Specification Guide for Procurement of NTCIP-compliant Dynamic Message Signs (DMS)

Version 01.10

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1 INTRODUCTION

This document is a tool for the author of a Dynamic Message Signs (DMS) procurement specification. With this tool, the user will be able to develop a meaningful NTCIP procurement specification to purchase interoperable and interchangeable DMS.

The National Transportation Communications for ITS Protocol (NTCIP) was developed in an effort to standardize the way transportation systems and devices exchange data. However, the people involved in the NTCIP effort also recognized it was not appropriate to try to mandate a one-size-fits-all mentality. Different projects would have different features and the NTCIP standards had to be flexible enough to support the end-user needs. The solution was to produce a modular set of standards and, in cases, have these standards define different *conformance groups* or *conformance levels*. The Conformance Groups are collections of data elements (or object definitions), the main items defined in the NTCIP Standard that are used to address a particular function. An example would be the Message Table Conformance Group, which contains all the data elements necessary (both required data elements for all technologies and optional data elements pertaining to particular technologies or "niceties") to download a message to the sign controller's message library.

Unfortunately, the rapid development pace of the NTCIP standards has outpaced the effort to provide our industry with the proper education needed to understand all of the NTCIP details. Thus, while the NTCIP standards provide features to allow for well-designed procurement specifications, the industry as a whole is not familiar with how to produce such specifications. Many early projects that attempted to include NTCIP as the communications protocol had trouble to correctly specifying NTCIP. The nature of specification issues is that any problem must be solved before the procurement occurs. It is important to understand the nature of standards in that they provide definitions, not specifications. One needs to understand this difference because while standards need to be as open as possible with as many options as possible to cover a wide range of implementation options, a specification has to be as specific as possible to procure exactly what is needed to fulfill the requirements of a particular project.

This document has been prepared to provide a procuring agency with a tool to integrate NTCIP requirements and language into traditional specifications. Additionally, common functions and features not yet standardized in the NTCIP standards will be identified and possible solutions, including insights into the NTCIP DMS Working Group's (WG's) current approach, will be provided. The NTCIP DMS Working Group is the technical working group developing the technical contents of the NTCIP 1203 standard.

As a rule, the document does not require specific features; rather it defines how the user of this document may include such requirements within a specification. For example, the sample wording indicates how one would specify how many messages the sign should store, but does not specify a quantity as that is a project-specific decision. Likewise, it specifies how one would require the sign to support font downloading in an NTCIP-compliant manner, but does not require this feature. However, to minimize the complexity of the document, those features that the reviewers felt were widely applicable are included in the main body of the text.

It should be understood this document is not intended to be an educational tool explaining the concept of operation for DMS, rather it assumes the reader / specification writer has an understanding of DMS functions and technologies.

It should also be noted the NTCIP standards development community is in the process of developing a Version 2 of DMS-related standards, which should be available in 9-12 months. These Version 2 standards will follow a Systems Engineering approach in that they will provide:

- Concept of Operations – general brief description of the overall purpose of the end-application/device
- Functional Requirements listing – the functions and features that are associated with an end-application/device
- Dialog and Interface specifications – explaining relationships between data elements and conformance groups
- Data Dictionaries – definition of data elements, or object definitions, which are basically the content of the Version 1 standards (plus the amendments)
- Traceability Matrix – a matrix linking the Functional Requirements to Dialogs/Interface specifications and to data elements
- Testing – test procedures[1] to ensure conformance to specific features.

It needs to be understood certain functions and/or features associated with dynamic message signs have not (yet) been standardized. Please refer to Section 3 to see which functions are supported by the relevant NTCIP DMS standards.

Another issue associated with the NTCIP standards is dialogs (*Certain data elements are interrelated and dialogs define the sequence in which these data elements have to be configured/set.*). While the current set of standards, including the amendments, do not provide explicit explanations of the interrelationships between object definitions, the future versions (Version 2) of these standards, which are currently under development, will include them. This interim document will include the most common dialogs associated with the current set of NTCIP standards related to dynamic message signs.

1.1 ACKNOWLEDGMENTS

The document was originally prepared for the Virginia Department of Transportation with funding provided by the ENTERPRISE Consortium (http://enterprise.prog.org/inch.html). The Cambridge Systematic Team used that document as the basis for the development of this "Generic DMS Specification version 01".

1.2 DEFINITIONS

Certain terms used throughout this document are being defined here to ease the understanding of the reader. The industry has used some of these terms interchangeability but this Guide will use these terms in a consistent manner, which is the reason why this definition section lists some of the terms together.

[1] The development of testing procedures should be part of any standards following the system engineering process. However, this work item was not (yet) approved for inclusion in Version 2 of NTCIP 1203 and may not be available initially.

Term(s)	*Definition*
Compliance vs Conformance	Conformance is the term used if an implementation or reference adheres to a standard. Compliance is the term used if an implementation or reference adheres to a contract or contract specification

1.3 SCOPE OF DOCUMENT

This document is intended as an interim version of the final DMS specification developed under this effort. The purpose is to provide agencies planning or ready to purchase DMS within the next 9-12 months with a guidance or sample specification document. An update to the DMS Specification will be based on Version 2 of the relevant NTCIP standards pertaining to DMS. This version is intended to provide users with specification language based on Version 1 and its amendments.

This document is based to a very large extent on the 'ENTERPRISE DMS Specification Guide' prepared in 1999, but was enhanced to include the features and clarifications provided in the amendments. Additionally, interrelationships between data elements and the sequence in which certain data elements (dialogs) have to be configured/set to achieve certain functions were also added. These interrelationships are demonstrated via the same diagrams the NTCIP DMS WG is considering for inclusion into Version 2. This approach has been selected to preserve as much funding as possible for the development and further enhancement of this document.

This document includes wording for both communication protocol details and functional details for the sign. Additionally, it provides to a limited extend and only as an example other details that should be addressed within a complete procurement specification, such as physical dimensions of the sign, environmental requirements, structural requirements, maintenance access requirements, etc (see Section 4). Some of these hardware issues could be addressed by the NEMA TS 4 standard that is currently under development.

1.4 STATUS OF THE NTCIP

The NTCIP is actually a large set of standards addressing different communications infrastructures as well as various end-applications such as signal controllers, dynamic message signs, and ramp metering controllers. This document references a few draft standards as well as several fully approved NTCIP Standards plus any applicable amendments. It is perhaps obvious that draft standards are subject to change, but it needs to be mentioned here. The users of most fully approved NTCIP Standards do not have to worry about the newness and infancy of these standards as it was stated in earlier documents, the ambiguities associated with NTCIP standards relevant to DMS have been addressed in the amendments. However, it is still advisable to check, the wording in this document against the most recent versions of the standards **and** any Amendments released for the subject standards prior to releasing any procurement specification.

The only draft standards referenced are *profiles*. Profiles are standards that simply state how to use one or more other standards in a given environment. For example, the Subnetwork Profile for the Point-to-Point Protocol (NTCIP 2103 – PPP/RS232) defines how to use PPP (a widely accepted Internet standard for dial-up links) within the NTCIP environment. PPP allows several

ways to ensure the remote computer is authorized to access the local system (i.e., no authentication, a scheme known as PAP, a scheme known as CHAP, or a custom scheme). The NTCIP 2103 requires the use of CHAP in order to maximize interoperability within our industry. Even if the profiles do change, the base standards to which the profiles refer are very stable. While such a (unlikely) change might affect the compliance of the device to the NTCIP-specific requirements in the specifications, the device would still be compatible with off-the-shelf software for the Internet. Thus, industry support for the device could still be obtained at a reasonable cost.

