, and shall not obscure any of the pixels in the sign. In the presence of wind, the overhead freeway DMS front face shall not distort in a manner that adversely affects LED message legibility.

Mount display modules to the inside of the front face panels using either standard hand tools or no tools for removal and replacement.

* 1. Exterior Finish

Powder-coat paint or anodize all outside surfaces. Border piece shall be coated with semi-gloss black Kynar 500 or an equivalent brand oven-fired fluropolymer coating which has an expected outdoor service life of 20 years. All other housing surfaces, including overhead freeway DMS mounting brackets shall be natural mill-finish aluminum. As an alternative to powder coating and anodization, the Vendor may propose an alternative housing finish that has an outdoor service life of 20 years and is covered by a corresponding warranty.

1. Maintenance Access
	1. General Information

Minimum distance from the interior rear wall to the closest display component shall be 32 inches. Minimum headroom of 72 inches shall also be provided. Free space shall be maintained across the entire length of the overhead freeway DMS housing, with the exception of structural frame members. Design the structural frame members to not obstruct the free movement of maintenance personnel throughout the overhead freeway DMS housing.

* 1. Access Door

Display matrix and other internal components shall be accessible through a walk-in doorway located on a sidewall of the sign housing (perpendicular to the LED display matrix). Housing shall have an access door on the right side of housing (as seen from the front). Access door shall hinder toward the rear of the sign. Access door shall have a minimum dimension of 72 inches high by 24 inches wide and shall be weatherproof. Door shall be positioned such that entrance into the sign by maintenance personnel shall meet OSHA and DIHLR.

Access door shall contain a stop that retains the door in a 90° open position. When a door is open, the door and its stop shall not be damaged by a 40-mph wind. When open at a 90° angle from the housing rear wall, shall not extend more than 38 inches from the housing. The bottom edge of the door shall be at least 6-inches from the bottom edge of the overhead freeway DMS housing. Doorframe shall be double flanged on all sides so they shed water. Each door shall close around its flanged frame and compress against a closed-cell foam gasket, which adheres to the door. Provide a locking mechanism for each door. The locking mechanism shall be failsafe in that it shall be possible for a person, with no tools or keys, to unlock and open the door from the inside.

Furnish each door with a lock that is keyed to the Engineer’s requirements.

Provide a door switch for the access door. When the door is opened the switch shall send a signal to the controller sufficient for the controller to log an alarm.

* 1. Service Walkway

Install a level walkway in the bottom of the overhead freeway DMS housing. The service walkway shall be a minimum of 24 inches wide, and it shall run the entire length of the housing. The walkway shall be made of 1/8-inch diamond tread 6061-T6 or 3003-H22 aluminum or sheet aluminum with non-slip traction tape applied. Walkway’s top surface shall be non-slip and shall be free of obstructions that would trip service personnel. Walkway shall support a load per NEMA TS4-2004, and it shall be constructed of multiple, removable panels.

* 1. Safety

Equip each DMS with a removable safety rail assembly that conforms to the following requirements:

* A single-piece assembly that extends 48 inches above the interior walkway and contains multiple horizontal rails that are no more than 12 inches apart.
* Attaches to the overhead freeway DMS using stainless steel hardware that requires simple or no tools for removal and replacement.

Mount one hard-wired UL 2034 carbon monoxide monitor to the DMS housing and located opposite of the access door.

Mount one ANSI Z308.1-1998 certified first aid kit to the inside of the DMS housing in an exposed area.

Provide documentation that describes any additional safety features including in the DMS design not listed in this section.

1. Sign to Cabinet Interconnect

Connect the DMS to its cabinet following the following minimum requirements:

* Provide communication control cables 300 feet in length between the sign and the sign controller cabinet (provided under a separate item) for operation of the sign.
* Provide fiber optic for all control, communication, and data purposes. As an option provide a copper signal cable if requested.
1. Electrical
	1. Wiring

Furnish all wiring both internal to the cabinet and between the cabinet and the overhead freeway DMS components within the housing to provide the following functionality:

* Wire and color-code all components per the most recent National Electrical Code (NEC) and Wisconsin Electrical Code requirements.
* Provide AC Power for control equipment with a series-connected surge suppresser capable of passing 15 amps of current that shall protect the field controller and modem (or signal converter).
* Provide electrical protection, bonding and grounding for the DMS.
1. Standards

The following is a list of standards and specifications that must be in full compliancy:

* 1. FHWA *Manual on Uniform Traffic Control Devices, 2009 Edition with Revisions*
	2. AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals*, 5th Edition
	3. ANSI/AWS (American Welding Society) D1.2/D1.2M:2003– Structural Welding Code – Aluminum
	4. NCHRP Report 412, *Fatigue-Resistant Design of Cantilevered Signal, Sign, and Light Supports*
	5. National (United States) and Wisconsin Electric Code
	6. NEMA Standards Publication 250 – *Enclosures for Electrical Equipment*
	7. NEMA Standard TS 1, Section 2 – *Environmental Standards and Test Procedures, Traffic Control Systems*
	8. NEMA Standard TS 4-2005 – *Hardware Standards for Dynamic Message Signs (DMS), with NTCIP Requirements*
	9. NTCIP Standards:
		1. NTCIP 1101: NTCIP 1101:1997 (NEMA TS 3.2-1996); *Simple Transportation Management Framework*
		2. NTCIP 1102: NTCIP 1201 v01.06, *Octet Encoding Rules (OER) Base Protocol*
		3. NTCIP 1103, *Simple Transportation Network Protocol (STMP)*
		4. NTCIP 1201: NTCIP 1201:1996 (NEMA TS 3.4-1996); *Global Object Definitions*
		5. NTCIP 1203: NTCIP 1203v03.04:2011; *Object Definitions for Dynamic Message Signs* - All Applicable Mandatory and Optional Requirements
		6. NTCIP 2001: NTCIP 2001:1996 (NEMA TS 3.3-1996); *NTCIP Class B Profile*
		7. NTCIP 2101: NTCIP 2101 v01.17 (NEMA TS3.SP-PMPP232), *Point to Multi-Point Protocol Using RS-232 Subnetwork Profile*
		8. NTCIP 2102: NTCIP 2102 v01.04, *Subnet Profile for PMPP Over FSK Modems*
		9. NTCIP 2103: NTCIP 2103 v01.05 (NEMA TS 3.SP-PPP232), *Subnet Profile for Point-to-Point Protocol Over RS-232*
		10. NTCIP 2104: NTCIP 2104 v01.07, *Subnet Profile for Ethernet*
		11. NTCIP 2201: NTCIP 2201 v01.11, *Transportation Transport Profile*
		12. NTCIP 2202: NTCIP 2202-1999, *Internet (TCP/IP and UDP/IP) Transport Profile*
		13. NTCIP 2301: NTCIP 2301-1999 (NEMA 3.AP-STMF), *Application Profile for Simple Transportation Management Framework (STMF)*
		14. NTCIP 2303: NTCIP 2303-1999, *Application Profile for File Transfer Protocol (FTP)*

Appendix B

Overhead Freeway Dynamic Message Signs (DMS),

Full Matrix, Front Access, Color, 6 Feet by 22 Feet

Specification

1. General Information
	1. DMS General Requirements

Furnish an overhead full color, full display matrix, front access dynamic message sign (DMS) assemblies. Submit signed and certified design drawings, calculations, and material specifications for all aspects of the sign assemblies including the electronics, housing, and mounting assemblies to the Engineer for review prior to incorporation into the work. Meet the following general requirements for each DMS provided:

* Design the sign for a minimum life of 20 years.
* Remove all company or vendor logos anywhere on the exterior of the sign housing.
* Comply with all applicable federal and state standards along with NTCIP standards.
	1. General Display Requirements

Meet the following display requirements for each DMS provided:

* Provide a continuous and uniform appearance to the traveling public that consists of Light Emitting Diode (LED) composed of multiple red, green, and blue LEDs.
* Conform to the appropriate National Transportation Communications for ITS Protocol (NTCIP) Standards, as herein after provided.
* Display area of with minimum dimensions of 6 feet high and 22 feet wide. A larger display area is allowable within the confines of other requirements in this specification.
* Display alphanumeric text, punctuation symbols and graphic images across multiple panels.
	1. General Dimension and Weight Requirements

Meet the following dimension and weight requirements for each DMS provided:

* Dimensions of DMS housing equal to or less than 10 feet tall by 26 feet long.
* Front-to-back housing depth equal to or less than 5 feet at its widest point, including any rear ventilation hoods.
* Total weight of the side mounted DMS equal to or less than 4,800 lbs.
* Design includes enclosed front access housing.
1. Environment
	1. Outside Environmental Requirements

Design the system to conform to all applicable NEMA requirements and to meet the following minimum requirements and characteristics for outside environmental conditions:

* + - * Ensure DMS enclosure, components, heating and ventilation and workmanship are new components, corrosion resistant and adequate to assure full sign functionality and durability in an outdoor environment.
			* Provide field equipment that performs to the minimum environmental and sign hardware requirements of -29°F to 165°F and a humidity range of 0 percent to 95 percent relative non-condensing.
			* All outdoor enclosures must resist water infiltration during hose-directed water per NEMA 250 – Class 3R requirements.
			* All connections, internal or external to the DMS must be watertight.
			* All DMS components will not be damaged by temporary exposure to temperatures of -50° F to +185°F.
	1. Environmental Monitoring Systems

Provide a system with multiple sensors that are mounted on the front, rear, and under side facing the ground of the DMS housing that monitor and report ambient external light level and temperature.

Provide light sensors to continuously monitor and adjust the LED display matrix intensity to a level that ensures a legible message on the DMS face.

Monitor the sensors continuously by the DMS controller and report to the DMS control software upon request. The DMS controller should only reply to polls from the central software and not send the information without being polled.

* 1. Inside Environment

Meet the following minimum requirements and characteristics for environmental conditions maintained inside the sign enclosure:

* Install a ventilation system designed to keep the internal DMS air temperature lower than +140°F, when the outdoor ambient temperature is +115°F or less.
* Eliminate condensation within the sign enclosure to ensure longevity of the LEDs and electronic components.
* Install a thermostat near the top of the DMS interior that will automatically activate the housing exhaust system whenever the internal air temperature exceeds +100°F.
* Design the sign to meet or exceed all International Mechanical (IM) standards (formally BOCA, ICBO and SBCCI) for human occupation. This standard can be best described as follows; in regards to the high temperature requirement of the DMS housing, the sign housing interior temperature must be maintained at a maximum of 25°F above the outside air temperature.

Fans and air filters shall be removable and replaceable. To ease serviceability, mount the fans at a pre-approved optimum locations not obstructed by other subsystems while meeting all the ventilation requirements.

Filters must be removable without the need for special tools and must remove airborne particles measuring 5 microns in diameter and larger. The intake air filter media must be readily available from three sources. The manufacturer recommended minimum filter replacement cycle must be a minimum of once every two months to a maximum of once every six months.

Install two electronic temperature monitoring devices to assure a failsafe monitoring of the interior temperature. The temperature monitoring devices will be wired independently and upon failure of either an alarm message must be transmitted through the DMS controller to the central sign control software. The system shall be configurable such that the DMS will automatically shut down the LED modules to prevent damage if the internal temperature exceeds a minimum threshold temperature.

Cover each intake and exhaust port on its front, and sides by an aluminum hood that is riveted to the rear DMS wall. Screen openings to prevent the entrance of insects and small animals. Fabricate hoods from 0.090-inch or thicker aluminum sheeting. Seal all hood-to-housing contact edges to prevent water from entering the housing.

If needed activate the front face panel defog/defrost system whenever the internal air temperature falls below +40° F automatically.

1. DMS Display
	1. LED Display Modules

The DMS shall contain LED display modules that include an LED pixel array and LED driver circuitry. Mount modules adjacently in a two-dimensional array to form a continuous LED pixel matrix. Construct each LED display module as follows:

* Each LED display module may consist of one or two circuit boards. If two boards are used, physically mount them to each other using durable non-corrosive hardware and electrically connect them via one or more header-type connectors. Key the header connectors such that the boards cannot be connected incorrectly.
* Manufacture all LED modules using laminated fiberglass printed circuit boards.
* Mount each LED display module using durable non-corrosive hardware. No tools shall be required to remove and replace the module. Mount the modules such that the face panel does not block any part of the viewing cone of any of the LEDs in any pixels. Do not use light enhancing lenses to achieve defined viewing cone.
* Use quick-disconnect locking connector type for LED display module power and signal connections. Removal of a display module from the DMS, or a pixel board or driver circuit board from its display module, shall not require a soldering operation.
* Protect all exposed metal on both sides of each printed circuit board, except connector contacts, from water and humidity exposure by a thorough application of conformal coating. Allow bench level repair of individual components, including discrete LED replacement and conformal coating repair.
* Configure individual addressing of the each LED display module via the communication wiring harness and connector. Do not use on-board addressing jumpers or switches.
* Removal or failure of any LED module shall not affect the operation of any other LED module or sign component. Removal of one or more LED modules shall not affect the structural integrity of any part of the sign.
* It shall not be possible to mount an LED display module upside-down or in an otherwise incorrect position within the DMS display matrix.
* All LED display modules, as well as the LED pixel boards and driver circuit boards, shall be identical and interchangeable throughout the DMS.
	1. LED Pixels

Manufacture LED modules on a printed circuit board to which LED pixels are soldered. The LED pixel matrix shall conform to the following specifications:

The distance from the center of one pixel to the center of all adjacent pixels, both horizontally and vertically, shall be 0.787 inches (20 mm).

Each pixel shall consist of a minimum of one independent string of discrete LEDs for each color. All pixels shall contain an equal quantity of LED strings.

The failure of an LED string or pixel shall not cause the failure of any other LED string or pixel in the DMS.

Each pixel shall contain the quantity of discrete LEDs needed to output white colored light at a minimum luminous intensity of 12,400 candelas per square meter when measured using a photometric meter through the DMS front face panel assembly. Failure to conform to the requirements will be cause for rejection.

Each pixel shall also be capable of displaying amber colored light with a minimum luminous intensity of 7,440 candelas per square meter when measured using a photometric meter through the DMS front face panel assembly. Failure to conform to the requirements will be cause for rejection.

Construct DMS pixels with discrete LEDs manufactured by a reputable manufacturer such as Avago Technologies (formerly Agilent Technologies), Toshiba Corporation, Nichia Corporation, OSRAM, Cree, Inc., or EOI. Discrete LEDs shall conform to the following specifications. All LEDs shall have a nominal viewing cone of 30 degrees with a half-power angle of 15 degrees measured from the longitudinal axis of the LED. Viewing cone tolerances shall be as specified in the LED manufacturer’s product specifications and shall not exceed +/- 5 degrees. Using optical enhancing lenses with 15 degree LED’s will not conform to 30 degree half-power viewing cone specifications and will be cause for rejection.

Red LEDs shall utilize AlInGaP semiconductor technology and shall emit red light that has a peak wavelength of 615-635nm

Green LEDs shall utilize InGaN semiconductor technology and shall emit green light that has a peak wavelength of 520-535nm

Blue LEDs shall utilize InGaN semiconductor technology and shall emit blue light that has a peak wavelength of 464-470nm

Fabricate the LED packages from UV light resistant epoxy.

The LED manufacturer shall perform color sorting of the bins. Obtain each color of LEDs from no more than two consecutive color “bins” as defined by the LED manufacturer.

The LED manufacturer shall perform intensity sorting of the bins. Obtain LEDs from no more than two consecutive luminous intensity “bins” as defined by the LED manufacturer.

Evenly distribute the various LED color and intensity bins throughout the sign and shall be consistent from pixel to pixel. Random distribution of the LED bins shall not be accepted.

The LED manufacturer shall assure color uniformity and consistency on the LED display face within the 30 degree cone of vision. Inconsistent color shifts or intensity will be cause for rejection.

All LEDs used in all DMS provided for this contract shall be from the same manufacturer and of the same part number, except for the variations in the part number due to the intensity and color.

The LEDs shall be rated by the LED manufacturer to have a minimum lifetime of 100,000 hours of continuous operation while maintaining a minimum of 70% of the original brightness.