The most up-to-date status of all NTCIP standards (or better, of all ITS Standards) can be viewed at http://www.ITS-standards.net.

1.5 STRUCTURE OF DOCUMENT

This document provides assistance to agencies by providing:
1. a brief explanation of the NTCIP,
2. why it is necessary to include particular information when developing an NTCIP specification for dynamic message signs (DMS), and
3. sample text for inclusion in procurement specifications.
4. example of the setup of procurement specifications that includes NTCIP language for applicable functional requirements.

This document also provides more background information to familiarize the authors of procurement specifications with terminology used within the NTCIP. This document serves as a sample guide that may be used in preparing procurement specifications for NTCIP compliant DMS and management systems for such signs.

The document is divided into the following sections:
5. Section 1 = Introduction – this section
6. Section 2 = Overview – describes the overall concepts of the NTCIP and how they are used in writing procurement specifications
7. Section 3 = Sample Wording for Procurement Specifications
8. Section 4 = Example of Procurement Specifications Setup and Integration of NTCIP into requirements
9. Section 5 = Description of selected dialogs/data exchanges – dialogs define specific sequences of data exchanges for more complex features that require several data elements.
10. Annex A – Protocol Requirements Lists (PRLs) for selected Communications Protocol Profiles
11. Annex B – Test Procedures

2 OVERVIEW

There are a large number of design decisions that must be made during a project to install a dynamic message sign. Some installation sites will want to use dial-up connections, whereas other sites may have existing twisted-pair. Some installations will require full matrix capabilities while others only need to support a small number of message displays. As you might expect, the procuring agency needs to determine the features and functions in the form of functional requirements for a particular procurement.

To address the needed functional requirements in a common, standardized way that enables interoperability and supports interchangeability, the transportation community developed ITS standards. To allow for a variety of different implementations and to allow a large variety of different functions, features, and communications methods, the NTCIP standards have been designed in a layered and modular fashion. However, this modularity also bears its challenges. Due to the large variety of possible combinations, the specification writer needs to be very specific in the 'ITS-standards'-specific requirements. Failure to be specific may lead to a lack of interoperability and especially interchangeability. Therefore, the focus of this document is helping the spec writer in achieving not only 'NTCIP conformance', but also in achieving the ultimate goals of specifying NTCIP in the first place, interoperability and interchangeability.

In general, a procurement official needs to select one standard at each of four distinct *profile levels*: application, transport, subnet, and information. Profiles reference one or more base standards in order to provide specific functions or services. Base standards define the details of specific functions/services and the profiles combine these base functions/services into useable components of the communications stacks (or packages). By using the standard NTCIP Profiles, the procuring agency has a way to specify all of the technical details in a way that will likely be widely supported in the ITS community. Figure 1 is used to better describe the relationship between the Base Standards and the Profiles described herein.

The Information Level is where ITS data is formally defined. This is roughly equivalent to a dictionary. A specific Information Profile defines which data elements a given device must support. Generally, the NTCIP standards have been written to require a bare minimum of features while providing a large number of optional conformance groups (a conformance group combines the data elements needed to enable a function or set of related functions). Sample wording for the Information Profile is provided in the Section 3 of this document because the information is closely related to the functionality of the sign. Version 2 of the NTCIP Information Profiles will also address issues such as concept of operations, features list (functional requirements), dialogs and interface specifications, and traceability matrix (test procedures might be added at a later time). Version 1 and amendments of these documents provide for some rudimentary description of the necessary dialogs (explanations of the sequence that must be used to exchange a particular set of data elements). However, to guide the understanding of the reader, this document includes the most common dialogs relevant to DMS, as they will be included in the Version 2 standards.

The Application Level defines how the data elements can be combined into a message in order to form a request or reply. Specifically, it deals with how information is organized into messages, how these messages are then encoded into a bit stream, and how the messages are authenticated. This is similar to specifying the rules for filling out a form. In the NTCIP, the fundamental rules are that you can perform either a *get* or a *set* on the defined data elements using either the Internet

standard Simple Network Management Protocol (SNMP), or a more bandwidth efficient solution customized for the transportation community called Simple Transportation Management Protocol (STMP).

The Transport Level defines how the data is sent over the network. There are basically two options currently defined in the NTCIP: null (i.e., the device is directly connected), and Internet (i.e., use the standard Internet protocols).

Finally, the Subnet Level defines how the device will interface with your infrastructure, or *plant*. This includes what constitutes the actual signal on the physical media as well as physical addressing and bit error checking. There are two options included in this document, a multi-drop twisted pair (i.e., the original Class B design of NTCIP), or dial-up.

The NTCIP Standards development effort has provided for many of the newer standards a Profile Requirements List (PRL), which becomes a Performance Implementation Conformance Statement (PICS) list after it has been filled out. These PRLs are presented in this document as they are applicable to DMS implementations. These PRLs are supposed to be completed by either vendors/system integrators to indicated the data elements supported by the Field Device DMS controller / Central System DMS Module or by user agencies to state their requirements in terms of DMS. The relevant PRL statements are shown in Annex A, provided courtesy of the Standards Development Organizations (SDOs) who publish the standards (AASHTO, ITE, NEMA).

The various options at each layer and the rules for how each option can be stacked together are depicted in Figure 2.