1. Housing Characteristics
	1. General Housing

Fabricate, weld, and inspect the DMS housing in accordance with AWS D1.2/D1.2M:2003 Structural Welding Code-Aluminum (2003). Perform welding according to documented in-house welding procedures, and certify personnel who perform welding on the overhead freeway DMS housing to AWS D1.2/D1.2M:2003 for all weld types required.

Design and construct the housing to follow the AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals, 2001*.

Housing shall protect internal components from rain, ice, dust, and corrosion in accordance with NEMA enclosure Type 3R standards, as described in *NEMA Standards Publication 250-1997, Enclosures for Electrical Equipment (1000 Volts Maximum)*.

Construct the housing and modules so that all maintenance is performed from the front of the sign. Demonstrate that maintenance by a single technician is feasible and safe.

Fabricate the housing from 0.125-inch (minimum) thick 3003-H14 or 5052-H32 aluminum alloy. Round all edges and corners.

Construct the housing to have a neat, professional appearance. Securely clamp or tie all cables in the sign housing.

Drain any water that accumulates due to condensation with small weep holes on the bottom side. Screen weep holes and ventilation/exhaust hoods to prevent the entrance of insects and small animals.

Mount the display elements on interior non-corrosive metal cage support frames. Design the cage support frame to withstand and minimize vibration when the sign is mounted with any number of display elements.

* 1. Housing Frame

Construct the housing’s right, left, and rear walls vertical. Construct the housing’s top and bottom sides horizontal. Use aluminum extrusions made from alloy number 6061-T6 or 6063-T5 for the structural frame.

* 1. Mounting Brackets

Provide two lifting eyes with a minimum one inch diameter on the housing to be used when placing the housing on the sign structure. The Engineer will position the lifting eyes. Fully assembled signs will be lifted into place using both lifting eyes. However, each eye shall have sufficient structural strength to allow the sign be lifted or moved without structural damage or permanent deformation to the sign.

Provide multiple mounting brackets in the form of I-beams or Z-extrusions bolted to the housing exterior rear wall, to facilitate attachment of the DMS to its support structure. Use mounting brackets made from extruded aluminum alloy number 6061-T6. Attach the mounting brackets to DMS structural frame members, not just the exterior sheet metal. Attach the mounting brackets to the DMS using galvanized A 105 grade high-strength steel bolts. Design and fabricate the mounting brackets such that the installing Vendor can drill into them without penetrating the DMS housing and comprising the housing’s ability to shed water.

DMS structural hardware and mounting brackets hardware (nuts, bolts, washers, and direct tension indicators) shall be stainless steel or galvanized high-strength steel appropriately sized for the application.

* 1. Front Face Construction

Construct the front face with multiple rigid panels, each of which supports and protects a full height section of the LED display matrix. Panel exteriors shall be fabricated from 0.090-inch aluminum sheeting and panel interiors shall be 0.125-inch polycarbonate sheeting. All sides, except the front, shall be covered with 0.125-inch thick aluminum sheets made from alloy number 5050-H34 or 3003-H14.

Bolt face panels to the DMS housing and to each other using stainless steel hardware. Seal seams that separate adjacent panels. Stitch weld the interior side of each sheet to the frame members. All exterior sheet seams shall be continuously seam welded to the frame, in order to form a unitized structure.

Panels shall be removable and shall not be welded to the DMS housing.

Weight of a single face panel shall not exceed 150 lbs.

Provide a high-contrast background on the front face. Paint aluminum portions of each panel black. Front face shall employ a flat black anti-glare sheeting substance. To maximize display contrast and legibility paint the DMS front face borders (top, bottom, left side, and right side), which surround the front face panels and LED display matrix, black.

Front panel shall be mounted securely as to withstand a 100 mph wind load, and shall not obscure any of the pixels in the sign. In the presence of wind, the DMS front face shall not distort in a manner that adversely affects LED message legibility.

Mount display modules to the inside of the front face panels using either standard hand tools or no tools for removal and replacement.

* 1. Exterior Finish

Powder-coat paint or anodize all outside surfaces. Border piece shall be coated with semi-gloss black Kynar 500 or an equivalent brand oven-fired fluropolymer coating which has an expected outdoor service life of 20 years. All other housing surfaces, including overhead freeway DMS mounting brackets shall be natural mill-finish aluminum. As an alternative to powder coating and anodization, the Vendor may propose an alternative housing finish that has an outdoor service life of 20 years and is covered by a corresponding warranty.

1. Maintenance Access
	1. General Information

Provide safe and convenient front access for all materials located within housing. All internal components shall be removable and replaced by a single technician.

Access panels shall open easily and be supported in their open position by multiple self-locking retaining devices. Means shall be designed to thoroughly support the access panel assembly in the open position in a 30-mph wind. Support systems shall be designed and configured for one maintenance person to safely and easily open and close the access panel assembly.

In the closed position, access panels shall be securely clamped by captive locking devices and attached to the DMS housing wall with stainless steel or aluminum hardware. The access panel assembly and all associated hardware shall be captive, so they cannot fall onto the roadway in any position.

 Demonstrate that maintenance is feasible and safe by a single technician.

Access panels shall open easily and be supported in their open position by multiple self-locking retaining devices. Means shall be designed to thoroughly support the access panel assembly in the open position in a 30-mph wind. Support systems shall be designed and configured for one maintenance person to safely and easily open and close the access panel assembly.

In the closed position, access panels shall be securely clamped by captive locking devices and attached to the DMS housing wall with stainless steel or aluminum hardware. The access panel assembly and all associated hardware shall be captive, so they cannot fall onto the roadway in any position.

1. Sign to Cabinet Interconnect

Connect the DMS to its cabinet following the following minimum requirements:

* Provide communication control cables 300 feet in length between the sign and the sign controller cabinet (provided under a separate item) for operation of the sign.
* Provide fiber optic for all control, communication, and data purposes. As an option provide a copper signal cable if requested.
1. Electrical
	1. Wiring

Furnish all wiring both internal to the cabinet and between the cabinet and the DMS components within the housing to provide the following functionality:

* Wire and color-code all components per the most recent National Electrical Code (NEC) and Wisconsin Electrical Code requirements.
* Provide AC Power for control equipment with a series-connected surge suppresser capable of passing 15 amps of current that shall protect the field controller and modem (or signal converter).
* Provide electrical protection, bonding and grounding for the DMS.
1. Standards

The following is a list of standards and specifications that must be in full compliancy:

* 1. FHWA *Manual on Uniform Traffic Control Devices, 2009 Edition with Revisions*
	2. AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals*, 5th Edition
	3. ANSI/AWS (American Welding Society) D1.2/D1.2M:2003– Structural Welding Code – Aluminum
	4. NCHRP Report 412, *Fatigue-Resistant Design of Cantilevered Signal, Sign, and Light Supports*
	5. National (United States) and Wisconsin Electrical Code
	6. NEMA Standards Publication 250 – *Enclosures for Electrical Equipment*
	7. NEMA Standard TS 1, Section 2 – *Environmental Standards and Test Procedures, Traffic Control Systems*
	8. NEMA Standard TS 4-2005 – *Hardware Standards for Dynamic Message Signs (DMS), with NTCIP Requirements*
	9. NTCIP Standards:
		1. NTCIP 1101: NTCIP 1101:1997 (NEMA TS 3.2-1996); *Simple Transportation Management Framework*
		2. NTCIP 1102: NTCIP 1201 v01.06, *Octet Encoding Rules (OER) Base Protocol*
		3. NTCIP 1103, *Simple Transportation Network Protocol (STMP)*
		4. NTCIP 1201: NTCIP 1201:1996 (NEMA TS 3.4-1996); *Global Object Definitions*
		5. NTCIP 1203: NTCIP 1203v03.04:2011; *Object Definitions for Dynamic Message Signs* - All Applicable Mandatory and Optional Requirements
		6. NTCIP 2001: NTCIP 2001:1996 (NEMA TS 3.3-1996); *NTCIP Class B Profile*
		7. NTCIP 2101: NTCIP 2101 v01.17 (NEMA TS3.SP-PMPP232), *Point to Multi-Point Protocol Using RS-232 Subnetwork Profile*
		8. NTCIP 2102: NTCIP 2102 v01.04, *Subnet Profile for PMPP Over FSK Modems*
		9. NTCIP 2103: NTCIP 2103 v01.05 (NEMA TS 3.SP-PPP232), *Subnet Profile for Point-to-Point Protocol Over RS-232*
		10. NTCIP 2104: NTCIP 2104 v01.07, *Subnet Profile for Ethernet*
		11. NTCIP 2201: NTCIP 2201 v01.11, *Transportation Transport Profile*
		12. NTCIP 2202: NTCIP 2202-1999, *Internet (TCP/IP and UDP/IP) Transport Profile*
		13. NTCIP 2301: NTCIP 2301-1999 (NEMA 3.AP-STMF), *Application Profile for Simple Transportation Management Framework (STMF)*
		14. NTCIP 2303: NTCIP 2303-1999, *Application Profile for File Transfer Protocol (FTP)*

Appendix C

Dynamic Message Signs (DMS),

Full Matrix, Full Color, 5 Feet by 16 Feet

Specification

1. General Information
	1. DMS General Requirements

Furnish overhead or side mount full color, full display matrix dynamic message sign (DMS) assemblies. Submit signed and certified design drawings, calculations, and material specifications for all aspects of the sign assemblies including the electronics, housing, and mounting assemblies to the Engineer for review prior to incorporation into the work. Meet the following general requirements for each DMS provided:

* Design the sign for a minimum life of 20 years.
* Remove all company or vendor logos anywhere on the exterior of the sign housing.
* Comply with all applicable federal and state standards along with NTCIP standards.
	1. General Display Requirements

Meet the following display requirements for each DMS provided:

* Provide a continuous and uniform appearance to the traveling public that consists of Light Emitting Diode (LED) composed of multiple red, green, and blue LEDs.
* Conform to the appropriate National Transportation Communications for ITS Protocol (NTCIP) Standards, as herein after provided.
* Display area of with minimum dimensions of 5 feet high and 16 feet wide. A larger display area is allowable within the confines of other requirements in this specification.
* Border around the display area of a minimum of 8 inches and a maximum of 10 inches.
* Display alphanumeric text, punctuation symbols and graphic images across multiple panels.
	1. General Dimension and Weight Requirements

Meet the following dimension and weight requirements for each DMS provided:

* Dimensions of DMS housing equal to or less than 8 feet tall by 19 feet long.
* Front-to-back housing depth equal to or less than 2 feet at its widest point, including any rear ventilation hoods.
* Total weight of the side mounted DMS equal to or less than 1,500 lbs.
* Design includes enclosed front or rear access housing.
1. Environment
	1. Outside Environmental Requirements

Design the system to conform to all applicable NEMA requirements and to meet the following minimum requirements and characteristics for outside environmental conditions:

* + - * Ensure DMS enclosure, components, heating and ventilation and workmanship are new components, corrosion resistant and adequate to assure full sign functionality and durability in an outdoor environment.
			* Provide field equipment that performs to the minimum environmental and sign hardware requirements of -29°F to 165°F and a humidity range of 0 percent to 95 percent relative non-condensing.
			* All outdoor enclosures must resist water infiltration during hose-directed water per NEMA 250 – Class 3R requirements.
			* All connections, internal or external to the DMS must be watertight.
			* All DMS components will not be damaged by temporary exposure to temperatures of -50° F to +185°F.
	1. Environmental Monitoring Systems

Provide a system with multiple sensors that are mounted on the front, rear, and under side facing the ground of the DMS housing that monitor and report ambient external light level and temperature.

Provide light sensors to continuously monitor and adjust the LED display matrix intensity to a level that ensures a legible message on the DMS face.

Monitor the sensors continuously by the DMS controller and report to the DMS control software upon request.

* 1. Inside Environment

Meet the following minimum requirements and characteristics for environmental conditions maintained inside the sign enclosure:

* Install a ventilation system designed to keep the internal DMS air temperature lower than +140°F, when the outdoor ambient temperature is +115°F or less.
* Eliminate condensation within the sign enclosure to ensure longevity of the LEDs and electronic components.
* Install a thermostat near the top of the ADMS interior that will automatically activate the housing exhaust system whenever the internal air temperature exceeds +100°F.
* Design the sign to meet or exceed all International Mechanical (IM) standards (formally BOCA, ICBO and SBCCI) for human occupation. This standard can be best described as follows; in regards to the high temperature requirement of the DMS housing, the sign housing interior temperature must be maintained at a maximum of 25°F above the outside air temperature.

Fans and air filters shall be removable and replaceable. To ease serviceability, mount the fans at a pre-approved optimum locations not obstructed by other subsystems while meeting all the ventilation requirements.

Filters must be removable without the need for special tools and must remove airborne particles measuring 5 microns in diameter and larger. The intake air filter media must be readily available from three sources. The manufacturer recommended minimum filter replacement cycle must be a minimum of once every two months to a maximum of once every six months.

Install two electronic temperature monitoring devices to assure a failsafe monitoring of the interior temperature. The temperature monitoring devices will be wired independently and upon failure of either an alarm message must be transmitted through the DMS controller to the central sign control software. The system shall be configurable such that the DMS will automatically shut down the LED modules to prevent damage if the internal temperature exceeds a minimum threshold temperature.

Cover each intake and exhaust port on its front, and sides by an aluminum hood that is riveted to the rear DMS wall. Screen openings to prevent the entrance of insects and small animals. Fabricate hoods from 0.090-inch or thicker aluminum sheeting. Seal all hood-to-housing contact edges to prevent water from entering the housing.

If needed activate the front face panel defog/defrost system whenever the internal air temperature falls below +40° F automatically.

1. DMS Display
	1. LED Display Modules

The DMS shall contain LED display modules that include an LED pixel array and LED driver circuitry. Mount modules adjacently in a two-dimensional array to form a continuous LED pixel matrix. Construct each LED display module as follows:

* Each LED display module may consist of one or two circuit boards. If two boards are used, physically mount them to each other using durable non-corrosive hardware and electrically connect them via one or more header-type connectors. Key the header connectors such that the boards cannot be connected incorrectly.
* Manufacture all LED modules using laminated fiberglass printed circuit boards.
* Mount each LED display module using durable non-corrosive hardware. No tools shall be required to remove and replace the module. Mount the modules such that the face panel does not block any part of the viewing cone of any of the LEDs in any pixels. Do not use light enhancing lenses to achieve defined viewing cone.
* Use quick-disconnect locking connector type for LED display module power and signal connections. Removal of a display module from the DMS, or a pixel board or driver circuit board from its display module, shall not require a soldering operation.
* Protect all exposed metal on both sides of each printed circuit board, except connector contacts, from water and humidity exposure by a thorough application of conformal coating. Allow bench level repair of individual components, including discrete LED replacement and conformal coating repair.
* Configure individual addressing of the each LED display module via the communication wiring harness and connector. Do not use on-board addressing jumpers or switches.
* Removal or failure of any LED module shall not affect the operation of any other LED module or sign component. Removal of one or more LED modules shall not affect the structural integrity of any part of the sign.
* It shall not be possible to mount an LED display module upside-down or in an otherwise incorrect position within the DMS display matrix.
* All LED display modules, as well as the LED pixel boards and driver circuit boards, shall be identical and interchangeable throughout the DMS.
	1. LED Pixels

Manufacture LED modules on a printed circuit board to which LED pixels are soldered. The LED pixel matrix shall conform to the following specifications:

The distance from the center of one pixel to the center of all adjacent pixels, both horizontally and vertically, shall be 0.787-inches (20 mm).

Each pixel shall consist of a minimum of one independent string of discrete LEDs for each color. All pixels shall contain an equal quantity of LED strings.

The failure of an LED string or pixel shall not cause the failure of any other LED string or pixel in the DMS.

Each pixel shall contain the quantity of discrete LEDs needed to output white colored light at a minimum luminous intensity of 12,400 candelas per square meter when measured using a photometric meter through the DMS front face panel assembly. Failure to conform to the requirements will be cause for rejection.

Each pixel shall also be capable of displaying amber colored light with a minimum luminous intensity of 7,440 candelas per square meter when measured using a photometric meter through the DMS front face panel assembly. Failure to conform to the requirements will be cause for rejection.

The circular base of the discrete LEDs shall be soldered so that they are flush and parallel to the surface of the printed circuit board. The longitudinal axis of the LEDs shall be perpendicular to the circuit board.

Construct DMS pixels with discrete LEDs manufactured by a reputable manufacturer such as Avago Technologies (formerly Agilent Technologies), Toshiba Corporation, Nichia Corporation, OSRAM, or EOI. Discrete LEDs shall conform to the following specifications:

All LEDs shall have a nominal viewing cone of 30 degrees with a half-power angle of 15 degrees measured from the longitudinal axis of the LED. Viewing cone tolerances shall be as specified in the LED manufacturer’s product specifications and shall not exceed +/- 5 degrees. Using optical enhancing lenses with 15 degree LED’s will not conform to 30 degree half-power viewing cone specifications and will be cause for rejection.

Red LEDs shall utilize AlInGaP semiconductor technology and shall emit red light that has a peak wavelength of 615-635nm

Green LEDs shall utilize InGaN semiconductor technology and shall emit green light that has a peak wavelength of 520-535nm

Blue LEDs shall utilize InGaN semiconductor technology and shall emit blue light that has a peak wavelength of 464-470nm

Fabricate the LED packages from UV light resistant epoxy.

The LED manufacturer shall perform color sorting of the bins. Obtain each color of LEDs from no more than two consecutive color “bins” as defined by the LED manufacturer.

The LED manufacturer shall perform intensity sorting of the bins. Obtain LEDs from no more than two consecutive luminous intensity “bins” as defined by the LED manufacturer.

Evenly distribute the various LED color and intensity bins throughout the sign and shall be consistent from pixel to pixel. Random distribution of the LED bins shall not be accepted.

The LED manufacturer shall assure color uniformity and consistency on the LED display face within the 30 degree cone of vision. Inconsistent color shifts or intensity will be cause for rejection.

All LEDs used in all DMS provided for this contract shall be from the same manufacturer and of the same part number, except for the variations in the part number due to the intensity and color.

The LEDs shall be rated by the LED manufacturer to have a minimum lifetime of 100,000 hours of continuous operation while maintaining a minimum of 70% of the original brightness.

1. Housing Characteristics
	1. General Housing

Fabricate, weld, and inspect the DMS housing in accordance with AWS D1.2/D1.2M:2003 Structural Welding Code-Aluminum (2003). Perform welding according to documented in-house welding procedures, and certify personnel who perform welding on the overhead freeway DMS housing to AWS D1.2/D1.2M:2003 for all weld types required.

Design and construct to follow the AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals, 5thEdition*.

Housing shall protect internal components from rain, ice, dust, and corrosion in accordance with NEMA enclosure Type 3R standards, as described in *NEMA Standards Publication 250-1997, Enclosures for Electrical Equipment (1000 Volts Maximum)*.

Construct the housing and modules so that all maintenance is performed from the rear of the sign. Demonstrate that maintenance by a single technician is feasible and safe.

Fabricate the housing from 0.125-inch (minimum) thick 3003-H14 or 5052-H32 aluminum alloy. Round all edges and corners.

Construct the housing to have a neat, professional appearance. Securely clamp or tie all cables in the sign housing.

Drain any water that accumulates due to condensation with small weep holes on the bottom side. Screen weep holes and ventilation/exhaust hoods to prevent the entrance of insects and small animals.

Mount the display elements on interior non-corrosive metal cage support frames. Design the cage support frame to withstand and minimize vibration when the sign is mounted with any number of display elements.

* 1. Housing Frame

Construct the housing’s right, left, and rear walls vertical. Construct the housing’s top and bottom sides horizontal. Construct the front wall with a permanent forward tilt angle of three degrees, so that the top of the DMS housing is deeper than its bottom. Use aluminum extrusions made from alloy number 6061-T6 or 6063-T5 for the structural frame.

* 1. Mounting Brackets

Provide two lifting eyes with a minimum one inch diameter on the housing to be used when placing the housing on the sign structure. The Engineer will position the lifting eyes. Fully assembled signs will be lifted into place using both lifting eyes. However, each eye shall have sufficient structural strength to allow the sign be lifted or moved without structural damage or permanent deformation to the sign.

Provide multiple mounting brackets in the form of I-beams or Z-extrusions bolted to the housing exterior rear wall, to facilitate attachment of the DMS to its support structure. Use mounting brackets made from extruded aluminum alloy number 6061-T6. Attach the mounting brackets to DMS structural frame members, not just the exterior sheet metal. Attach the mounting brackets to the DMS using galvanized A 105 grade high-strength steel bolts. Design and fabricate the mounting brackets such that the installing Vendor can drill into them without penetrating the DMS housing and comprising the housing’s ability to shed water.

DMS structural hardware and mounting brackets hardware (nuts, bolts, washers, and direct tension indicators) shall be stainless steel or galvanized high-strength steel and appropriately sized for the application.

* 1. Front Face Construction

Construct the front face with multiple rigid panels, each of which supports and protects a full height section of the LED display matrix. Panel exteriors shall be fabricated from 0.090-inch aluminum sheeting and panel interiors shall be 0.125-inch polycarbonate sheeting. All sides, except the front, shall be covered with 0.125-inch thick aluminum sheets made from alloy number 5050-H34 or 3003-H14.

Bolt face panels to the DMS housing and to each other using stainless steel hardware. Seal seams that separate adjacent panels. Stitch weld the interior side of each sheet to the frame members. All exterior sheet seams shall be continuously seam welded to the frame, in order to form a unitized structure.

Panels shall be removable and shall not be welded to the DMS housing.

Weight of a single face panel shall not exceed 150 lbs.

Provide a high-contrast background on the front face. Paint aluminum portions of each panel black. Front face shall employ a flat black anti-glare sheeting substance. To maximize display contrast and legibility paint the DMS front face borders (top, bottom, left side, and right side), which surround the front face panels and LED display matrix, black.

Front panel shall be mounted securely as to withstand a 100 mph wind load, and shall not obscure any of the pixels in the sign. In the presence of wind, the DMS front face shall not distort in a manner that adversely affects LED message legibility.

Mount display modules to the inside of the front face panels using either standard hand tools or no tools for removal and replacement.

* 1. Exterior Finish

Powder-coat paint or anodize all outside surfaces. Border piece shall be coated with semi-gloss black Kynar 500 or an equivalent brand oven-fired fluropolymer coating which has an expected outdoor service life of 20 years. All other housing surfaces, including overhead freeway DMS mounting brackets shall be natural mill-finish aluminum. As an alternative to powder coating and anodization, the Vendor may propose an alternative housing finish that has an outdoor service life of 20 years and is covered by a corresponding warranty.

1. Maintenance Access
	1. General Information

Provide safe and convenient front or rear service access for all materials located within housing. All internal components shall be removable and replaced by a single technician.

Housing may be front access, but must demonstrate that maintenance manageability by a single technician is feasible and safe.

Access panels shall open easily and be supported in their open position by multiple self-locking retaining devices. Means shall be designed to thoroughly support the access panel assembly in the open position in a 30-mph wind. Support systems shall be designed and configured for one maintenance person to safely and easily open and close the access panel assembly.

In the closed position, access panels shall be securely clamped by captive locking devices and attached to the DMS housing wall with stainless steel or aluminum hardware. The access panel assembly and all associated hardware shall be captive, so they cannot fall onto the roadway in any position.

1. Sign to Cabinet Interconnect

Connect the DMS to its cabinet following the following minimum requirements:

* Provide communication control cables 300 feet in length between the sign and the sign controller cabinet (provided under a separate item) for operation of the sign.
* Provide fiber optic for all control, communication, and data purposes. As an option provide a copper signal cable if requested.
1. Electrical
	1. Wiring

Furnish all wiring both internal to the cabinet and between the cabinet and the DMS components within the housing to provide the following functionality:

* Wire and color-code all components per the most recent National Electrical Code (NEC) and Wisconsin Electrical Code requirements.
* Provide AC Power for control equipment with a series-connected surge suppresser capable of passing 15 amps of current that shall protect the field controller and modem (or signal converter).
* Provide electrical protection, bonding and grounding for the DMS.
1. Standards

The following is a list of standards and specifications that must be in full compliancy:

* 1. FHWA *Manual on Uniform Traffic Control Devices, 2009 Edition with Revisions*
	2. AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals*, 5th Edition
	3. ANSI/AWS (American Welding Society) D1.2/D1.2M:2003– Structural Welding Code – Aluminum
	4. NCHRP Report 412, *Fatigue-Resistant Design of Cantilevered Signal, Sign, and Light Supports*
	5. National (United States) and Wisconsin Electrical Code
	6. NEMA Standards Publication 250 – *Enclosures for Electrical Equipment*
	7. NEMA Standard TS 1, Section 2 – *Environmental Standards and Test Procedures, Traffic Control Systems*
	8. NEMA Standard TS 4-2005 – *Hardware Standards for Dynamic Message Signs (DMS), with NTCIP Requirements*
	9. NTCIP Standards:
		1. NTCIP 1101: NTCIP 1101:1997 (NEMA TS 3.2-1996); *Simple Transportation Management Framework*
		2. NTCIP 1102: NTCIP 1201 v01.06, *Octet Encoding Rules (OER) Base Protocol*
		3. NTCIP 1103, *Simple Transportation Network Protocol (STMP)*
		4. NTCIP 1201: NTCIP 1201:1996 (NEMA TS 3.4-1996); *Global Object Definitions*
		5. NTCIP 1203: NTCIP 1203v03.04:2011; *Object Definitions for Dynamic Message Signs* - All Applicable Mandatory and Optional Requirements
		6. NTCIP 2001: NTCIP 2001:1996 (NEMA TS 3.3-1996); *NTCIP Class B Profile*
		7. NTCIP 2101: NTCIP 2101 v01.17 (NEMA TS3.SP-PMPP232), *Point to Multi-Point Protocol Using RS-232 Subnetwork Profile*
		8. NTCIP 2102: NTCIP 2102 v01.04, *Subnet Profile for PMPP Over FSK Modems*
		9. NTCIP 2103: NTCIP 2103 v01.05 (NEMA TS 3.SP-PPP232), *Subnet Profile for Point-to-Point Protocol Over RS-232*
		10. NTCIP 2104: NTCIP 2104 v01.07, *Subnet Profile for Ethernet*
		11. NTCIP 2201: NTCIP 2201 v01.11, *Transportation Transport Profile*
		12. NTCIP 2202: NTCIP 2202-1999, *Internet (TCP/IP and UDP/IP) Transport Profile*
		13. NTCIP 2301: NTCIP 2301-1999 (NEMA 3.AP-STMF), *Application Profile for Simple Transportation Management Framework (STMF)*
		14. NTCIP 2303: NTCIP 2303-1999, *Application Profile for File Transfer Protocol (FTP)*

Appendix D

Arterial Dynamic Message Signs (ADMS),

Full Matrix, Full Color, 4.25 Feet by 14 Feet

Specification

1. General Information
	1. DMS General Requirements

Furnish overhead or side mount full color, full display matrix arterial dynamic message sign (ADMS) assemblies. Submit signed and certified design drawings, calculations, and material specifications for all aspects of the sign assemblies including the electronics, housing, and mounting assemblies to the Engineer for review prior to incorporation into the work. Meet the following general requirements for each ADMS provided:

* Design the sign for a minimum life of 20 years.
* Remove all company or vendor logos anywhere on the exterior of the sign housing.
* Comply with all applicable federal and state standards along with NTCIP standards.
	1. General Display Requirements

Meet the following display requirements for each DMS provided:

* Provide a continuous and uniform appearance to the traveling public that consists of Light Emitting Diode (LED) composed of multiple red, green, and blue LEDs.
* Conform to the appropriate National Transportation Communications for ITS Protocol (NTCIP) Standards, as herein after provided.
* Display area of with minimum dimensions of 4 feet-3 inches high and 14 feet wide. A larger display area is allowable within the confines of other requirements in this specification. Display alphanumeric text, punctuation symbols and graphic images across multiple panels.
	1. General Dimension and Weight Requirements

Meet the following dimension and weight requirements for each ADMS provided:

* Dimensions of ADMS housing equal to or less than 6 feet tall by 17 feet long.
* Front-to-back housing depth equal to or less than 2 feet at its widest point, including any rear ventilation hoods.
* Total weight of the ADMS equal to or less than 1200 lbs.
* Design includes enclosed front or rear access housing.
1. Environment
	1. Outside Environmental Requirements

Design the system to conform to all applicable NEMA requirements and to meet the following minimum requirements and characteristics for outside environmental conditions:

* + - * Ensure ADMS enclosure, components, heating and ventilation and workmanship are new components, corrosion resistant and adequate to assure full sign functionality and durability in an outdoor environment.
			* Provide field equipment that performs to the minimum environmental and sign hardware requirements of -29°F to 165°F and a humidity range of 0 percent to 95 percent relative non-condensing.
			* All outdoor enclosures must resist water infiltration during hose-directed water per NEMA 250 – Class 3R requirements.
			* All connections, internal or external to the ADMS must be watertight.
			* All ADMS components will not be damaged by temporary exposure to temperatures of -50° F to +185°F.
	1. Environmental Monitoring Systems

Provide a system with multiple sensors that are mounted on the front, rear, and under side facing the ground of the ADMS housing that monitor and report ambient external light level and temperature.

Provide light sensors to continuously monitor and adjust the LED display matrix intensity to a level that ensures a legible message on the ADMS face.

Monitor the sensors continuously by the ADMS controller and report to the ADMS control software upon request. The DMS controller should only reply to polls from the central software and not send the information without being polled.

* 1. Inside Environment

Meet the following minimum requirements and characteristics for environmental conditions maintained inside the sign enclosure:

* Install a ventilation system designed to keep the internal ADMS air temperature lower than +140°F, when the outdoor ambient temperature is +115°F or less.
* Eliminate condensation within the sign enclosure to ensure longevity of the LEDs and electronic components.
* Install a thermostat near the top of the ADMS interior that will automatically activate the housing exhaust system whenever the internal air temperature exceeds +100°F.
* Design the sign to meet or exceed all International Mechanical (IM) standards (formally BOCA, ICBO and SBCCI) for human occupation. This standard can be best described as follows; in regards to the high temperature requirement of the ADMS housing, the sign housing interior temperature must be maintained at a maximum of 25°F above the outside air temperature.

Fans and air filters shall be removable and replaceable. To ease serviceability, mount the fans at a pre-approved optimum locations not obstructed by other subsystems while meeting all the ventilation requirements.

Filters must be removable without the need for special tools and must remove airborne particles measuring 5 microns in diameter and larger. The intake air filter media must be readily available from three sources. The manufacturer recommended minimum filter replacement cycle must be a minimum of once every two months to a maximum of once every six months.

Install two electronic temperature monitoring devices to assure a failsafe monitoring of the interior temperature. The temperature monitoring devices will be wired independently and upon failure of either an alarm message must be transmitted through the ADMS controller to the central sign control software. The system shall be configurable such that the ADMS will automatically shut down the LED modules to prevent damage if the internal temperature exceeds a minimum threshold temperature.

Cover each intake and exhaust port on its front, and sides by an aluminum hood that is riveted to the rear ADMS wall. Screen openings to prevent the entrance of insects and small animals. Fabricate hoods from 0.090-inch or thicker aluminum sheeting. Seal all hood-to-housing contact edges to prevent water from entering the housing.

If needed activate the front face panel defog/defrost system whenever the internal air temperature falls below +40° F automatically.