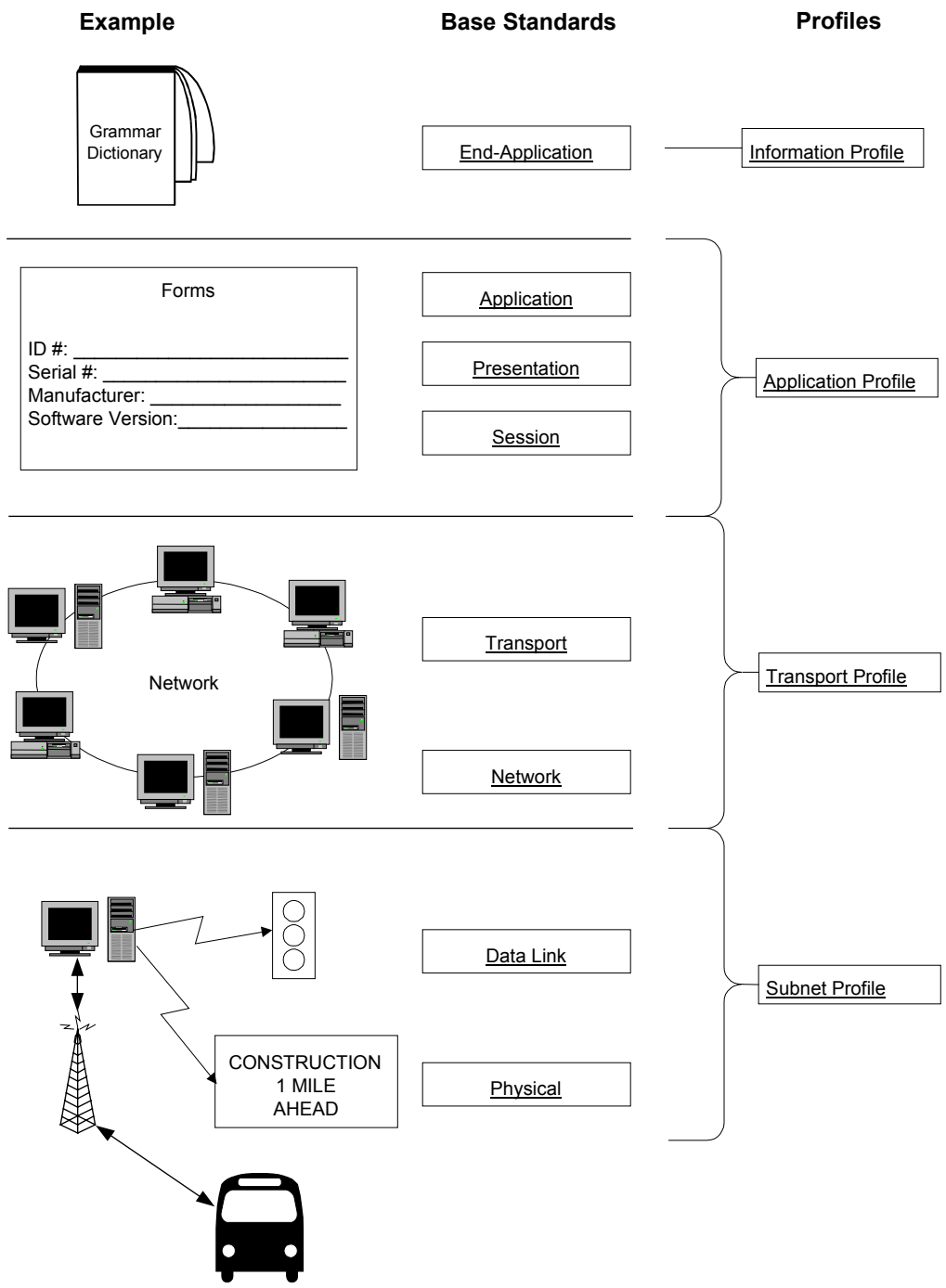

Figure 1 – Relationship between NTCIP Profiles and the ISO Layers of Base Standards

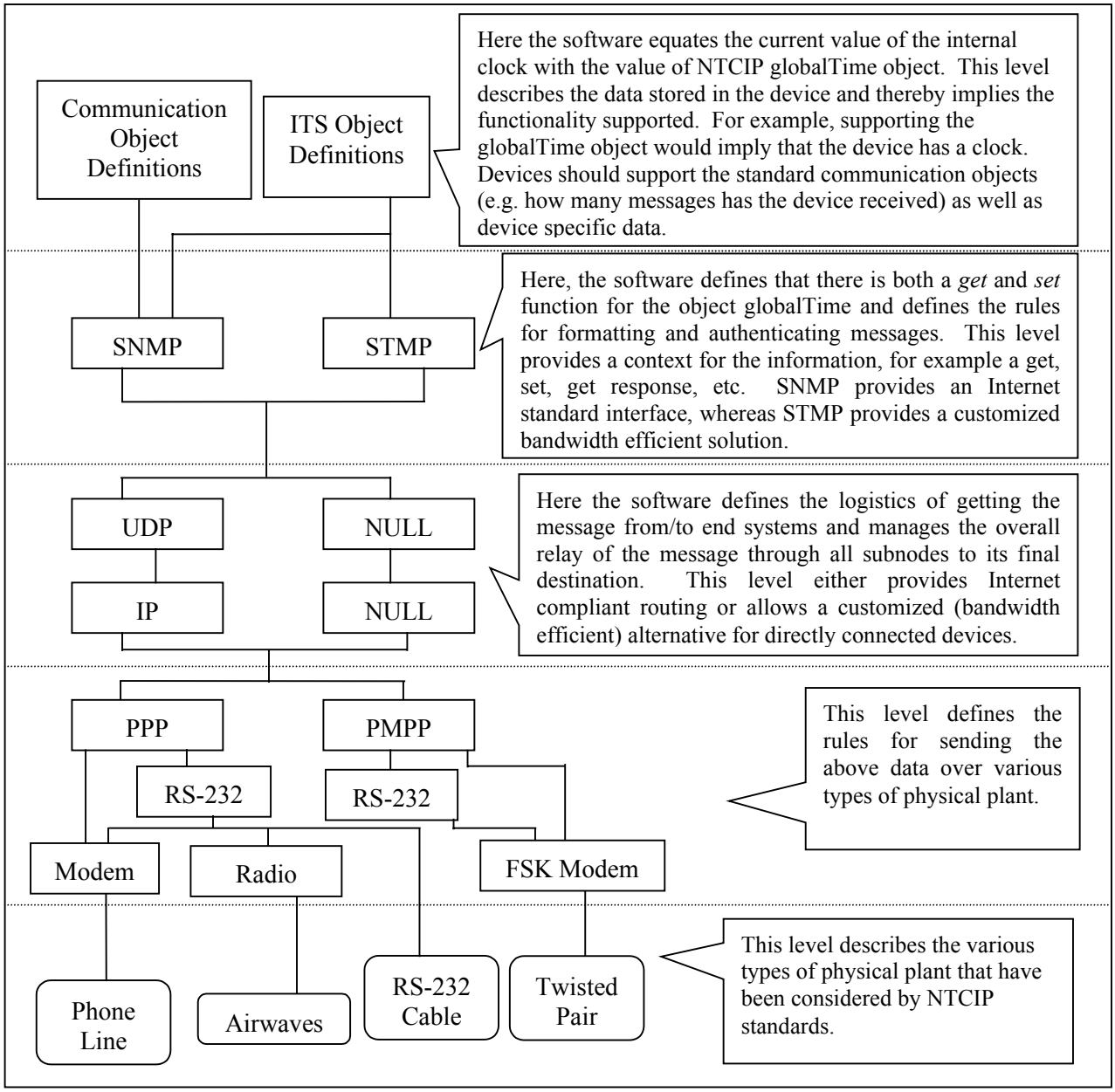

Figure 2 – Possible communication stacks allowed in this specification

Profile Layer	***Available NTCIP Standards (applicable to DMS Implementations)***
Information Profile	NTCIP 1201 (Global Object Definitions) NTCIP 1203 (DMS Object Definitions)
Application Profile	NTCIP 2301 (Simple Transportation Management Framework [STMF])
Transport Profile	NTCIP 2201 (Transportation Transport Profile) NTCIP 2202 (TCP/UDP/IP)
Subnetwork Profile	NTCIP 2101 (Point to MultiPoint over RS 232) NTCIP 2102 (Point to MultiPoint over FSK Modem) NTCIP 2103 (Point to Point) NTCIP 2104 (Ethernet)

Figure 3 – Relationship between Layers and NTCIP Standards

3 SAMPLE WORDING FOR PROCUREMENT SPECIFICATIONS

The sign specification is divided into the following parts:
1. Introduction
2. Device requirements
3. Management system requirements
4. Acceptance testing
5. Maintenance and support
6. Interpretation resolution.