1. DMS Display
	1. LED Display Modules

The ADMS shall contain LED display modules that include an LED pixel array and LED driver circuitry. Mount modules adjacently in a two-dimensional array to form a continuous LED pixel matrix. Construct each LED display module as follows:

* Each LED display module may consist of one or two circuit boards. If two boards are used, physically mount them to each other using durable non-corrosive hardware and electrically connect them via one or more header-type connectors. Key the header connectors such that the boards cannot be connected incorrectly.
* Manufacture all LED modules using laminated fiberglass printed circuit boards.
* Mount each LED display module using durable non-corrosive hardware. No tools shall be required to remove and replace the module. Mount the modules such that the face panel does not block any part of the viewing cone of any of the LEDs in any pixels. Do not use light enhancing lenses to achieve defined viewing cone.
* Use quick-disconnect locking connector type for LED display module power and signal connections. Removal of a display module from the ADMS, or a pixel board or driver circuit board from its display module, shall not require a soldering operation.
* Protect all exposed metal on both sides of each printed circuit board, except connector contacts, from water and humidity exposure by a thorough application of conformal coating. Allow bench level repair of individual components, including discrete LED replacement and conformal coating repair.
* Configure individual addressing of the each LED display module via the communication wiring harness and connector. Do not use on-board addressing jumpers or switches.
* Removal or failure of any LED module shall not affect the operation of any other LED module or sign component. Removal of one or more LED modules shall not affect the structural integrity of any part of the sign.
* It shall not be possible to mount an LED display module upside-down or in an otherwise incorrect position within the ADMS display matrix.
* All LED display modules, as well as the LED pixel boards and driver circuit boards, shall be identical and interchangeable throughout the ADMS.
	1. LED Pixels

Manufacture LED modules on a printed circuit board to which LED pixels are soldered. The LED pixel matrix shall conform to the following specifications:

The distance from the center of one pixel to the center of all adjacent pixels, both horizontally and vertically, shall be 0.787-inches (20 mm).

Each pixel shall consist of a minimum of one independent string of discrete LEDs for each color. All pixels shall contain an equal quantity of LED strings.

The failure of an LED string or pixel shall not cause the failure of any other LED string or pixel in the ADMS.

Each pixel shall contain the quantity of discrete LEDs needed to output white colored light at a minimum luminous intensity of 12,400 candelas per square meter when measured using a photometric meter through the ADMS front face panel assembly. Failure to conform to the requirements will be cause for rejection.

Each pixel shall also be capable of displaying amber colored light with a minimum luminous intensity of 7,440 candelas per square meter when measured using a photometric meter through the ADMS front face panel assembly. Failure to conform to the requirements will be cause for rejection.

The circular base of the discrete LEDs shall be soldered so that they are flush and parallel to the surface of the printed circuit board. The longitudinal axis of the LEDs shall be perpendicular to the circuit board.

Construct DMS pixels with discrete LEDs manufactured by a reputable manufacturer such as Avago Technologies (formerly Agilent Technologies), Toshiba Corporation, Nichia Corporation, OSRAM, Cree, Inc., or EOI. Discrete LEDs shall conform to the following specifications.

All LEDs shall have a nominal viewing cone of 30 degrees with a half-power angle of 15 degrees measured from the longitudinal axis of the LED. Viewing cone tolerances shall be as specified in the LED manufacturer’s product specifications and shall not exceed +/- 5 degrees. Using optical enhancing lenses with 15 degree LED’s will not conform to 30 degree half-power viewing cone specifications and will be cause for rejection.

Red LEDs shall utilize AlInGaP semiconductor technology and shall emit red light that has a peak wavelength of 615-635nm

Green LEDs shall utilize InGaN semiconductor technology and shall emit green light that has a peak wavelength of 520-535nm

Blue LEDs shall utilize InGaN semiconductor technology and shall emit blue light that has a peak wavelength of 464-470nm

Fabricate the LED packages from UV light resistant epoxy.

The LED manufacturer shall perform color sorting of the bins. Obtain each color of LEDs from no more than two consecutive color “bins” as defined by the LED manufacturer.

The LED manufacturer shall perform intensity sorting of the bins. Obtain LEDs from no more than two consecutive luminous intensity “bins” as defined by the LED manufacturer.

Evenly distribute the various LED color and intensity bins throughout the sign and shall be consistent from pixel to pixel. Random distribution of the LED bins shall not be accepted.

The LED manufacturer shall assure color uniformity and consistency on the LED display face within the 30 degree cone of vision. Inconsistent color shifts or intensity will be cause for rejection.

All LEDs used in all ADMS provided for this contract shall be from the same manufacturer and of the same part number, except for the variations in the part number due to the intensity and color.

The LEDs shall be rated by the LED manufacturer to have a minimum lifetime of 100,000 hours of continuous operation while maintaining a minimum of 70% of the original brightness.

1. Housing Characteristics
	1. General Housing

Fabricate, weld, and inspect the ADMS housing in accordance with AWS D1.2/D1.2M:2003 Structural Welding Code-Aluminum (2003). Perform welding according to documented in-house welding procedures, and certify personnel who perform welding on ADMS housing to AWS D1.2/D1.2M:2003 for all weld types required.

Design and construct the housing to follow the AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals, 5th Edition*.

Housing shall protect internal components from rain, ice, dust, and corrosion in accordance with NEMA enclosure Type 3R standards, as described in *NEMA Standards Publication 250-1997, Enclosures for Electrical Equipment (1000 Volts Maximum)*.

Construct the housing and modules so that all maintenance is performed from the rear of the sign. As an option housing may be front access, but must demonstrate that maintenance by a single technician is feasible and safe.

Fabricate the housing from 0.125-inch (minimum) thick 3003-H14 or 5052-H32 aluminum alloy. Round all edges and corners.

Construct the housing to have a neat, professional appearance. Securely clamp or tie all cables in the sign housing.

* 1. Mounting Brackets

Provide two lifting eyes with a minimum one inch diameter on the housing to be used when placing the housing on the sign structure. The Engineer will position the lifting eyes. Fully assembled signs will be lifted into place using both lifting eyes. However, each eye shall have sufficient structural strength to allow the sign be lifted or moved without structural damage or permanent deformation to the sign.

Provide multiple mounting brackets in the form of I-beams or Z-extrusions bolted to the housing exterior rear wall, to facilitate attachment of the ADMS to its support structure. Use mounting brackets made from extruded aluminum alloy number 6061-T6. Attach the mounting brackets to ADMS structural frame members, not just the exterior sheet metal. Attach the mounting brackets to the ADMS using galvanized A 105 grade high-strength steel bolts. Design and fabricate the mounting brackets such that the installing Vendor can drill into them without penetrating the ADMS housing and comprising the housing’s ability to shed water.

ADMS structural hardware and mounting brackets hardware (nuts, bolts, washers, and direct tension indicators) shall be stainless steel or galvanized high-strength steel appropriately sized for the application.

* 1. Front Face Construction

Construct the front face with multiple rigid panels, each of which supports and protects a full height section of the LED display matrix. Panel exteriors shall be fabricated from 0.090-inch aluminum sheeting and panel interiors shall be 0.125-inch polycarbonate sheeting. All sides, except the front, shall be covered with 0.125-inch thick aluminum sheets made from alloy number 5050-H34 or 3003-H14.

Bolt face panels to the ADMS housing and to each other using stainless steel hardware. Seal seams that separate adjacent panels. Stitch weld the interior side of each sheet to the frame members. All exterior sheet seams shall be continuously seam welded to the frame, in order to form a unitized structure.

Panels shall be removable and shall not be welded to the ADMS housing.

Weight of a single face panel shall not exceed 150 lbs.

Provide a high-contrast background on the front face. Paint aluminum portions of each panel black. Front face shall employ a flat black anti-glare sheeting substance. To maximize display contrast and legibility paint the ADMS front face borders (top, bottom, left side, and right side), which surround the front face panels and LED display matrix, black.

All housing shall follow the AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals, 5th Edition*. The housing shall be designed and constructed to withstand a minimum sustained wind load of 100 mph and a truck gusting induced fatigue, with a 30 percent wind gust factor. Housing shall support a front face ice load of 4 lbs per square foot.

Front panel shall be mounted securely as to withstand a 100 mph wind load, and shall not obscure any of the pixels in the sign. In the presence of wind, the ADMS front face shall not distort in a manner that adversely affects LED message legibility.

Mount display modules to the inside of the front face panels using either standard hand tools or no tools for removal and replacement.

* 1. Exterior Finish

Powder-coat paint or anodize all outside surfaces. Border piece shall be coated with semi-gloss black Kynar 500 or an equivalent brand oven-fired fluropolymer coating which has an expected outdoor service life of 20 years. All other housing surfaces, including ADMS mounting brackets shall be natural mill-finish aluminum. As an alternative to powder coating and anodization, the Vendor may propose an alternative housing finish that has an outdoor service life of 20 years and is covered by a corresponding warranty.

1. Maintenance Access
	1. General Information

Provide safe and convenient front or rear service access for all materials located within housing. All internal components shall be removable and replaced by a single technician.

Housing may be front access, but must demonstrate that maintenance manageability by a single technician is feasible and safe.

Access panels shall open easily and be supported in their open position by multiple self-locking retaining devices. Means shall be designed to thoroughly support the access panel assembly in the open position in a 30-mph wind. Support systems shall be designed and configured for one maintenance person to safely and easily open and close the access panel assembly.

In the closed position, access panels shall be securely clamped by captive locking devices and attached to the DMS housing wall with stainless steel or aluminum hardware. The access panel assembly and all associated hardware shall be captive, so they cannot fall onto the roadway in any position.

1. Sign to Cabinet Interconnect

Connect the ADMS to its cabinet following the following minimum requirements:

* Provide communication control cables 300 feet in length between the sign and the sign controller cabinet (provided under a separate item) for operation of the sign.
* Provide fiber optic for all control, communication, and data purposes. As an option provide a copper signal cable if requested.
1. Electrical
	1. Wiring

Furnish all wiring both internal to the cabinet and between the cabinet and the ADMS components within the housing to provide the following functionality:

* Wire and color-code all components per the most recent National Electrical Code (NEC) and Wisconsin Electrical Code requirements.
* Provide AC Power for control equipment with a series-connected surge suppresser capable of passing 15 amps of current that shall protect the field controller and modem (or signal converter).
* Provide electrical protection, bonding and grounding for the ADMS
1. Standards

The following is a list of standards and specifications that must be in full compliancy:

* 1. FHWA *Manual on Uniform Traffic Control Devices, 2009 Edition with Revisions*
	2. AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals*, 5th Edition
	3. ANSI/AWS (American Welding Society) D1.2/D1.2M:2003– Structural Welding Code – Aluminum
	4. NCHRP Report 412, *Fatigue-Resistant Design of Cantilevered Signal, Sign, and Light Supports*
	5. National (United States) and Wisconsin Electrical Code
	6. NEMA Standards Publication 250 – *Enclosures for Electrical Equipment*
	7. NEMA Standard TS 1, Section 2 – *Environmental Standards and Test Procedures, Traffic Control Systems*
	8. NEMA Standard TS 4-2005 – *Hardware Standards for Dynamic Message Signs (DMS), with NTCIP Requirements*
	9. NTCIP Standards:
		1. NTCIP 1101: NTCIP 1101:1997 (NEMA TS 3.2-1996); *Simple Transportation Management Framework*
		2. NTCIP 1102: NTCIP 1201 v01.06, *Octet Encoding Rules (OER) Base Protocol*
		3. NTCIP 1103, *Simple Transportation Network Protocol (STMP)*
		4. NTCIP 1201: NTCIP 1201:1996 (NEMA TS 3.4-1996); *Global Object Definitions*
		5. NTCIP 1203: NTCIP 1203v03.04:2011; *Object Definitions for Dynamic Message Signs* - All Applicable Mandatory and Optional Requirements
		6. NTCIP 2001: NTCIP 2001:1996 (NEMA TS 3.3-1996); *NTCIP Class B Profile*
		7. NTCIP 2101: NTCIP 2101 v01.17 (NEMA TS3.SP-PMPP232), *Point to Multi-Point Protocol Using RS-232 Subnetwork Profile*
		8. NTCIP 2102: NTCIP 2102 v01.04, *Subnet Profile for PMPP Over FSK Modems*
		9. NTCIP 2103: NTCIP 2103 v01.05 (NEMA TS 3.SP-PPP232), *Subnet Profile for Point-to-Point Protocol Over RS-232*
		10. NTCIP 2104: NTCIP 2104 v01.07, *Subnet Profile for Ethernet*
		11. NTCIP 2201: NTCIP 2201 v01.11, *Transportation Transport Profile*
		12. NTCIP 2202: NTCIP 2202-1999, *Internet (TCP/IP and UDP/IP) Transport Profile*
		13. NTCIP 2301: NTCIP 2301-1999 (NEMA 3.AP-STMF), *Application Profile for Simple Transportation Management Framework (STMF)*
		14. NTCIP 2303: NTCIP 2303-1999, *Application Profile for File Transfer Protocol (FTP)*

Appendix E

Arterial Dynamic Message Signs (ADMS),

Full Matrix, Full Color, 2 Feet by 9.75 Feet

Specification

1. General Information
	1. DMS General Requirements

Furnish overhead or side mount full color, full display matrix arterial dynamic message sign (ADMS) assemblies. Submit signed and certified design drawings, calculations, and material specifications for all aspects of the sign assemblies including the electronics, housing, and mounting assemblies to the Engineer for review prior to incorporation into the work. Meet the following general requirements for each ADMS provided:

* Design the sign for a minimum life of 20 years.
* Remove all company or vendor logos anywhere on the exterior of the sign housing.
* Comply with all applicable federal and state standards along with NTCIP standards.
	1. General Display Requirements

Meet the following display requirements for each DMS provided:

* Provide a continuous and uniform appearance to the traveling public that consists of Light Emitting Diode (LED) composed of multiple red, green, and blue LEDs.
* Conform to the appropriate National Transportation Communications for ITS Protocol (NTCIP) Standards, as herein after provided.
* Display area of with minimum dimensions of 2 feet high and 9.75 feet wide. A larger display area is allowable within the confines of other requirements in this specification. Display alphanumeric text, punctuation symbols and graphic images across multiple panels. Each character shall be formed by a matrix of luminous pixels.
	1. General Dimension and Weight Requirements

Meet the following dimension and weight requirements for each ADMS provided:

* Dimensions of ADMS housing equal to or less than 4.25 feet tall by 10.75 feet long.
* Front-to-back housing depth equal to or less than 2 feet at its widest point, including any rear ventilation hoods.
* Total weight of the ADMS equal to or less than 650 lbs.
* Design includes enclosed front or rear access housing.
1. Environment
	1. Outside Environmental Requirements

Design the system to conform to all applicable NEMA requirements and to meet the following minimum requirements and characteristics for outside environmental conditions:

* + - * Ensure ADMS enclosure, components, heating and ventilation and workmanship are new components, corrosion resistant and adequate to assure full sign functionality and durability in an outdoor environment.
			* Provide field equipment that performs to the minimum environmental and sign hardware requirements of -29°F to 165°F and a humidity range of 0 percent to 95 percent relative non-condensing.
			* All outdoor enclosures must resist water infiltration during hose-directed water per NEMA 250 – Class 3R requirements.
			* All connections, internal or external to the ADMS must be watertight.
			* All ADMS components will not be damaged by temporary exposure to temperatures of -50°F to +185°F.
	1. Environmental Monitoring Systems

Provide a system with multiple sensors that are mounted on the front, rear, and under side facing the ground of the ADMS housing that monitor and report ambient external light level and temperature.

Provide light sensors to continuously monitor and adjust the LED display matrix intensity to a level that ensures a legible message on the ADMS face.

Monitor the sensors continuously by the ADMS controller and report to the ADMS control software upon request. The DMS controller should only reply to polls from the central software and not send the information without being polled.

* 1. Inside Environment

Meet the following minimum requirements and characteristics for environmental conditions maintained inside the sign enclosure:

* Install a ventilation system designed to keep the internal ADMS air temperature lower than +140°F, when the outdoor ambient temperature is +115°F or less.
* Eliminate condensation within the sign enclosure to ensure longevity of the LEDs and electronic components.
* Install a thermostat near the top of the ADMS interior that will automatically activate the housing exhaust system whenever the internal air temperature exceeds +100°F.
* Design the sign to meet or exceed all International Mechanical (IM) standards (formally BOCA, ICBO and SBCCI) for human occupation. This standard can be best described as follows; in regards to the high temperature requirement of the ADMS housing, the sign housing interior temperature must be maintained at a maximum of 25°F above the outside air temperature.

Fans and air filters shall be removable and replaceable. To ease serviceability, mount the fans at a pre-approved optimum locations not obstructed by other subsystems while meeting all the ventilation requirements.

Filters must be removable without the need for special tools and must remove airborne particles measuring 5 microns in diameter and larger. The intake air filter media must be readily available from three sources. The manufacturer recommended minimum filter replacement cycle must be a minimum of once every two months to a maximum of once every six months.