It is important to realize the functionality of the sign is closely related to the data (i.e., NTCIP objects) supported by the sign. Thus, authors of procurement specifications should not view the NTCIP requirements as strictly a communications issue. While the specification writer must always start with the determination of the functional requirements and then select the corresponding NTCIP standard items (communications protocols, data dictionaries, conformance groups, data element, and options within those), it must be understood that in turn, the specified NTCIP items enable the corresponding functionalities. Thus, including NTCIP reference language that does not correspond to the desired functional requirements will lead to confusion and possible integration and incompatibility problems.

A number of textual formatting conventions are used in the remainder of this document in order to distinguish instructions to the procurement specification author, the main body of the procurement specification, and various optional clauses. These are discussed below:

Normal text is used to provide instructions to the procurement specification author. *Italicized* text is used to provide sample wording. A radio button (○) will precede those items in a "one-of" selection list and a check box (☐) will precede those items in a multiple selection list. If one of the items in the multiple selection list is required, it shall be indicated with a check mark (☑). Finally, underlined text (such as this) indicates a location where the author of the procurement specification is required to fill in a blank with sample text provided.

3.1 INTRODUCTION

This portion of the specification defines the detailed NTCIP requirements for the

- *Dynamic Message Signs*
- *Dynamic Message Sign Management System (DMS Module within an Integrated ATMS/ATIS)*

3.1.1 Definitions

The following terms shall apply within the scope of this procurement specification:

DMS - A Dynamic Message Sign, includes the sign display, controller, cabinet, and other associated field equipment. The specific type of dynamic message sign (i.e., blank-out sign, changeable message sign, character matrix sign, full-matrix sign, etc.) for this procurement is specified elsewhere within this procurement specification.

FSOR – Full Standardized Object Range

Full, Standardized Object Range – Support for, and proper implementation of, all valid values of an object as defined within the object's OBJECT-TYPE macro in the subject NTCIP standard; this is further defined in two distinct sub-requirements. (1) If the ACCESS of the object is read-write, a Management System shall be able to set the object to any valid value as defined by the SYNTAX and DESCRIPTION fields (except that the value of 'other' need not be supported when such a value is defined) and the indicated functionality shall be provided. (2) The value indicated by the object (e.g., in response to a 'get'), regardless of the ACCESS, shall reflect the current condition per the rules specified in the object's DESCRIPTION.

Management System – A management system used to control a DMS. This includes any laptop software used for field control as well as the central control software.

NTCIP Component – Either a DMS or a Management System.

NTCIP System – A DMS Management System plus the various DMS controlled by the Management System.

Response Time – The time to prepare and begin transmission of a complete response containing the requested Application Layer information. This is measured as the time from receipt of the closing flag of the request to the transmission of the opening flag of the response when the device has immediate access to transmit.

3.1.2 Acronyms

CDPD – Cellular Digital Packet Data

FSK – Frequency Shift Key

IP – Internet Protocol

NEMA – National Electrical Manufacturers Association

NTCIP – National Transportation Communications for ITS Protocol

PMPP – Point-to-Multi-Point Protocol

PPP – Point-to-Point Protocol

UDP – User Datagram Protocol

3.1.3 References

This specification references several standards through their NTCIP designated names. The following list provides the full reference to the current version of each of these standards. In many cases, the standard is more widely known by its original NEMA assigned number; in these cases, the NEMA number is also identified. The content of the NEMA standard is identical to that of the NTCIP standard.

Each NTCIP Component covered by these project specifications shall implement the most recent version of the standard that is at the stage of Recommended or higher as of May 31, 2002, including any and all Approved and Recommended Amendments to these standards as of the same date. It is the ultimate responsibility of the VENDOR to monitor NTCIP activities to discover any more recent documents.

3.1.3.1 Relevant Data Dictionaries

Abbreviated Number	***Full Number***	***Title***	***Known Amendments***
NTCIP 1201	*NTCIP 1201:1997 (formerly NEMA TS 3.4 – 1996)*	*Global Object Definitions*	*Amendment #1 dated November 2, 1998.*
NTCIP 1203	*NTCIP 1203:1997 (formerly NEMA TS 3.6 – 1997)*	*Object Definitions for Dynamic Message Signs (DMS)*	*Amendment #1 dated July 3, 2001*

3.1.3.2 Relevant Communications Protocol Profiles

Abbreviated Number	***Full Number***	***Title***	***Known Amendments***
NTCIP 2101	*NTCIP 2101:2001 (formerly NEMA TS 3.SP-PMPP/232)*	*Point-to-Multi-Point Protocol over RS – 232 Subnetwork Profile (SP-PMPP)*	*Amendment #1 dated November 2, 1998.*
NTCIP 2102	*NTCIP 2102 (Recommended)*	*Point-to-Multi-Point Protocol over FSK Modem Subnetwork Profile (SP-PMPP/FSK)*	
NTCIP 2103	*NTCIP 2103 (formerly NEMA TS 3.SP-PPP) (Recommended)*	*Point-to-Point Protocol over RS – 232 Subnetwork Profile (SP-PPP)*	
NTCIP 2104	*NTCIP 2104 (formerly NEMA TS 3.SP-Ethernet) (Recommended)*	*Ethernet Subnetwork Profile (SP-Ethernet)*	
NTCIP 2201	*NTCIP 2201 (formerly NEMA TS 3.TP-Null) (Recommended)*	*Transportation Transport Profile*	
NTCIP 2201	*NTCIP 2202:2001 (formerly NEMA TS 3.TP-Internet)*	*Internet (TCP/IP and UDP/IP) Transport Profile*	
NTCIP 2301	*NTCIP 2301:2001 (formerly NEMA TS3.AP-STMF)*	*Simple Transportation Management Framework (STMF) Application Profile*[1]	

[1] This Profile references the following NTCIP Base Standards:

- *NTCIP 1101 (formerly NEMA TS 3.2 – 1996), National Transportation Communications for ITS Protocol (NTCIP) Simple Transportation Management Framework (STMF)*[2]
- *NTCIP 1101 – Amendment 1 (formerly NEMA TS 3.2 – 1996, Amendment 1), National Transportation Communications for ITS Protocol (NTCIP) Simple Transportation Management Framework (STMF)*
- *NTCIP 1102 (Recommended Standard), National Transportation Communications for ITS Protocol (NTCIP) Octet Encoding Rules (OER)*
- *NTCIP 1103 – **v01.14 November 19,2001 DRAFT**, National Transportation Communications for ITS Protocol (NTCIP) Transportation Management Protocol (TMP)*
- *NTCIP 8004 – **v01.21 November 09, 2001 DRAFT**, National Transportation Communications for ITS Protocol (NTCIP) Structure and Identification of Management Information (SMI)*

- *NTCIP 9001, National Transportation Communications for ITS Protocol (NTCIP) Guide* (not a standard but an information/education document)

The following two approved standards are listed for completeness since they were being used in DMS implementations; however, they are not used in the DMS industry at this point in time.

- NTCIP 2302:2001 (formerly NEMA TS3.AP-TFTP), National Transportation Communications for ITS Protocol (NTCIP) Trivial File Transfer Protocol (TFTP) Application Profile
- NTCIP 2303:2001 (formerly NEMA TS3.AP-FTP), National Transportation Communications for ITS Protocol (NTCIP) File Transfer Protocol (FTP) Application Profile

3.1.4 General Requirements

As discussed above, there are a large number of design decisions that must be made during a project to install a dynamic message sign. The NTCIP standards have been designed in a layered fashion to allow for a modular design of a procurement specification. This Guide Specification takes advantage of this modular design and follows this same basic outline. In general, the procurement official must select at least one standard profile at each of four distinct profile levels: application, transport, subnet, and information.