Install two electronic temperature monitoring devices to assure a failsafe monitoring of the interior temperature. The temperature monitoring devices will be wired independently and upon failure of either an alarm message must be transmitted through the ADMS controller to the central sign control software. The system shall be configurable such that the ADMS will automatically shut down the LED modules to prevent damage if the internal temperature exceeds a minimum threshold temperature.

Cover each intake and exhaust port on its front, and sides by an aluminum hood that is riveted to the rear ADMS wall. Screen openings to prevent the entrance of insects and small animals. Fabricate hoods from 0.090-inch or thicker aluminum sheeting. Seal all hood-to-housing contact edges to prevent water from entering the housing.

If needed activate the front face panel defog/defrost system whenever the internal air temperature falls below +40° F automatically.

1. DMS Display
	1. LED Display Modules

The ADMS shall contain LED display modules that include an LED pixel array and LED driver circuitry. Mount modules adjacently in a two-dimensional array to form a continuous LED pixel matrix. Construct each LED display module as follows:

* Each LED display module may consist of one or two circuit boards. If two boards are used, physically mount them to each other using durable non-corrosive hardware and electrically connect them via one or more header-type connectors. Key the header connectors such that the boards cannot be connected incorrectly.
* Manufacture all LED modules using laminated fiberglass printed circuit boards.
* Mount each LED display using durable non-corrosive hardware. No tools shall be required to remove and replace the module. Mount the modules such that the face panel does not block any part of the viewing cone of any of the LEDs in any pixels. Do not use light enhancing lenses to achieve defined viewing cone.
* Use quick-disconnect locking connector type for LED display module power and signal connections. Removal of a display module from the ADMS, or a pixel board or driver circuit board from its display module, shall not require a soldering operation.
* Protect all exposed metal on both sides of each printed circuit board, except connector contacts, from water and humidity exposure by a thorough application of conformal coating. Allow bench level repair of individual components, including discrete LED replacement and conformal coating repair.
* Configure individual addressing of the each LED display module via the communication wiring harness and connector. Do not use on-board addressing jumpers or switches.
* Removal or failure of any LED module shall not affect the operation of any other LED module or sign component. Removal of one or more LED modules shall not affect the structural integrity of any part of the sign.
* It shall not be possible to mount an LED display module upside-down or in an otherwise incorrect position within the ADMS display matrix.
* All LED display modules, as well as the LED pixel boards and driver circuit boards, shall be identical and interchangeable throughout the ADMS.
	1. LED Pixels

Manufacture LED modules on a printed circuit board to which LED pixels are soldered. The LED pixel matrix shall conform to the following specifications:

The distance from the center of one pixel to the center of all adjacent pixels, both horizontally and vertically, shall be 0.787-inches (20 mm).

Each pixel shall consist of a minimum of one independent string of discrete LEDs for each color. All pixels shall contain an equal quantity of LED strings.

The failure of an LED string or pixel shall not cause the failure of any other LED string or pixel in the ADMS.

Each pixel shall contain the quantity of discrete LEDs needed to output white colored light at a minimum luminous intensity of 12,400 candelas per square meter when measured using a photometric meter through the ADMS front face panel assembly. Failure to conform to the requirements will be cause for rejection.

Each pixel shall also be capable of displaying amber colored light with a minimum luminous intensity of 7,440 candelas per square meter when measured using a photometric meter through the ADMS front face panel assembly. Failure to conform to the requirements will be cause for rejection.

The circular base of the discrete LEDs shall be soldered so that they are flush and parallel to the surface of the printed circuit board. The longitudinal axis of the LEDs shall be perpendicular to the circuit board.

Construct DMS pixels with discrete LEDs manufactured by a reputable manufacturer such as Avago Technologies (formerly Agilent Technologies), Toshiba Corporation, Nichia Corporation, OSRAM, Cree, Inc., or EOI. Discrete LEDs shall conform to the following specifications.

All LEDs shall have a nominal viewing cone of 30 degrees with a half-power angle of 15 degrees measured from the longitudinal axis of the LED. Viewing cone tolerances shall be as specified in the LED manufacturer’s product specifications and shall not exceed +/- 5 degrees. Using optical enhancing lenses with 15 degree LED’s will not conform to 30 degree half-power viewing cone specifications and will be cause for rejection.

Red LEDs shall utilize AlInGaP semiconductor technology and shall emit red light that has a peak wavelength of 615-635nm

Green LEDs shall utilize InGaN semiconductor technology and shall emit green light that has a peak wavelength of 520-535nm

Blue LEDs shall utilize InGaN semiconductor technology and shall emit blue light that has a peak wavelength of 464-470nm

Fabricate the LED packages from UV light resistant epoxy.

The LED manufacturer shall perform color sorting of the bins. Obtain each color of LEDs from no more than two consecutive color “bins” as defined by the LED manufacturer.

The LED manufacturer shall perform intensity sorting of the bins. Obtain LEDs from no more than two consecutive luminous intensity “bins” as defined by the LED manufacturer.

Evenly distribute the various LED color and intensity bins throughout the sign and shall be consistent from pixel to pixel. Random distribution of the LED bins shall not be accepted.

The LED manufacturer shall assure color uniformity and consistency on the LED display face within the 30 degree cone of vision. Inconsistent color shifts or intensity will be cause for rejection.

All LEDs used in all ADMS provided for this contract shall be from the same manufacturer and of the same part number, except for the variations in the part number due to the intensity and color.

The LEDs shall be rated by the LED manufacturer to have a minimum lifetime of 100,000 hours of continuous operation while maintaining a minimum of 70% of the original brightness.

1. Housing Characteristics
	1. General Housing

Fabricate, weld, and inspect the ADMS housing in accordance with AWS D1.2/D1.2M:2003 Structural Welding Code-Aluminum (2003). Perform welding according to documented in-house welding procedures, and certify personnel who perform welding on ADMS housing to AWS D1.2/D1.2M:2003 for all weld types required.

Design and construct the housing to follow the AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals, 5th Edition*.

Housing shall protect internal components from rain, ice, dust, and corrosion in accordance with NEMA enclosure Type 3R standards, as described in *NEMA Standards Publication 250-1997, Enclosures for Electrical Equipment (1000 Volts Maximum)*.

Construct the housing and modules so that all maintenance is performed from the rear of the sign. As an option housing may be front access, but must demonstrate that maintenance by a single technician is feasible and safe.

Fabricate the housing from 0.125-inch (minimum) thick 3003-H14 or 5052-H32 aluminum alloy. Round all edges and corners.

Construct the housing to have a neat, professional appearance. Securely clamp or tie all cables in the sign housing.

* 1. Mounting Brackets

Provide two lifting eyes with a minimum one inch diameter on the housing to be used when placing the housing on the sign structure. The Engineer will position the lifting eyes. Fully assembled signs will be lifted into place using both lifting eyes. However, each eye shall have sufficient structural strength to allow the sign be lifted or moved without structural damage or permanent deformation to the sign.

Provide multiple mounting brackets in the form of I-beams or Z-extrusions bolted to the housing exterior rear wall, to facilitate attachment of the ADMS to its support structure. Use mounting brackets made from extruded aluminum alloy number 6061-T6. Attach the mounting brackets to ADMS structural frame members, not just the exterior sheet metal. Attach the mounting brackets to the ADMS using galvanized A 105 grade high-strength steel bolts. Design and fabricate the mounting brackets such that the installing Vendor can drill into them without penetrating the ADMS housing and comprising the housing’s ability to shed water.

ADMS structural hardware and mounting brackets hardware (nuts, bolts, washers, and direct tension indicators) shall be stainless steel or galvanized high-strength steel appropriately sized for the application.

* 1. Front Face Construction

Construct the front face with multiple rigid panels, each of which supports and protects a full height section of the LED display matrix. Panel exteriors shall be fabricated from 0.090-inch aluminum sheeting and panel interiors shall be 0.125-inch polycarbonate sheeting. All sides, except the front, shall be covered with 0.125-inch thick aluminum sheets made from alloy number 5050-H34 or 3003-H14.

Bolt face panels to the ADMS housing and to each other using stainless steel hardware. Seal seams that separate adjacent panels. Stitch weld the interior side of each sheet to the frame members. All exterior sheet seams shall be continuously seam welded to the frame, in order to form a unitized structure.

Panels shall be removable and shall not be welded to the ADMS housing.

Weight of a single face panel shall not exceed 150 lbs.

Provide a high-contrast background on the front face. Paint aluminum portions of each panel black. Front face shall employ a flat black anti-glare sheeting substance. To maximize display contrast and legibility paint the ADMS front face borders (top, bottom, left side, and right side), which surround the front face panels and LED display matrix, black.

All housing shall follow the AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals, 5th Edition*. The housing shall be designed and constructed to withstand a minimum sustained wind load of 100 mph and a truck gusting induced fatigue, with a 30 percent wind gust factor. Housing shall support a front face ice load of 4 lbs per square foot.

Front panel shall be mounted securely as to withstand a 100 mph wind load, and shall not obscure any of the pixels in the sign. In the presence of wind, the ADMS front face shall not distort in a manner that adversely affects LED message legibility.

Mount display modules to the inside of the front face panels using either standard hand tools or no tools for removal and replacement.

* 1. Exterior Finish

Powder-coat paint or anodize all outside surfaces. Border piece shall be coated with semi-gloss black Kynar 500 or an equivalent brand oven-fired fluropolymer coating which has an expected outdoor service life of 20 years. All other housing surfaces, including ADMS mounting brackets shall be natural mill-finish aluminum. As an alternative to powder coating and anodization, the Vendor may propose an alternative housing finish that has an outdoor service life of 20 years and is covered by a corresponding warranty.

1. Maintenance Access
	1. General Information

Provide safe and convenient front or rear service access for all materials located within housing. All internal components shall be removable and replaced by a single technician.

Housing may be front access, but must demonstrate that maintenance manageability by a single technician is feasible and safe.

Access panels shall open easily and be supported in their open position by multiple self-locking retaining devices. Means shall be designed to thoroughly support the access panel assembly in the open position in a 30-mph wind. Support systems shall be designed and configured for one maintenance person to safely and easily open and close the access panel assembly.

In the closed position, access panels shall be securely clamped by captive locking devices and attached to the DMS housing wall with stainless steel or aluminum hardware. The access panel assembly and all associated hardware shall be captive, so they cannot fall onto the roadway in any position.

1. Sign to Cabinet Interconnect

Connect the ADMS to its cabinet following the following minimum requirements:

* Provide communication control cables 300 feet in length between the sign and the sign controller cabinet (provided under a separate item) for operation of the sign.
* Provide fiber optic for all control, communication, and data purposes. As an option provide a copper signal cable if requested.
1. Electrical
	1. Wiring

Furnish all wiring both internal to the cabinet and between the cabinet and the ADMS components within the housing to provide the following functionality:

* Wire and color-code all components per the most recent National Electrical Code (NEC) and Wisconsin Electrical Code requirements.
* Provide AC Power for control equipment with a series-connected surge suppresser capable of passing 15 amps of current that shall protect the field controller and modem (or signal converter).
* Provide electrical protection, bonding and grounding for the ADMS
1. Standards

The following is a list of standards and specifications that must be in full compliancy:

* 1. FHWA *Manual on Uniform Traffic Control Devices, 2009 Edition with Revisions*
	2. AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals*, 5th Edition
	3. ANSI/AWS (American Welding Society) D1.2/D1.2M:2003– Structural Welding Code – Aluminum
	4. NCHRP Report 412, *Fatigue-Resistant Design of Cantilevered Signal, Sign, and Light Supports*
	5. National (United States) and Wisconsin Electrical Code
	6. NEMA Standards Publication 250 – *Enclosures for Electrical Equipment*
	7. NEMA Standard TS 1, Section 2 – *Environmental Standards and Test Procedures, Traffic Control Systems*
	8. NEMA Standard TS 4-2005 – *Hardware Standards for Dynamic Message Signs (DMS), with NTCIP Requirements*
	9. NTCIP Standards:
		1. NTCIP 1101: NTCIP 1101:1997 (NEMA TS 3.2-1996); *Simple Transportation Management Framework*
		2. NTCIP 1102: NTCIP 1201 v01.06, *Octet Encoding Rules (OER) Base Protocol*
		3. NTCIP 1103, *Simple Transportation Network Protocol (STMP)*
		4. NTCIP 1201: NTCIP 1201:1996 (NEMA TS 3.4-1996); *Global Object Definitions*
		5. NTCIP 1203: NTCIP 1203v03.04:2011; *Object Definitions for Dynamic Message Signs* - All Applicable Mandatory and Optional Requirements
		6. NTCIP 2001: NTCIP 2001:1996 (NEMA TS 3.3-1996); *NTCIP Class B Profile*
		7. NTCIP 2101: NTCIP 2101 v01.17 (NEMA TS3.SP-PMPP232), *Point to Multi-Point Protocol Using RS-232 Subnetwork Profile*
		8. NTCIP 2102: NTCIP 2102 v01.04, *Subnet Profile for PMPP Over FSK Modems*
		9. NTCIP 2103: NTCIP 2103 v01.05 (NEMA TS 3.SP-PPP232), *Subnet Profile for Point-to-Point Protocol Over RS-232*
		10. NTCIP 2104: NTCIP 2104 v01.07, *Subnet Profile for Ethernet*
		11. NTCIP 2201: NTCIP 2201 v01.11, *Transportation Transport Profile*
		12. NTCIP 2202: NTCIP 2202-1999, *Internet (TCP/IP and UDP/IP) Transport Profile*
		13. NTCIP 2301: NTCIP 2301-1999 (NEMA 3.AP-STMF), *Application Profile for Simple Transportation Management Framework (STMF)*
		14. NTCIP 2303: NTCIP 2303-1999, *Application Profile for File Transfer Protocol (FTP)*

Appendix F

DMS Panel for Hybrid Signs

Full Matrix, Color, 1.5 Feet by 7.75 Feet

Specification

1. General Information
	1. DMS General Requirements

Furnish a DMS insert to a static sign (hybrid DMS) for the display of travel times that is full color, full display matrix. Submit signed and certified design drawings, calculations, and material specifications for all aspects of the sign assemblies including the electronics, and mounting assemblies to the Engineer for review prior to incorporation into the work. Meet the following general requirements for each hybrid DMS provided:

* Design the sign for a minimum life of 20 years.
* Remove all company or vendor logos anywhere on the exterior of the sign housing.
* Comply with all applicable federal and state standards along with NTCIP standards.
	1. General Display Requirements

Meet the following display requirements for each DMS provided:

* Provide a continuous and uniform appearance to the traveling public that consists of Light Emitting Diode (LED) composed of multiple red, green, and blue LEDs.
* Conform to the appropriate National Transportation Communications for ITS Protocol (NTCIP) Standards, as herein after provided.
* Display area of with minimum dimensions of 18 inches high and 7 feet-9 inches wide. A larger display area is allowable within the confines of other requirements in this specification.
* Display alphanumeric text, punctuation symbols and graphic images across multiple panels. Each character shall be formed by a matrix of luminous pixels.
	1. General Dimension and Weight Requirements

Meet the following dimension and weight requirements for each hybrid DMS provided:

* Dimensions of hybrid DMS housing equal to or less than 2 feet tall by 8 feet long.
* Front-to-back housing depth equal to or less than 2 feet at its widest point, including any rear ventilation hoods.
* Design includes enclosed front or rear access assembly with mounting assembly.
1. Environment
	1. Outside Environmental Requirements

Design the system to conform to all applicable NEMA requirements and to meet the following minimum requirements and characteristics for outside environmental conditions:

* + - * Ensure hybrid DMS enclosure, components, heating and ventilation and workmanship are new components, corrosion resistant and adequate to assure full sign functionality and durability in an outdoor environment.
			* Provide field equipment that performs to the minimum environmental and sign hardware requirements of -29°F to 165°F and a humidity range of 0 percent to 95 percent relative non-condensing.
			* All outdoor enclosures must resist water infiltration during hose-directed water per NEMA 250 – Class 3R requirements.
			* All connections, internal or external to the hybrid DMS must be watertight.
			* All DMS components will not be damaged by temporary exposure to temperatures of -50° F to +185°F.
	1. Environmental Monitoring Systems

Provide a system with multiple sensors that are mounted on the front, rear, and under side facing the ground of the DMS housing that monitor and report ambient external light level and temperature.

Provide light sensors to continuously monitor and adjust the LED display matrix intensity to a level that ensures a legible message on the hybrid DMS face.

Monitor the sensors continuously by the DMS controller and report to the DMS control software upon request. The DMS controller should only reply to polls from the central software and not send the information without being polled.

1. DMS Display
	1. LED Display Modules

The hybrid DMS shall contain LED display modules that include an LED pixel array and LED driver circuitry. Mount modules adjacently in a two-dimensional array to form a continuous LED pixel matrix. Construct each LED display module as follows:

* Each LED display module may consist of one or two circuit boards. If two boards are used, physically mount them to each other using durable non-corrosive hardware and electrically connect them via one or more header-type connectors. Key the header connectors such that the boards cannot be connected incorrectly.
* Manufacture all LED modules using laminated fiberglass printed circuit boards.
* Mount each LED display module using durable non-corrosive hardware. No tools shall be required to remove and replace the module. Mount the modules such that the face panel does not block any part of the viewing cone of any of the LEDs in any pixels. Do not use light enhancing lenses to achieve defined viewing cone.
* Use quick-disconnect locking connector type for LED display module power and signal connections. Removal of a display module from the hybrid DMS, or a pixel board or driver circuit board from its display module, shall not require a soldering operation.
* Protect all exposed metal on both sides of each printed circuit board, except connector contacts, from water and humidity exposure by a thorough application of conformal coating. Allow bench level repair of individual components, including discrete LED replacement and conformal coating repair.
* Configure individual addressing of the each LED display module via the communication wiring harness and connector. Do not use on-board addressing jumpers or switches.
* Removal or failure of any LED module shall not affect the operation of any other LED module or sign component. Removal of one or more LED modules shall not affect the structural integrity of any part of the sign.
* It shall not be possible to mount an LED display module upside-down or in an otherwise incorrect position within the hybrid DMS display matrix.
* All LED display modules, as well as the LED pixel boards and driver circuit boards, shall be identical and interchangeable throughout the hybrid DMS.
	1. LED Pixels

Manufacture LED modules on a printed circuit board to which LED pixels are soldered. The LED pixel matrix shall conform to the following specifications:

The distance from the center of one pixel to the center of all adjacent pixels, both horizontally and vertically, shall be 0.787-inches (20 mm).

Each pixel shall consist of a minimum of one independent string of discrete LEDs for each color. All pixels shall contain an equal quantity of LED strings.

The failure of an LED string or pixel shall not cause the failure of any other LED string or pixel in the hybrid DMS.

Each pixel shall contain the quantity of discrete LEDs needed to output white colored light at a minimum luminous intensity of 12,400 candelas per square meter when measured using a photometric meter through the DMS front face panel assembly. Failure to conform to the requirements will be cause for rejection.

Each pixel shall also be capable of displaying amber colored light with a minimum luminous intensity of 7,440 candelas per square meter when measured using a photometric meter through the DMS front face panel assembly. Failure to conform to the requirements will be cause for rejection.

The circular base of the discrete LEDs shall be soldered so that they are flush and parallel to the surface of the printed circuit board. The longitudinal axis of the LEDs shall be perpendicular to the circuit board.

Construct DMS pixels with discrete LEDs manufactured by a reputable manufacturer such as Avago Technologies (formerly Agilent Technologies), Toshiba Corporation, Nichia Corporation, OSRAM, Cree, Inc., or EOI. Discrete LEDs shall conform to the following specifications.

All LEDs shall have a nominal viewing cone of 30 degrees with a half-power angle of 15 degrees measured from the longitudinal axis of the LED. Viewing cone tolerances shall be as specified in the LED manufacturer’s product specifications and shall not exceed +/- 5 degrees. Using optical enhancing lenses with 15 degree LED’s will not conform to 30 degree half-power viewing cone specifications and will be cause for rejection.

Red LEDs shall utilize AlInGaP semiconductor technology and shall emit red light that has a peak wavelength of 615-635nm

Green LEDs shall utilize InGaN semiconductor technology and shall emit green light that has a peak wavelength of 520-535nm

Blue LEDs shall utilize InGaN semiconductor technology and shall emit blue light that has a peak wavelength of 464-470nm

Fabricate the LED packages from UV light resistant epoxy.

The LED manufacturer shall perform color sorting of the bins. Obtain each color of LEDs from no more than two consecutive color “bins” as defined by the LED manufacturer.

The LED manufacturer shall perform intensity sorting of the bins. Obtain LEDs from no more than two consecutive luminous intensity “bins” as defined by the LED manufacturer.

Evenly distribute the various LED color and intensity bins throughout the sign and shall be consistent from pixel to pixel. Random distribution of the LED bins shall not be accepted.

The LED manufacturer shall assure color uniformity and consistency on the LED display face within the 30 degree cone of vision. Inconsistent color shifts or intensity will be cause for rejection.

All LEDs used in all DMS provided for this contract shall be from the same manufacturer and of the same part number, except for the variations in the part number due to the intensity and color.

The LEDs shall be rated by the LED manufacturer to have a minimum lifetime of 100,000 hours of continuous operation while maintaining a minimum of 70% of the original brightness.

1. Housing Characteristics
	1. General Housing

Fabricate, weld, and inspect the hybrid DMS housing in accordance with AWS D1.2/D1.2M:2003 Structural Welding Code-Aluminum (2003). Perform welding according to documented in-house welding procedures, and certify personnel who perform welding on the hybrid DMS housing to AWS D1.2/D1.2M:2003 for all weld types required.

Design and construct the housing to follow the AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals, 5th Edition*.

Housing shall protect internal components from rain, ice, dust, and corrosion in accordance with NEMA enclosure Type 3R standards, as described in *NEMA Standards Publication 250-1997, Enclosures for Electrical Equipment (1000 Volts Maximum)*.

Construct the housing and modules so that all maintenance is performed from the front or rear of the sign. As an option housing may be front access, but must demonstrate that maintenance manageability by a single technician is feasible and safe.

Fabricate the housing from 0.125-inch (minimum) thick 3003-H14 or 5052-H32 aluminum alloy. Round all edges and corners.

Construct the housing to have a neat, professional appearance. Securely clamp or tie all cables in the sign housing.

The DMS housing when installed in a static sign panel shall not have light leakage around the housing from ambient light.

* 1. Front Face Construction

Provide a high-contrast background on the front face. Paint aluminum portions of each panel black. Front face shall employ a flat black anti-glare sheeting substance. To maximize display contrast and legibility paint the hybrid DMS front face borders (top, bottom, left side, and right side), which surround the front face panels and LED display matrix, black.

All housing shall follow the AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals, 5th Edition*.

Front panel shall be mounted securely as to withstand a 100 mph wind load, and shall not obscure any of the pixels in the sign. In the presence of wind, the hybrid DMS front face shall not distort in a manner that adversely affects LED message legibility.

Mount display modules to the inside of the front face panels using either standard hand tools or no tools for removal and replacement.

* 1. Exterior Finish

Powder-coat paint or anodize all outside surfaces. Border piece shall be coated with semi-gloss black Kynar 500 or an equivalent brand oven-fired fluropolymer coating which has an expected outdoor service life of 20 years. All other housing surfaces, including hybrid DMS mounting brackets shall be natural mill-finish aluminum. As an alternative to powder coating and anodization, the Vendor may propose an alternative housing finish that has an outdoor service life of 20 years and is covered by a corresponding warranty.

1. Maintenance Access
	1. General Information

Provide safe and convenient front or rear service access for all materials located within housing. All internal components shall be removable and replaced by a single technician.

Housing may be front access, but must demonstrate that maintenance manageability by a single technician is feasible and safe.

Access panels shall open easily and be supported in their open position by multiple self-locking retaining devices. Means shall be designed to thoroughly support the access panel assembly in the open position in a 30-mph wind. Support systems shall be designed and configured for one maintenance person to safely and easily open and close the access panel assembly.

In the closed position, access panels shall be securely clamped by captive locking devices and attached to the DMS housing wall with stainless steel or aluminum hardware. The access panel assembly and all associated hardware shall be captive, so they cannot fall onto the roadway in any position.

1. Sign to Cabinet Interconnect

Connect the hybrid DMS to its cabinet following the following minimum requirements:

* Provide communication control cables 300 feet in length between the sign and the sign controller cabinet (provided under a separate item) for operation of the sign.
* Provide fiber optic for all control, communication, and data purposes. As an option provide a copper signal cable if requested.
1. Electrical
	1. Wiring

Furnish all wiring both internal to the cabinet and between the cabinet and the hybrid DMS components within the housing to provide the following functionality:

* Wire and color-code all components per the most recent National Electrical Code (NEC) and Wisconsin Electrical Code requirements.
* Provide AC Power for control equipment with a series-connected surge suppresser capable of passing 15 amps of current that shall protect the field controller and modem (or signal converter).
* Provide electrical protection, bonding, and grounding for the hybrid DMS
1. Standards

The following is a list of standards and specifications that must be in full compliancy:

* 1. FHWA *Manual on Uniform Traffic Control Devices, 2009 Edition with Revisions*
	2. AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals*, 5th Edition
	3. ANSI/AWS (American Welding Society) D1.2/D1.2M:2003– Structural Welding Code – Aluminum
	4. NCHRP Report 412, *Fatigue-Resistant Design of Cantilevered Signal, Sign, and Light Supports*
	5. National (United States) and Wisconsin Electrical Code
	6. NEMA Standards Publication 250 – *Enclosures for Electrical Equipment*
	7. NEMA Standard TS 1, Section 2 – *Environmental Standards and Test Procedures, Traffic Control Systems*
	8. NEMA Standard TS 4-2005 – *Hardware Standards for Dynamic Message Signs (DMS), with NTCIP Requirements*
	9. NTCIP Standards:
		1. NTCIP 1101: NTCIP 1101:1997 (NEMA TS 3.2-1996); *Simple Transportation Management Framework*
		2. NTCIP 1102: NTCIP 1201 v01.06, *Octet Encoding Rules (OER) Base Protocol*
		3. NTCIP 1103, *Simple Transportation Network Protocol (STMP)*
		4. NTCIP 1201: NTCIP 1201:1996 (NEMA TS 3.4-1996); *Global Object Definitions*
		5. NTCIP 1203: NTCIP 1203v03.04:2011; *Object Definitions for Dynamic Message Signs* - All Applicable Mandatory and Optional Requirements
		6. NTCIP 2001: NTCIP 2001:1996 (NEMA TS 3.3-1996); *NTCIP Class B Profile*
		7. NTCIP 2101: NTCIP 2101 v01.17 (NEMA TS3.SP-PMPP232), *Point to Multi-Point Protocol Using RS-232 Subnetwork Profile*
		8. NTCIP 2102: NTCIP 2102 v01.04, *Subnet Profile for PMPP Over FSK Modems*
		9. NTCIP 2103: NTCIP 2103 v01.05 (NEMA TS 3.SP-PPP232), *Subnet Profile for Point-to-Point Protocol Over RS-232*
		10. NTCIP 2104: NTCIP 2104 v01.07, *Subnet Profile for Ethernet*
		11. NTCIP 2201: NTCIP 2201 v01.11, *Transportation Transport Profile*
		12. NTCIP 2202: NTCIP 2202-1999, *Internet (TCP/IP and UDP/IP) Transport Profile*
		13. NTCIP 2301: NTCIP 2301-1999 (NEMA 3.AP-STMF), *Application Profile for Simple Transportation Management Framework (STMF)*
		14. NTCIP 2303: NTCIP 2303-1999, *Application Profile for File Transfer Protocol (FTP)*

Appendix G

DMS Panel for Hybrid Signs

Full Matrix, Color, 1-Foot by 4.75 Feet

Specification

1. General Information
	1. DMS General Requirements

Furnish a DMS insert to a static sign (hybrid DMS) for the display of travel times that is full color, full display matrix. Submit signed and certified design drawings, calculations, and material specifications for all aspects of the sign assemblies including the electronics, and mounting assemblies to the Engineer for review prior to incorporation into the work. Meet the following general requirements for each DMS provided:

* Design the sign for a minimum life of 20 years.
* Remove all company or vendor logos anywhere on the exterior of the sign housing.
* Comply with all applicable federal and state standards along with NTCIP standards.
	1. General Display Requirements

Meet the following display requirements for each DMS provided:

* Provide a continuous and uniform appearance to the traveling public that consists of Light Emitting Diode (LED) composed of multiple red, green, and blue LEDs.
* Conform to the appropriate National Transportation Communications for ITS Protocol (NTCIP) Standards, as herein after provided.
* Display area of with minimum dimensions of 12 inches high and 4 feet - 9inches wide. A larger display area is allowable within the confines of other requirements in this specification. Display alphanumeric text, punctuation symbols and graphic images across multiple panels.
	1. General Dimension and Weight Requirements

Meet the following dimension and weight requirements for each hybrid DMS provided:

* Dimensions of hybrid DMS housing equal to or less than 18 inches tall by 7 feet long.
* Front-to-back housing depth equal to or less than 2 feet at its widest point, including any rear ventilation hoods.
* Design includes enclosed front or rear access assembly with mounting assembly.
1. Environment
	1. Outside Environmental Requirements

Design the system to conform to all applicable NEMA requirements and to meet the following minimum requirements and characteristics for outside environmental conditions:

* + - * Ensure hybrid DMS enclosure, components, heating and ventilation and workmanship are new components, corrosion resistant and adequate to assure full sign functionality and durability in an outdoor environment.
			* Provide field equipment that performs to the minimum environmental and sign hardware requirements of -29°F to 165°F and a humidity range of 0 percent to 95 percent relative non-condensing.
			* All outdoor enclosures must resist water infiltration during hose-directed water per NEMA 250 – Class 3R requirements.
			* All connections, internal or external to the hybrid DMS must be watertight.
			* All DMS components will not be damaged by temporary exposure to temperatures of -50° F to +185°F.
	1. Environmental Monitoring Systems

Provide a system with multiple sensors that are mounted on the front, rear, and under side facing the ground of the DMS housing that monitor and report ambient external light level and temperature.

Provide light sensors to continuously monitor and adjust the LED display matrix intensity to a level that ensures a legible message on the hybrid DMS face.

Monitor the sensors continuously by the DMS controller and report to the DMS control software upon request. The DMS controller should only reply to polls from the central software and not send the information without being polled.

1. DMS Display
	1. LED Display Modules

The hybrid DMS shall contain LED display modules that include an LED pixel array and LED driver circuitry. Mount modules adjacently in a two-dimensional array to form a continuous LED pixel matrix. Construct each LED display module as follows:

* Each LED display module may consist of one or two circuit boards. If two boards are used, physically mount them to each other using durable non-corrosive hardware and electrically connect them via one or more header-type connectors. Key the header connectors such that the boards cannot be connected incorrectly.
* Manufacture all LED modules using laminated fiberglass printed circuit boards.
* Mount each LED display module using durable non-corrosive hardware. No tools shall be required to remove and replace the module. Mount the modules such that the face panel does not block any part of the viewing cone of any of the LEDs in any pixels. Do not use light enhancing lenses to achieve defined viewing cone.
* Use quick-disconnect locking connector type for LED display module power and signal connections. Removal of a display module from the hybrid DMS, or a pixel board or driver circuit board from its display module, shall not require a soldering operation.
* Protect all exposed metal on both sides of each printed circuit board, except connector contacts, from water and humidity exposure by a thorough application of conformal coating. Allow bench level repair of individual components, including discrete LED replacement and conformal coating repair.
* Configure individual addressing of the each LED display module via the communication wiring harness and connector. Do not use on-board addressing jumpers or switches.
* Removal or failure of any LED module shall not affect the operation of any other LED module or sign component. Removal of one or more LED modules shall not affect the structural integrity of any part of the sign.
* It shall not be possible to mount an LED display module upside-down or in an otherwise incorrect position within the hybrid DMS display matrix.
* All LED display modules, as well as the LED pixel boards and driver circuit boards, shall be identical and interchangeable throughout the hybrid DMS.
	1. LED Pixels

Manufacture LED modules on a printed circuit board to which LED pixels are soldered. The LED pixel matrix shall conform to the following specifications:

The distance from the center of one pixel to the center of all adjacent pixels, both horizontally and vertically, shall be 0.787-inches (20 mm).