The application, transport, and subnetwork profile level address the communications protocol profiles, while the information profile level address the corresponding data dictionaries. In the following sections, the communications infrastructures and the selection of applicable standards will be addressed first. The data dictionaries (information profile level) are addressed in a subsequent section.

[2] Note that NTCIP 1101 is being replaced by NTCIP 1102, NTCIP 1103, and NTCIP 8004. As soon as these standards are published, NTCIP 1101 will be deprecated and does not need to be referenced anymore. These three standards should be available as recommended standard very soon (please monitor the NTCIP homepage http://www.ntcip.org frequently).

3.1.4.1 Communications Protocol Profiles and Communications Infrastructure

The communications infrastructures used in DMS deployments vary widely. The current set of NTCIP Standards has been developed to address the most widely used infrastructures. The format used in the next sections will first identify the communications infrastructures addressed by NTCIP standards, and then provide a discussion for each communications profile level and presenting suggested NTCIP procurement language. Lastly, we present communications infrastructures that are used to communicate with dynamic message signs but for which there are currently no NTCIP Standards. That subsection provides the specification writer with some suggestions to still require NTCIP standards.

3.1.4.2 Communications Infrastructures addressed by NTCIP Standards

The current set of NTCIP standards addressing communications protocol profiles cover the following types of infrastructures:

- Direct-connect multi-drop communications typically using serial RS232 connections. The devices are directly connected and do not require routing.
- Dial-up communications in either routable or non-routable networks. Dial-up in routable networks typically make use of existing IT software, while dial-up in non-routable networks are based on vendor enhancements from their initial direct connect multi-drop developments. Both solutions are viable.
- Ethernet communications. More installations are using this IT industry's networking standard all the way from the central computer out to the field. Even though both Ethernet (and inherently TCP/IP) have a lot of data 'overhead', the use of high-speed communications lines connecting field and central computers as well as the readily availability of off-the-shelf software makes this approach more attractive.

The next subsections provide explanations of the standards available on each communications protocol profile level (application, transport, subnetwork) as well as corresponding NTCIP language that should be included into the specifications.

3.1.4.2.1 Application Level

The procurement specification needs to indicate which Application Level protocols are required. Both options defined in NTCIP are referenced within the NTCIP Standard "NTCIP 2301".

Conformance Level 1 is the minimum level of support. It uses a protocol known as Simple Network Management Protocol (SNMP) from the Internet community and thus should be relatively easy and inexpensive for most manufacturers to implement. However, this tends to be a more bandwidth intensive solution than Conformance Level 2. As a general rule, Conformance Level 1 should be sufficient for most dial-up links or links where bandwidth is not perceived to be a problem. However, agencies are advised to investigate the project specific bandwidth limitations to ensure that Conformance Level 1 will provide sufficient performance (see the NTCIP Guide, Section 6 for further information; http://www.ntcip.org/library).

Conformance Level 2 provides complete support of Conformance Level 1 in addition to supporting a protocol (Simple Transportation Management Protocol [STMP]) customized within the NTCIP standards. STMP is significantly more complex than SNMP, but can save a considerable amount of bandwidth, especially when large numbers of integer values are frequently exchanged. The complexity is due to a scheme that allows a management system to dynamically configure messages at run-time, which requires the introduction of specialized software. Savings in bandwidth are realized because it is no longer necessary to include large data identifiers for each data transmission as the manager and agent have already negotiated the

data contents of most messages. However, since most exchanges with DMSs involve text strings, the bandwidth savings are less significant than for other devices. Thus, Conformance Level 2 is only recommended where the DMS is expected to communicate on links that are (1) severely bandwidth constrained, (2) multi-drop (i.e., the link is shared with other DMS or other devices), **and** (3) timely data transfer is required. It is likely that requiring Conformance Level 2 will increase the cost of the sign.

As a minimum, a specification should include the following wording:

Each DMS shall conform to NTCIP 2301 as a Managed Agent and shall meet the requirements for Conformance Level 1 (NOTE - See Amendment to standard).

An NTCIP Component may support additional Application Profiles at the manufacturer's option. Responses shall use the same Application Profile used by the request. Each NTCIP Component shall support the receipt of Application data packets at any time allowed by the subject standards.

Alternatively, a specification could also include the following wording, if the system designs consists of low capacity bandwidth communications lines and requires high communications frequency:

Each DMS shall conform to NTCIP 2301 as a Managed Agent and shall meet the requirements for Conformance Level 2 (NOTE – See Amendment to standard).

An NTCIP Component may support additional Application Profiles at the manufacturer's option. Responses shall use the same Application Profile used by the request. Each NTCIP Component shall support the receipt of Application data packets at any time allowed by the subject standards.

The implementation shall be provided with a completed PICS statement as contained in NTCIP 2301, Annex A to indicate which options of this NTCIP standard were implemented. The PICS statement is a listing of mandatory and optional elements specified within the corresponding standard. Users can use the PICS statement to detail the optional items are to be supported as well as the required value ranges for the data elements. Vendors can use the PICS to indicate what the device actually supports.

3.1.4.2.2 Transport Level

There are also two options available at the Transport Level. If the DMS will be indirectly connected to the management station (i.e., messages will need to be routed through other devices such as a field master or a communications hub), support of NTCIP 2202 must be considered.

Generally, if Conformance Level 1 was selected for NTCIP 2301 (under Application Profiles above), support of the NTCIP 2202 is recommended. This is especially true for dial-up communications, where an openly accessible medium is used and where security issues must be addressed (the non-routable Transport Profile does not offer any security). There are a wide variety of tools to aid manufacturers in implementing such a communications scheme; thus, it is expected that this would be the minimal cost solution.

NTCIP 2201 provides a more bandwidth-efficient solution; however, this profile does not support routing and may increase cost, as it is not an Internet community-developed protocol and as software development costs are typically added to the cost of a product. If, however, the DMS

will be required to communicate over a bandwidth-restricted link such as a less than 9600 bps link with high communications frequency, use of NTCIP 2201 may be justified.

- *The communications link between the DMS Sign Controller and the DMS Control Computer shall use a routable protocol. The NTCIP Component shall conform to NTCIP 2202 and shall support the following options defined by the standard:*
  - UDP/IP
    (Internet compatible, inexpensive)

- *The communications link between the DMS Sign Controller and the DMS Control Computer shall be direct-connect, non-routable. The NTCIP Component shall conform to NTCIP 2201.*
  (Transportation specific, bandwidth-efficient)

The implementation shall be provided with a completed PICS statement of the selected NTCIP standard (see Annex A of that standard) to indicate which options of the standard were implemented. The PICS statement is a listing of mandatory and optional elements specified within the corresponding standard. Users can use the PICS statement to detail the optional items that are to be supported as well as the required value ranges for the required data elements. Vendors can use the PICS to indicate what the device actually supports.

NTCIP Components may support additional Transport Profiles at the manufacturer's option. Response datagrams shall use the same Transport Profile used in the request.

Each DMS component shall support the receipt of datagrams conforming to any of the identified Transport Profiles at any time.