Each pixel shall consist of a minimum of one independent string of discrete LEDs for each color. All pixels shall contain an equal quantity of LED strings.

The failure of an LED string or pixel shall not cause the failure of any other LED string or pixel in the hybrid DMS.

Each pixel shall contain the quantity of discrete LEDs needed to output white colored light at a minimum luminous intensity of 12,400 candelas per square meter when measured using a photometric meter through the DMS front face panel assembly. Failure to conform to the requirements will be cause for rejection.

Each pixel shall also be capable of displaying amber colored light with a minimum luminous intensity of 7,440 candelas per square meter when measured using a photometric meter through the DMS front face panel assembly. Failure to conform to the requirements will be cause for rejection.

The circular base of the discrete LEDs shall be soldered so that they are flush and parallel to the surface of the printed circuit board. The longitudinal axis of the LEDs shall be perpendicular to the circuit board.

Construct DMS pixels with discrete LEDs manufactured by a reputable manufacturer such as Avago Technologies (formerly Agilent Technologies), Toshiba Corporation, Nichia Corporation, OSRAM, Cree, Inc., or EOI. Discrete LEDs shall conform to the following specifications.

All LEDs shall have a nominal viewing cone of 30 degrees with a half-power angle of 15 degrees measured from the longitudinal axis of the LED. Viewing cone tolerances shall be as specified in the LED manufacturer’s product specifications and shall not exceed +/- 5 degrees. Using optical enhancing lenses with 15 degree LED’s will not conform to 30 degree half-power viewing cone specifications and will be cause for rejection.

Red LEDs shall utilize AlInGaP semiconductor technology and shall emit red light that has a peak wavelength of 615-635nm

Green LEDs shall utilize InGaN semiconductor technology and shall emit green light that has a peak wavelength of 520-535nm

Blue LEDs shall utilize InGaN semiconductor technology and shall emit blue light that has a peak wavelength of 464-470nm

Fabricate the LED packages from UV light resistant epoxy.

The LED manufacturer shall perform color sorting of the bins. Obtain each color of LEDs from no more than two consecutive color “bins” as defined by the LED manufacturer.

The LED manufacturer shall perform intensity sorting of the bins. Obtain LEDs from no more than two consecutive luminous intensity “bins” as defined by the LED manufacturer.

Evenly distribute the various LED color and intensity bins throughout the sign and shall be consistent from pixel to pixel. Random distribution of the LED bins shall not be accepted.

The LED manufacturer shall assure color uniformity and consistency on the LED display face within the 30 degree cone of vision. Inconsistent color shifts or intensity will be cause for rejection.

All LEDs used in all DMS provided for this contract shall be from the same manufacturer and of the same part number, except for the variations in the part number due to the intensity and color.

The LEDs shall be rated by the LED manufacturer to have a minimum lifetime of 100,000 hours of continuous operation while maintaining a minimum of 70% of the original brightness.

1. Housing Characteristics
	1. General Housing

Fabricate, weld, and inspect the hybrid DMS housing in accordance with AWS D1.2/D1.2M:2003 Structural Welding Code-Aluminum (2003). Perform welding according to documented in-house welding procedures, and certify personnel who perform welding on the hybrid DMS housing to AWS D1.2/D1.2M:2003 for all weld types required.

Design and construct the housing to follow the AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals, 5th Edition*.

Housing shall protect internal components from rain, ice, dust, and corrosion in accordance with NEMA enclosure Type 3R standards, as described in *NEMA Standards Publication 250-1997, Enclosures for Electrical Equipment (1000 Volts Maximum)*.

Construct the housing and modules so that all maintenance is performed from the front or rear of the sign. As an option housing may be front access, but must demonstrate that maintenance manageability by a single technician is feasible and safe.

Fabricate the housing from 0.125-inch (minimum) thick 3003-H14 or 5052-H32 aluminum alloy. Round all edges and corners.

Construct the housing to have a neat, professional appearance. Securely clamp or tie all cables in the sign housing.

The DMS housing when installed in a static sign panel shall not have light leakage around the housing from ambient light.

* 1. Front Face Construction

Provide a high-contrast background on the front face. Paint aluminum portions of each panel black. Front face shall employ a flat black anti-glare sheeting substance. To maximize display contrast and legibility paint the hybrid DMS front face borders (top, bottom, left side, and right side), which surround the front face panels and LED display matrix, black.

All housing shall follow the AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals, 5th Edition*. The housing shall be designed and constructed to withstand a minimum sustained wind load of 100 mph and a truck gusting induced fatigue, with a 30 percent wind gust factor. Housing shall support a front face ice load of 4 lbs per square foot.

Front panel shall be mounted securely as to withstand a 100 mph wind load, and shall not obscure any of the pixels in the sign. In the presence of wind, the hybrid DMS front face shall not distort in a manner that adversely affects LED message legibility.

Mount display modules to the inside of the front face panels using either standard hand tools or no tools for removal and replacement.

* 1. Exterior Finish

Powder-coat paint or anodize all outside surfaces. Border piece shall be coated with semi-gloss black Kynar 500 or an equivalent brand oven-fired fluropolymer coating which has an expected outdoor service life of 20 years. All other housing surfaces, including hybrid DMS mounting brackets shall be natural mill-finish aluminum. As an alternative to powder coating and anodization, the Vendor may propose an alternative housing finish that has an outdoor service life of 20 years and is covered by a corresponding warranty.

1. Maintenance Access
	1. General Information

Provide safe and convenient front or rear service access for all materials located within housing. All internal components shall be removable and replaced by a single technician.

Housing may be front access, but must demonstrate that maintenance manageability by a single technician is feasible and safe.

Access panels shall open easily and be supported in their open position by multiple self-locking retaining devices. Means shall be designed to thoroughly support the access panel assembly in the open position in a 30-mph wind. Support systems shall be designed and configured for one maintenance person to safely and easily open and close the access panel assembly.

In the closed position, access panels shall be securely clamped by captive locking devices and attached to the DMS housing wall with stainless steel or aluminum hardware. The access panel assembly and all associated hardware shall be captive, so they cannot fall onto the roadway in any position.

1. Sign to Cabinet Interconnect

Connect the hybrid DMS to its cabinet following the following minimum requirements:

* Provide communication control cables 300 feet in length between the sign and the sign controller cabinet (provided under a separate item) for operation of the sign.
* Provide fiber optic for all control, communication, and data purposes. As an option provide a copper signal cable if requested.
1. Electrical
	1. Wiring

Furnish all wiring both internal to the cabinet and between the cabinet and the hybrid DMS components within the housing to provide the following functionality:

* Wire and color-code all components per the most recent National Electrical Code (NEC) and Wisconsin Electrical Code requirements.
* Provide AC Power for control equipment with a series-connected surge suppresser capable of passing 15 amps of current that shall protect the field controller and modem (or signal converter).
* Provide electrical protection, bonding, and grounding for the hybrid DMS
1. Standards

The following is a list of standards and specifications that must be in full compliancy:

* 1. FHWA *Manual on Uniform Traffic Control Devices, 2009 Edition with Revisions*
	2. AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals*, 5th Edition
	3. ANSI/AWS (American Welding Society) D1.2/D1.2M:2003– Structural Welding Code – Aluminum
	4. NCHRP Report 412, *Fatigue-Resistant Design of Cantilevered Signal, Sign, and Light Supports*
	5. National (United States) and Wisconsin Electrical Code
	6. NEMA Standards Publication 250 – *Enclosures for Electrical Equipment*
	7. NEMA Standard TS 1, Section 2 – *Environmental Standards and Test Procedures, Traffic Control Systems*
	8. NEMA Standard TS 4-2005 – *Hardware Standards for Dynamic Message Signs (DMS), with NTCIP Requirements*
	9. NTCIP Standards:
		1. NTCIP 1101: NTCIP 1101:1997 (NEMA TS 3.2-1996); *Simple Transportation Management Framework*
		2. NTCIP 1102: NTCIP 1201 v01.06, *Octet Encoding Rules (OER) Base Protocol*
		3. NTCIP 1103, *Simple Transportation Network Protocol (STMP)*
		4. NTCIP 1201: NTCIP 1201:1996 (NEMA TS 3.4-1996); *Global Object Definitions*
		5. NTCIP 1203: NTCIP 1203v03.04:2011; *Object Definitions for Dynamic Message Signs* - All Applicable Mandatory and Optional Requirements
		6. NTCIP 2001: NTCIP 2001:1996 (NEMA TS 3.3-1996); *NTCIP Class B Profile*
		7. NTCIP 2101: NTCIP 2101 v01.17 (NEMA TS3.SP-PMPP232), *Point to Multi-Point Protocol Using RS-232 Subnetwork Profile*
		8. NTCIP 2102: NTCIP 2102 v01.04, *Subnet Profile for PMPP Over FSK Modems*
		9. NTCIP 2103: NTCIP 2103 v01.05 (NEMA TS 3.SP-PPP232), *Subnet Profile for Point-to-Point Protocol Over RS-232*
		10. NTCIP 2104: NTCIP 2104 v01.07, *Subnet Profile for Ethernet*
		11. NTCIP 2201: NTCIP 2201 v01.11, *Transportation Transport Profile*
		12. NTCIP 2202: NTCIP 2202-1999, *Internet (TCP/IP and UDP/IP) Transport Profile*
		13. NTCIP 2301: NTCIP 2301-1999 (NEMA 3.AP-STMF), *Application Profile for Simple Transportation Management Framework (STMF)*
		14. NTCIP 2303: NTCIP 2303-1999, *Application Profile for File Transfer Protocol (FTP)*

Appendix H

Lane Control Sign

Full Matrix, Color

Specification

1. General Information
	1. LCS General Requirements

Furnish a Lane Control Sign (LCS) that is full color, full display matrix. Submit signed and certified design drawings, calculations, and material specifications for all aspects of the sign assemblies including the electronics, and mounting assemblies to the Engineer for review prior to incorporation into the work. Meet the following general requirements for each LCS provided:

* Design the sign for a minimum life of 20 years.
* Remove all company or vendor logos anywhere on the exterior of the sign housing.
* Comply with all applicable federal and state standards along with NTCIP standards.
	1. General Display Requirements

Meet the following display requirements for each LCS provided:

* Provide a continuous and uniform appearance to the traveling public that consists of Light Emitting Diode (LED) composed of multiple red, green, and blue LEDs.
* Display area of with minimum dimensions of 3 feet high and 3 feet wide. A larger display area is allowable within the confines of other requirements in this specification. Display alphanumeric text, punctuation symbols and graphic images across multiple panels.
	1. General Dimension and Weight Requirements

Meet the following dimension and weight requirements for each LCS provided:

* Dimensions of LCS housing equal to or less than 42 inches tall by 42 inches long.
* Front-to-back housing depth equal to or less than 2 feet at its widest point, including any rear ventilation hoods.
* Design includes enclosed front or rear access assembly with mounting assembly.
1. Environment
	1. Outside Environmental Requirements

Design the system to conform to all applicable NEMA requirements and to meet the following minimum requirements and characteristics for outside environmental conditions:

* + - * Ensure LCS enclosure, components, heating and ventilation and workmanship are new components, corrosion resistant and adequate to assure full sign functionality and durability in an outdoor environment.
			* Provide field equipment that performs to the minimum environmental and sign hardware requirements of -29°F to 165°F and a humidity range of 0 percent to 95 percent relative non-condensing.
			* All outdoor enclosures must resist water infiltration during hose-directed water per NEMA 250 – Class 3R requirements.
			* All connections, internal or external to the LCS must be watertight.
			* All DMS components will not be damaged by temporary exposure to temperatures of -50°F to +185°F.
	1. Environmental Monitoring Systems

Provide a system with multiple sensors that are mounted on the front, rear, and under side facing the ground of the DMS housing that monitor and report ambient external light level and temperature.

Provide light sensors to continuously monitor and adjust the LED display matrix intensity to a level that ensures a legible message on the LCS face.

Monitor the sensors continuously by the DMS controller and report to the DMS control software upon request. The DMS controller should only reply to polls from the central software and not send the information without being polled.

1. DMS Display
	1. LED Display Modules

The LCS shall contain LED display modules that include an LED pixel array and LED driver circuitry. Mount modules adjacently in a two-dimensional array to form a continuous LED pixel matrix. Construct each LED display module as follows:

* Each LED display module may consist of one or two circuit boards. If two boards are used, physically mount them to each other using durable non-corrosive hardware and electrically connect them via one or more header-type connectors. Key the header connectors such that the boards cannot be connected incorrectly.
* Manufacture all LED modules using laminated fiberglass printed circuit boards.
* Mount each LED display module using durable non-corrosive hardware. No tools shall be required to remove and replace the module. Mount the modules such that the face panel does not block any part of the viewing cone of any of the LEDs in any pixels. Do not use light enhancing lenses to achieve defined viewing cone.
* Use quick-disconnect locking connector type for LED display module power and signal connections. Removal of a display module from the LCS, or a pixel board or driver circuit board from its display module, shall not require a soldering operation.
* Protect all exposed metal on both sides of each printed circuit board, except connector contacts, from water and humidity exposure by a thorough application of conformal coating. Allow bench level repair of individual components, including discrete LED replacement and conformal coating repair.
* Configure individual addressing of the each LED display module via the communication wiring harness and connector. Do not use on-board addressing jumpers or switches.
* Removal or failure of any LED module shall not affect the operation of any other LED module or sign component. Removal of one or more LED modules shall not affect the structural integrity of any part of the sign.
* It shall not be possible to mount an LED display module upside-down or in an otherwise incorrect position within the LCS display matrix.
* All LED display modules, as well as the LED pixel boards and driver circuit boards, shall be identical and interchangeable throughout the LCS.
	1. LED Pixels

Manufacture LED modules on a printed circuit board to which LED pixels are soldered. The LED pixel matrix shall conform to the following specifications:

The distance from the center of one pixel to the center of all adjacent pixels, both horizontally and vertically, shall be 0.787-inches (20 mm).

Each pixel shall consist of a minimum of one independent string of discrete LEDs for each color. All pixels shall contain an equal quantity of LED strings.

The failure of an LED string or pixel shall not cause the failure of any other LED string or pixel in the LCS.

Each pixel shall contain the quantity of discrete LEDs needed to output white colored light at a minimum luminous intensity of 12,400 candelas per square meter when measured using a photometric meter through the DMS front face panel assembly. Failure to conform to the requirements will be cause for rejection.

Each pixel shall also be capable of displaying amber colored light with a minimum luminous intensity of 7,440 candelas per square meter when measured using a photometric meter through the DMS front face panel assembly. Failure to conform to the requirements will be cause for rejection.

The circular base of the discrete LEDs shall be soldered so that they are flush and parallel to the surface of the printed circuit board. The longitudinal axis of the LEDs shall be perpendicular to the circuit board.

Construct DMS pixels with discrete LEDs manufactured by a reputable manufacturer such as Avago Technologies (formerly Agilent Technologies), Toshiba Corporation, Nichia Corporation, OSRAM, Cree, Inc., or EOI. Discrete LEDs shall conform to the following specifications.

All LEDs shall have a nominal viewing cone of 30 degrees with a half-power angle of 15 degrees measured from the longitudinal axis of the LED. Viewing cone tolerances shall be as specified in the LED manufacturer’s product specifications and shall not exceed +/- 5 degrees. Using optical enhancing lenses with 15 degree LED’s will not conform to 30 degree half-power viewing cone specifications and will be cause for rejection.

Red LEDs shall utilize AlInGaP semiconductor technology and shall emit red light that has a peak wavelength of 615-635nm

Green LEDs shall utilize InGaN semiconductor technology and shall emit green light that has a peak wavelength of 520-535nm

Blue LEDs shall utilize InGaN semiconductor technology and shall emit blue light that has a peak wavelength of 464-470nm

Fabricate the LED packages from UV light resistant epoxy.

The LED manufacturer shall perform color sorting of the bins. Obtain each color of LEDs from no more than two consecutive color “bins” as defined by the LED manufacturer.

The LED manufacturer shall perform intensity sorting of the bins. Obtain LEDs from no more than two consecutive luminous intensity “bins” as defined by the LED manufacturer.

Evenly distribute the various LED color and intensity bins throughout the sign and shall be consistent from pixel to pixel. Random distribution of the LED bins shall not be accepted.

The LED manufacturer shall assure color uniformity and consistency on the LED display face within the 30 degree cone of vision. Inconsistent color shifts or intensity will be cause for rejection.

All LEDs used in all DMS provided for this contract shall be from the same manufacturer and of the same part number, except for the variations in the part number due to the intensity and color.

The LEDs shall be rated by the LED manufacturer to have a minimum lifetime of 100,000 hours of continuous operation while maintaining a minimum of 70% of the original brightness.

1. Housing Characteristics
	1. General Housing

Fabricate, weld, and inspect the LCS housing in accordance with AWS D1.2/D1.2M:2003 Structural Welding Code-Aluminum (2003). Perform welding according to documented in-house welding procedures, and certify personnel who perform welding on the LCS housing to AWS D1.2/D1.2M:2003 for all weld types required.

Design and construct the housing to follow the AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals, 5th Edition*.

Housing shall protect internal components from rain, ice, dust, and corrosion in accordance with NEMA enclosure Type 3R standards, as described in *NEMA Standards Publication 250-1997, Enclosures for Electrical Equipment (1000 Volts Maximum)*.

Construct the housing and modules so that all maintenance is performed from the front or rear of the sign. As an option housing may be front access, but must demonstrate that maintenance manageability by a single technician is feasible and safe.

Fabricate the housing from 0.125-inch (minimum) thick 3003-H14 or 5052-H32 aluminum alloy. Round all edges and corners.

Construct the housing to have a neat, professional appearance. Securely clamp or tie all cables in the sign housing.

* 1. Front Face Construction

Provide a high-contrast background on the front face. Paint aluminum portions of each panel black. Front face shall employ a flat black anti-glare sheeting substance. To maximize display contrast and legibility paint the LCS front face borders (top, bottom, left side, and right side), which surround the front face panels and LED display matrix, black.

All housing shall follow the AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals, 5th Edition*. The housing shall be designed and constructed to withstand a minimum sustained wind load of 100 mph and a truck gusting induced fatigue, with a 30 percent wind gust factor. Housing shall support a front face ice load of 4 lbs per square foot.

Front panel shall be mounted securely as to withstand a 100 mph wind load, and shall not obscure any of the pixels in the sign. In the presence of wind, the LCS front face shall not distort in a manner that adversely affects LED message legibility.

Mount display modules to the inside of the front face panels using either standard hand tools or no tools for removal and replacement.

* 1. Exterior Finish

Powder-coat paint or anodize all outside surfaces. Border piece shall be coated with semi-gloss black Kynar 500 or an equivalent brand oven-fired fluropolymer coating which has an expected outdoor service life of 20 years. All other housing surfaces, including LCS mounting brackets shall be natural mill-finish aluminum. As an alternative to powder coating and anodization, the Vendor may propose an alternative housing finish that has an outdoor service life of 20 years and is covered by a corresponding warranty.

1. Maintenance Access
	1. General Information

Provide safe and convenient front or rear service access for all materials located within housing. All internal components shall be removable and replaced by a single technician.

Housing may be front access, but must demonstrate that maintenance manageability by a single technician is feasible and safe.

Access panels shall open easily and be supported in their open position by multiple self-locking retaining devices. Means shall be designed to thoroughly support the access panel assembly in the open position in a 30-mph wind. Support systems shall be designed and configured for one maintenance person to safely and easily open and close the access panel assembly.

In the closed position, access panels shall be securely clamped by captive locking devices and attached to the DMS housing wall with stainless steel or aluminum hardware. The access panel assembly and all associated hardware shall be captive, so they cannot fall onto the roadway in any position.

1. Sign to Cabinet Interconnect

Connect the LCS to its cabinet following the following minimum requirements:

* Provide communication control cables 300 feet in length between the sign and the sign controller cabinet (provided under a separate item) for operation of the sign.
* Provide fiber optic for all control, communication, and data purposes. As an option provide a copper signal cable if requested.
1. Electrical
	1. Wiring

Furnish all wiring both internal to the cabinet and between the cabinet and the LCS components within the housing to provide the following functionality:

* Wire and color-code all components per the most recent National Electrical Code (NEC) and Wisconsin Electrical Code requirements.
* Provide AC Power for control equipment with a series-connected surge suppresser capable of passing 15 amps of current that shall protect the field controller and modem (or signal converter).
* Provide electrical protection, bonding, and grounding for the LCS
1. Standards

The following is a list of standards and specifications that must be in full compliancy:

* 1. FHWA *Manual on Uniform Traffic Control Devices, 2009 Edition with Revisions*
	2. AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals*, 5th Edition
	3. ANSI/AWS (American Welding Society) D1.2/D1.2M:2003– Structural Welding Code – Aluminum
	4. NCHRP Report 412, *Fatigue-Resistant Design of Cantilevered Signal, Sign, and Light Supports*
	5. National (United States) and Wisconsin Electrical Code
	6. NEMA Standards Publication 250 – *Enclosures for Electrical Equipment*
	7. NEMA Standard TS 1, Section 2 – *Environmental Standards and Test Procedures, Traffic Control Systems*
	8. NEMA Standard TS 4-2005 – *Hardware Standards for Dynamic Message Signs (DMS), with NTCIP Requirements*
	9. NTCIP Standards:
		1. NTCIP 1101: NTCIP 1101:1997 (NEMA TS 3.2-1996); *Simple Transportation Management Framework*
		2. NTCIP 1102: NTCIP 1201 v01.06, *Octet Encoding Rules (OER) Base Protocol*
		3. NTCIP 1103, *Simple Transportation Network Protocol (STMP)*
		4. NTCIP 1201: NTCIP 1201:1996 (NEMA TS 3.4-1996); *Global Object Definitions*
		5. NTCIP 1203: NTCIP 1203v03.04:2011; *Object Definitions for Dynamic Message Signs* - All Applicable Mandatory and Optional Requirements
		6. NTCIP 2001: NTCIP 2001:1996 (NEMA TS 3.3-1996); *NTCIP Class B Profile*
		7. NTCIP 2101: NTCIP 2101 v01.17 (NEMA TS3.SP-PMPP232), *Point to Multi-Point Protocol Using RS-232 Subnetwork Profile*
		8. NTCIP 2102: NTCIP 2102 v01.04, *Subnet Profile for PMPP Over FSK Modems*
		9. NTCIP 2103: NTCIP 2103 v01.05 (NEMA TS 3.SP-PPP232), *Subnet Profile for Point-to-Point Protocol Over RS-232*
		10. NTCIP 2104: NTCIP 2104 v01.07, *Subnet Profile for Ethernet*
		11. NTCIP 2201: NTCIP 2201 v01.11, *Transportation Transport Profile*
		12. NTCIP 2202: NTCIP 2202-1999, *Internet (TCP/IP and UDP/IP) Transport Profile*
		13. NTCIP 2301: NTCIP 2301-1999 (NEMA 3.AP-STMF), *Application Profile for Simple Transportation Management Framework (STMF)*
		14. NTCIP 2303: NTCIP 2303-1999, *Application Profile for File Transfer Protocol (FTP)*

Appendix I

Dynamic Message Sign Controller

Specification

1. General Information
	1. Controller Requirements

Work under this item shall consist of furnishing a field controller for the signs in this contract. The field controller shall be a stand-alone microprocessor-based computer that runs on an embedded operating system and must control any of the sign types procured through this contract. Provide a full featured controller that meets all appropriate NTCIP standards.

Field controller shall be mounted in a ground controller cabinet (by others). Controller shall mount to a standard EIA 19-inch equipment rack. Controller shall have a maximum weight of 20 lbs, not including the enclosure.

The controller shall display any combination of text and graphics and have the capability to store multiple changeable messages. The controller shall support all FHWA fonts, symbols, route shields and colors.

The front panel of the controller shall have an LCD interface panel and keypad for creating, previewing and activating messages from the front panel. The front panel includes a status display of the DMS and communication of the system.

They controller shall perform diagnostic and maintenance activities of the DMS including:

* Real time diagnostics of pixels, lights, doors, power systems, fans and other sensors
* Monitor in-sign sensors including temperature, light, and door
* Real time messaging in WYSIWYG format

Provide a data key for configuration and firmware transfer to the controller.

* 1. Communication

All ports on the controller shall be fully NTCIP compliant and be capable to support dial-up modem, cellular modem, direct serial, fiber optic, radio, and other communication networks.

Provide integrated Ethernet (RJ-45), dial-up modem (RJ-11), serial (DB-9) and other communication ports and allow multiple communication ports for simultaneous or backup operations.

Provide appropriate connectors for fiber optic signal cable from the controller to the DMS.

Appendix J

Overhead Freeway Dynamic Message Signs (DMS),

Full Matrix, Walk-In, Color, 6 Feet by 22 Feet

Mounting Hardware

Specification

1. General Information
	1. Mounting Hardware Requirements

Furnish any materials necessary to allow for the DMS to be mounted to a horizontal structure.

Design the mounting materials for appropriate space and quantity to properly support the DMS.

All mounting materials must be corrosion resistant and meet all pertinent requirements of AASHTO.

Precise included materials are to be determined by the DMS manufacturer. A partial list of expected components are includes vertical I-Beams; and bolts, nuts, and washers for mounting I-Beams to back of DMS enclosure.

Provide a set of mounting instructions, requirements, and restrictions with each DMS ordered with the mounting hardware.

Appendix K

Overhead Freeway Dynamic Message Signs (DMS)

Full Matrix, Front Access, Color, 6 Feet by 22 Feet

Mounting Hardware

Specification

1. General Information
	1. Mounting Hardware Requirements

Furnish any materials necessary to allow for the DMS to be mounted to a horizontal structure.

Design the mounting materials for appropriate space and quantity to properly support the DMS.

All mounting materials must be corrosion resistant and meet all pertinent requirements of AASHTO.

Precise included materials are to be determined by the DMS manufacturer. A partial list of expected components are includes vertical I-Beams; and bolts, nuts, and washers for mounting I-Beams to back of DMS enclosure.

Provide a set of mounting instructions, requirements, and restrictions with each DMS ordered with the mounting hardware.

Appendix L

Dynamic Message Signs (DMS),

Full Matrix, Full Color, 5 Feet by 16 Feet

Mounting Hardware

Specification

1. General Information
	1. Mounting Hardware Requirements

Furnish any materials necessary to allow for the DMS to be mounted to a horizontal structure.

Design the mounting materials for appropriate space and quantity to properly support the DMS.

All mounting materials must be corrosion resistant and meet all pertinent requirements of AASHTO.

Precise included materials are to be determined by the DMS manufacturer. A partial list of expected components are includes vertical I-Beams; and bolts, nuts, and washers for mounting I-Beams to back of DMS enclosure.

Provide a set of mounting instructions, requirements, and restrictions with each DMS ordered with the mounting hardware.

Appendix M

Arterial Dynamic Message Signs (ADMS),

Full Matrix, Full Color, 4.25 Feet by 14 Feet

Mounting Hardware

Specification

1. General Information
	1. Mounting Hardware Requirements

Furnish any materials necessary to allow for the DMS to be mounted to a horizontal structure.

Design the mounting materials for appropriate space and quantity to properly support the DMS.

All mounting materials must be corrosion resistant and meet all pertinent requirements of AASHTO.

Precise included materials are to be determined by the DMS manufacturer. A partial list of expected components are includes vertical I-Beams; and bolts, nuts, and washers for mounting I-Beams to back of DMS enclosure.

Provide a set of mounting instructions, requirements, and restrictions with each DMS ordered with the mounting hardware.

Appendix N

Arterial Dynamic Message Signs (ADMS),

Full Matrix, Full Color, 2 Feet by 9.75 Feet

Mounting Hardware

Specification

1. General Information
	1. Mounting Hardware Requirements

Furnish any materials necessary to allow for the DMS to be mounted to a horizontal structure.

Design the mounting materials for appropriate space and quantity to properly support the DMS.

All mounting materials must be corrosion resistant and meet all pertinent requirements of AASHTO.

Precise included materials are to be determined by the DMS manufacturer. A partial list of expected components are includes vertical I-Beams; and bolts, nuts, and washers for mounting I-Beams to back of DMS enclosure.

Provide a set of mounting instructions, requirements, and restrictions with each DMS ordered with the mounting hardware.

Appendix O

DMS Panel for Hybrid Signs

Full Matrix, Color, 1.5 Feet by 7.75 Feet

Mounting Hardware

Specification

1. General Information
	1. Mounting Hardware Requirements

Furnish any materials necessary to allow for the DMS to be mounted to a horizontal structure.

Design the mounting materials for appropriate space and quantity to properly support the DMS.

All mounting materials must be corrosion resistant and meet all pertinent requirements of AASHTO.

Precise included materials are to be determined by the DMS manufacturer. A partial list of expected components are includes vertical I-Beams; and bolts, nuts, and washers for mounting I-Beams to back of DMS enclosure.

Provide a set of mounting instructions, requirements, and restrictions with each DMS ordered with the mounting hardware.

Appendix P

DMS Panel for Hybrid Signs

Full Matrix, Color, 1-Foot by 4.75 Feet

Mounting Hardware

Specification

1. General Information
	1. Mounting Hardware Requirements

Furnish any materials necessary to allow for the DMS to be mounted to a horizontal structure.

Design the mounting materials for appropriate space and quantity to properly support the DMS.

All mounting materials must be corrosion resistant and meet all pertinent requirements of AASHTO.

Precise included materials are to be determined by the DMS manufacturer. A partial list of expected components are includes vertical I-Beams; and bolts, nuts, and washers for mounting I-Beams to back of DMS enclosure.

Provide a set of mounting instructions, requirements, and restrictions with each DMS ordered with the mounting hardware.

Appendix Q

Lane Control Sign

Full Matrix, Color

Mounting Hardware

Specification

1. General Information
	1. Mounting Hardware Requirements

Furnish any materials necessary to allow for the LCS to be mounted to a horizontal structure.

Design the mounting materials for appropriate space and quantity to properly support the LCS.

All mounting materials must be corrosion resistant and meet all pertinent requirements of AASHTO.

Precise included materials are to be determined by the DMS manufacturer. A partial list of expected components are includes vertical I-Beams; and bolts, nuts, and washers for mounting I-Beams to back of DMS enclosure.

Provide a set of mounting instructions, requirements, and restrictions with each LCS ordered with the mounting hardware.

Appendix R

Dynamic Message Sign and Controller Training

Work under this item shall consist of providing a one day training session for WisDOT and its representatives regarding sign control and software as well as maintenance.

The Vendor shall have qualified instructors and provide all materials for training Department personnel and other designated personnel in the operations of the dynamic message signs.

The Vendor shall develop and submit training course outlines, samples of all training aids and manuals, and description of instructors and their qualifications to the Engineer for approval at least thirty days prior to the proposed scheduled start of the training sessions. Written approval of this material shall be required prior to the final scheduling of the training sessions or the final production of training materials. Training shall not begin until after approval of the submitted training material.

All training sessions shall be conducted at locations as determined by the Department. Training shall consist of formal classroom lectures as well as hands-on training. Hands-on training shall consist of working with the actual sign. See Attachment F – Cost Proposal, for reference regarding training for each type of dynamic message sign.

A day of training shall consist of 6 hours. The two sessions for each equipment category/subsystem shall be identical in content. The training sessions shall not overlap unless otherwise permitted by the Department. The attendance of each session shall not be more than twenty people. Each session shall provide a basic understanding of the sign and associated operation and maintenance. These training sessions include as appropriate, and as a minimum:

 - Background on concepts of equipment/subsystem, and theory of operation.

 - Day to day typical operation and capabilities.

 - Procedures for installing and setting up equipment and components.

 - Basic troubleshooting and fault determination procedures.

 - Preventive maintenance procedures and schedules.

The Vendor shall video record all training sessions, and provide the recordings to the Department for training new personnel in the future.