3.1.4.2.3 Subnet Level

The subnet level includes the Data Link Layer and the Physical Layer. Several options or Data Link Layer/Physical Layer combinations are available at the Subnet Level.

If the DMS will be used with a dial-up link or a dedicated single-drop point-to-point link (i.e., RS-485), the DMS should support the NTCIP 2103. This is a common protocol used widely in the Internet community and should be relatively easy for manufacturers to implement.

If the DMS will be used over a multi-drop link (i.e., multi-drop twisted pair), the NTCIP 2101 should be selected. This likely will result in increased costs, as this standard is less widely used in DMS. Note that NTCIP 2101 achieves the same results, as NTCIP 2102. NTCIP 2102 defines the FSK modem communications used for multi-drop modems; however, NTCIP 2101 defines the communications leading from the computer (DMS controller or DMS Central Computer) into the multi-drop modem. Thus, either one of these standards would be sufficient, but NTCIP 2101 is used more widely.

Note – The fastest speed defined in the subject standards (i.e., EIA/TIA 232) is 19.2 kbps, rates faster than this are outside the scope of the current NTCIP standards.

If the DMS will be used over an Ethernet communications link, the NTCIP 2104 must be selected. The Ethernet protocol is the de-facto standard for network communications and is widely supported in various types of systems. Software is readily available for both embedded and non-embedded systems.

- □ *The communications link between the DMS Sign Controller and the DMS Control Computer shall be dial-up communications. Each NTCIP Component shall conform to NTCIP 2103 over both a null-modem connection and a contractor-provided, external dial-up modem connection. The dial-up modem shall support data rates of 14.4 kbps, 9600 bps, 4800 bps, 2400 bps, 1200 bps, 600 bps, and 300 bps. The null-modem shall support the same speeds with a maximum of 19.2 kbps. Additionally, the NTCIP Component shall be able to make outgoing and receive incoming calls as necessary and support the following modem command sets:*
  - *Hayes AT -Command Set*
  - *MNP5*
  - *MNP10*
  - *V.42bis*

- □ *The communications link between the DMS Sign Controller and the DMS Control Computer shall be serial multi-drop communications. Each NTCIP Component shall conform to NTCIP 2101 with an RS-232 physical interface and data rates of 1200, 2400, 4800, 9600, and 19,200 bits per second.*

- □ *The communications link between the DMS Sign Controller and the DMS Control Computer shall be Ethernet communications. Each NTCIP Component shall conform to NTCIP 2104 with an Ethernet physical interface and data rates of at least 10 megabits per second.*

The implementation shall be provided with a completed PICS statement of the selected NTCIP standard (see Annex A of that standard) to indicate which options of the standard were implemented. The PICS statement is a listing of mandatory and optional elements specified within the corresponding standard. Users can use the PICS statement to detail the optional items to be supported as well as the required value ranges for the data elements. Vendors can use the PICS to indicate what the device actually supports.

NTCIP Components may support additional Subnet Profiles at the manufacturer's option. A DMS component may support additional Subnet Profiles at the manufacturer's option. At any one time, only one Subnet Profile shall be active on a given serial port of the DMS component. If the DMS component has a serial port that supports multiple Subnet Profiles, the DMS component shall be configurable to allow the field technician to activate the desired Subnet Profile and shall provide a visual indication of the currently selected Subnet Profile.

3.1.4.3 Communications Infrastructures NOT addressed by NTCIP Standards

One could easily state that all other communications infrastructures fall into this category. And while it is true that the NTCIP Standards do not specifically provide Communications Protocol Profiles, some of these infrastructures could still benefit from the use of these standards.

What it really boils down to is where one physically tests for conformance, i.e., testing the serial connection between a DMS Sign Controller and a fiberoptic modem instead of the connection between the sending and receiving fiberoptic modem.

Examples of common communications infrastructures not addressed by NTCIP Standards include:

- Fiberoptic communications (Note: While the fiberoptic industry states that there are fiberoptic standards, the reality is that the modems used on a link must be from the same company to ensure interoperability. Thus, the NTCIP Standards Development community did not attempt to develop a subnetwork profile to address this issue).

- Wireless communications such as
  - Cellphone
  - CDPD (also a cellular technology but using a different frequency)
  - Spread Spectrum
  - Radio (i.e., 800 MHz trunked)

  (Note: Initially, the NTCIP Standards Development community was tasked with wireline communications leaving wireless communications profile development to others. This decision may change in the future, but currently there is no NTCIP Standard addressing these types of communications)

3.1.4.4 Incorporation of NTCIP Standards with non-NTCIP Communications Infrastructures

As stated above, wireless communications are not standardized by NTCIP Standards. However, it is possible to require the use of NTCIP standards with these infrastructures. Let us assume that an agency owns a central computer system that utilizes the NTCIP Communications Protocol Profiles NTCIP 2101, 2201, 2301 to communicate with existing signs over a multi-drop direct connect communications line. Let us further assume that the agency wants to add additional signs but determines that the most economical way of communication would be using CDPD communications.

The agency is now faced with a problem: Should the proprietary CDPD standard be used including the development of specific 'protocol translators' at the central computer?

Theoretically, there are two possible methods to achieve this. The first one is in line with the Information Technology industry's approach to layer modularity and should be the preferred method. However, submittal responses might come in proposing the second method because it is easier, can be tested with COTS tools, and does not require any modification to the NTCIP communications protocols implemented for other methods.

Method 1: The method conforming to the modularity and spirit of the Information Technology's approach will require that the CDPD modem receives the data packet from the DMS. This data packet would contain Information, Application, Transport and Subnetwork Layer data. The CDPD modem would than strip off the layers that it used to route the information (typically only the subnetwork and transport layer aspects of the entire stack, but since the CDPD modems are proprietary, we cannot determine this). The CDPD modem would than transmit the data. At the receiving end, a corresponding CDPD modem would strip off the proprietary information and add the previously stripped DMS data information back in.

Method 2: Another, simpler but effective work-around is the following: utilize the existing NTCIP standards in that the DMS Sign Controller and the DMS Central Computer prepare an NTCIP package containing NTCIP 2101, NTCIP 2201, and NTCIP 2301 data which is being handed to the CDPD modem. The CDPD modem adds its own routing data (consisting of another subnetwork profile and transport profile layer) to the package, in effect **double-wrapping** it, and strips this information off at the receiving CDPD modem handing over a 'pure' NTCIP data packet.

Double-wrapping is a methodology that can be utilized for communications links that do not require very frequent data exchanges (in the sub-minute range). However, this is not applicable to systems that may require frequent data exchanges such as a Variable Speed Limit system.

This same methodology can be used for Fiber optic communications links, since Fiberoptic communications are also not standardized by NTCIP Standards.

This document should not and cannot recommend how to handle these situations. However, since these non-NTCIP-addressed communications infrastructures are being put in place today, this document needed to address the issue and provide some 'work-around'.

3.1.4.5 Information Level

Conformance groups are used to specify what functionality the sign should support. Conformance Groups are groups of inter-related NTCIP objects. An object is a single component of a conformance group that provides the formal definition of data. By properly requiring their support, the indicated functionality will be required as well.

The key to properly specifying support of these conformance groups is identifying the required range for each object. For example, the message table defines the format used to define messages, but the user also needs to define how many messages the table should support. Without this additional specification, the NTCIP allows a device to claim conformance to the standard by supporting only a single value for each object (e.g., in this case, only a single message in the table).

A blanket statement can be used to identify the required range for most objects (i.e., the range as specified in the subject NTCIP object standard). However, in some cases (e.g., number of messages), requiring the full NTCIP range may result in increased costs for features that will never be used (e.g., most projects do not require the signs to support 65,535 messages, and requiring the full range will require the implementation of much larger memory cards and a much larger demand on the processing software). As each conformance group is identified below, text is included to indicate which objects should have restricted ranges. The agency reviewing submittals or performing NTCIP testing should understand that they are looking for compliance to their specifications (i.e., the more restricted ranges), since adherence to these more restricted values will determine whether an implementation will be interoperable and interchangeable within a system.

Each DMS component shall support the full, standardized object range of all objects required by these procurement specifications, unless otherwise indicated below or approved by the Project Engineer. The maximum Response Time for any object or group of objects shall be 200 milliseconds.

A small number of conformance groups are required by the NTCIP standards referenced above, but most conformance groups are optional and must be specifically called out by the procurement specification. However, virtually all DMS specifications require the use of functions and features addressed by the optional conformance groups. It is therefore vital that the corresponding optional conformance groups are related to the desired functions and features.
NOTE: The reason why the NTCIP standard did not standardize these features and functions common to large variable message signs (VMS) is that the standards were also to address Drum Signs and Blank-Out signs. Both Drum and Blank-Out signs do not support most of these functions, and therefore the standards could not require the common VMS functions.

The required (mandatory) conformance groups are described below.

- ✓ Configuration - This Global Object (NTCIP 1201) conformance group provides basic information that all NTCIP-compliant devices must support. This includes the type of device as well as the manufacturer name, model, and version of the device.

- ✓ Sign Configuration - This configuration group identifies the type of sign (e.g., blank-out versus full matrix) and arrangement of any beacons (i.e., flashing lights). This information can be used to accurately identify signs in the field and to determine whether beacons are present.

- ✓ Message Table - The Message Table enables the user to define the messages for the sign.

- ✓ Sign Control - This conformance group includes the data for controlling the fundamental features of the sign (e.g., it allows a user to activate a message).

The values of some of the objects in these mandatory conformance groups should be explicitly stated to meet project expectations. Throughout this Generic DMS Specification, a common table format is used to present this information. The first column in the table references the formal object name. The formal definition of this object can be found in the NTCIP standards, although the names are generally fairly descriptive. The second column defines the range of values that the standard allows for this object. The third column should be filled out by the procurement official to ensure that the values meet the unique needs of the specific project (shown are suggested values based on implementation experiences by the authors).

Each DMS shall support all mandatory objects of all mandatory Conformance Groups as defined in NTCIP 1201 and NTCIP 1203 as well as their amendments. The following list indicates the modified object requirements for these mandatory objects.

OBJECT Name	*Object Range Limits*	*Possible Project Requirements*
globalMaxModules	*0-255*	*1*[1]
communityNamesMax[2]	*1-255*	*2*
communityNameAccessMask[2]	*0-4294967295*	*0,4294967295*
dmsNumPermanentMsg	*0-65535*	*0*[3]
dmsMaxChangeableMsg	*0-65535*	*32*
dmsFreeChangeableMemory	*0-4 billion*	*5,000*
dmsMaxVolatileMsg[4]	*0-65535*	*0*
dmsFreeVolatileMemory[4]	*0-4 billion*	*0*
dmsMessageMultiString	*OCTET STRING*	*The DMS shall support any valid MULTI string containing any subset of those MULTI tags specified below.*
dmsControlMode[5]	*1-6*	*2, 3, 4, 5*

[1] The Module Table shall contain at least one row with moduleType equal to 3 (software). The moduleMake shall specify the name of the manufacturer, the moduleModel shall specify the manufacturer's name of the component and the modelVersion shall indicate the model version number of the component.

[2] The support of the Security Conformance Group is MANDATORY for NTCIP 2103. For other NTCIP Subnetwork Profile, it is OPTIONAL.

The Security Conformance Group provides a user with a certain level of access security. While the support of this conformance group may not be critical in implementations where the infrastructure is owned and operated by an agency (i.e., many direct connect, multi-drop communications networks are agency owned), dial-up connections are typically leased. Moreover, because NTCIP is an open standard and anyone can establish a telephone connection once the phone number is known, there is a great risk that an intruder might gain control of a sign. Therefore, this Conformance Group is Mandatory for NTCIP 2103.

The 'possible project requirements' values indicate to provide at least 2 levels of access. One value (zero for the communityNameAccessMask) indicates that the entire database is read-only, while the other (2^{32}) allows complete read-write access.

[3] Permanent messages are messages stored in memory that cannot be changed by the user. Messages stored in this memory area can include test messages or user-defined, pre-defined, factory-installed messages. These messages should either be defined within the procurement specifications or be suggested by the VENDOR (however, this latter method would need to be specified in the procurement specifications).

[4] Changeable memory and changeable messages in excess of the project requirements are considered to meet or exceed the specification for an equivalent amount of volatile memory and volatile messages.

[5] The values for dmsControlMode have the following meanings:
1 – other
2 – local control (e.g., via the controller's interface)
3 – external control (e.g., by a connected laptop in the field)
4 – central control
5 – the local/central switch is set to local, but central is overriding this setting
6 – simulation (i.e., the commands are only simulated and not displayed on the sign)

Three different types of memory storage are defined in the standard, and the specification writer needs to understand the difference between them and require their provision appropriately. Additionally, the specification writer needs to determine how much space (or how many messages) for each type of memory must be provided.

Permanent – Under this memory type, pre-programmed messages are defined. These messages cannot be modified. When requiring this type of memory, the spec writer is advised to define these messages within the RFP. For example, certain test messages that are desired could be defined within this memory area.

Changeable – Under this memory type, messages that can be created, deleted, or edited are defined. Messages defined under this message type will NOT be lost during power outages.

Volatile – Under this memory type, messages that can be created, deleted, or edited are defined. Messages defined under this message type will be lost during power outages.

There is also a range of other (optional) conformance groups that should be considered on a project-by-project basis. These are listed in the text below.

Software shall also implement all mandatory objects of the following optional conformance groups.

As explained above, the NTCIP Standards contain mandatory and optional Conformance Groups. Each Conformance Group also contains optional and mandatory data elements/objects. The setup requires that an implementation must support all mandatory data elements within a conformance group (regardless of whether it itself is mandatory or optional), but optional data elements do not have to be supported. Thus, an implementation desiring the support of optional data elements within a specified conformance group must specify them specifically.

- *Database Management, as defined in NTCIP 1201*

  This feature is not recommended for DMS procurements. The conformance group enables a device to buffer a large number of messages for simultaneous implementation within the device. This feature can be important in some devices, such as signal controllers, but the NTCIP database design for signs does not require this feature. Requiring this feature would significantly increase costs.

- *Time Management, as defined in NTCIP 1201*

  The Time Management Conformance Group allows the sign to store the time of day, including a day-lights saving feature (which can be disabled, if needed). This is required if the sign is required to support the Timebase Event Schedule Conformance Group. It should be selected if the Report Conformance Group is required, as this will allow a meaningful time-stamp on each recorded event. It should also be selected if the DMS is to display the time of day and or date on the sign display.

- *Timebase Event Schedule, as defined in NTCIP 1201. The following list indicates the modified object requirements for this conformance group..*

OBJECT	*Object Range Limits*	*Possible Project Requirements*
maxTimeBaseScheduleEntries	*0-65535*	*24*
maxDayPlans	*1-255*	*10*
maxDayPlanEvents	*1-255*	*10*

  The Timebase Event Schedule Conformance Group allows the sign to perform actions (e.g., display messages) according to a time-based schedule. This may be particularly useful for dial-up sites or portable signs that might be used for construction. If this group is selected, the Scheduling Conformance Group must also be selected.

- *Report, as defined in NTCIP 1201. The following list indicates the modified object requirements for this conformance group.*

OBJECT	*Object Range Limits*	*Possible Project Requirements*
maxEventLogConfigs	*0-65535*	*32*
eventConfigurationMode	*1,2,3,4,5,6*	*2*
maxEventLogSize	*0-65535*	*255*
maxEventClasses	*0-255*	*16*

  The Report Conformance Group allows a user to define certain events which the sign will then begin logging with a time-stamp. This information can then be retrieved by subsequent messages. This feature can be useful to record a variety of events (e.g., cabinet temperatures

exceeding a certain range, when new messages are posted, etc.), but implementation of this feature may increase costs.

The values for event configuration mode have the following meanings:
1 – other
2 – onChange - a log entry will be entered when the reference value changes
3 – greaterThanValue - a log entry will be entered when the object value becomes greater than the reference value
4 – smallerThanValue - a log entry will be entered when the object value becomes less than the reference value
5 – hysteresis - a log entry will be entered based on a hysteresis algorithm
6 – periodic - a log entry will be entered after a particular time duration has elapsed.

□ *STMF, as defined in NTCIP 1201*

If Conformance Level 2 was selected under the Application Profile (NTCIP 2301), this group must be selected. This conformance group contains an object that defines the 'time to live' for dynamic objects defined in the device.

□ *PMPP, as defined in NTCIP 1201. The following list indicates the modified object requirements for this conformance group.*

OBJECT	*Object Range Limits*	*Possible Project Requirements*
maxGroupAddresses	*0-255*	*1*

If the Subnetwork Profile (NTCIP 2101 (or NTCIP 2102)) was selected, this group must also be selected. The value of the 'possible project requirement' is '1' because a device only needs to support one group address, i.e., it will respond to commands sent to it's local drop address as well as to one group address.

□ *GUI Appearance, as defined in NTCIP 1203.*

The GUI Appearance Conformance Group allows any central system to query the sign so that it may properly display a "what you see is what you get" (WYSIWYG) view of the sign hardware. For example, the conformance group contains such data as the sign height, width, and border information. In general, if this feature is selected, the Font Configuration and VMS Configuration Groups should be selected as well so that the central system can display what the text will look like on the sign. This would allow the user to remotely query the sign and determine its physical layout characteristics without manually entering the data at central. However, because this information is static (e.g., sign dimensions), this operation can also be achieved by simply configuring the central system with the relevant information (i.e., rather than exchanging this information over the wire).

□ *Font Configuration, as defined in NTCIP 1203. The following list indicates the modified object requirements for this conformance group.*

OBJECT	*Object Range Limits*	*Possible Project Requirements*
numFonts	*0-255*	*2*
maxFontCharacters	*0-65535*	*59*[1]

[1] *Each font shall support character numbers from 32 (0x20) to 90 (0x5A), inclusive. Upon delivery, each character shall be set to a bit pattern that resembles the associated ASCII character.*

The Font Definition Conformance Group allows a central system to configure the fonts supported by the sign. This feature is desirable if an agency wants to ensure that all signs use a common font set within its jurisdiction. As a minimum, the following ASCII (ASCII NVT) characters should be supported:

- A, B, C, D, …, X, Y, Z
- 1, 2, 3, … 9, 0
- Special characters: . , / ? ; ‘ : “ < > @ # & * - 🡐 🡒 🡑 🡓 🡔 🡕 🡗 🡖

□ *VMS Configuration, as defined in NTCIP 1203.*

This conformance group provides the user with the dimensions of the sign in the field in pixels as well as the spacing between pixels. This group should be supported for all pixel-based technologies (e.g., character matrix, line matrix, or full matrix).

□ *Multi Configuration, as defined in NTCIP 1203. The following list indicates the modified object requirements for this conformance group.*

OBJECT	*Object Range Limits*	*Possible Project Requirements*
defaultBackgroundColor	*0-9*	*At least 0 and one of 1, 2, 7, or 9*[1]
defaultForegroundColor	*0-9*	*At least one of 1, 2, 7, or 9*[1]*, and 0*
defaultLineJustification	*1-5*	*2, 3, 4, 5*
defaultPageJustification	*1-4*	*2, 3, 4*
defaultPageOnTime[2]	*1-255*	*40*
defaultPageOffTime[2]	*0-255*	*10*
defaultCharacterSet	*1-2*	*2*

[1] The color specified (1,2,7, or 9) must be used in both dmsBackgroundColor and dmsForegroundColor to enable inverse fonts.

[2] The DMS shall support the full range of these objects with step sizes no larger than 0.5 seconds.

The color values have the following meanings:
0 – black
1 – red
2 – yellow
3 – green
4 – cyan
5 – blue
6 – magenta
7 – white
8 – orange
9 – amber

The line justification values have the following meanings:

1 – other
2 – left
3 – center
4 – right
5 – full

The page justification values have the following meanings:
1 – other
2 – top
3 – middle
4 – bottom

The Multi Configuration Conformance Group enables the user to modify the defaults for how information is displayed on the sign. For example, the user can set default values for background and foreground colors, the flash rate for flashing text, the period of time a page of text is displayed on multi-page messages, etc. This group is generally recommended on signs that allow remote definition of messages, but is not needed on blank-out signs and other fixed message technologies. The Multi Error Configuration Group should be supported if this group is supported.

MULTI is a language (not an object) that is used to convey the message to be displayed on the sign; this includes the text along with any message attributes. The codes used to identify the message attributes for the text message (e.g., font, flashing attributes, moving text, etc.) are called tags. MULTI uses tags similar to how Hyper Text Markup Language (HTML) uses tags to adjust the attributes of the text. The procurement specification must call out which tags are required for an implementation.

Additionally, the software shall implement the following tags (opening and closing, where defined) of MULTI as defined in NTCIP 1203.

Note that, in order to achieve interchangeability, the specification writer must avoid the use of the Manufacturer-specific Tag, or define the function behind this tag and consistently use this function/manufacturer-specific tag combination in the same manner, no exception.

- ☐ *Color Background* - allows a message to set the background color of the sign
- ☐ *Color Foreground* - allows a message to set the color of the foreground (i.e., the text)
- ☐ *Field* - allows inclusion of fields such as time, date, speed, etc.
- ☐ *Flash* - allows the message to contain flashing text
- ☐ *Font* - allows the message to choose one or more fonts for the display
- ☐ *Hexadecimal* - allows extended character sets to be defined (e.g., for Chinese displays)
- ☐ *Justification Line* - allows the message to be centered on a line
- ☐ *Justification Page* - allows the message to be centered on a page (i.e., vertically)
- ☐ *Moving Text* - allows for scrolling text (i.e., text coming in from the top, bottom, side, etc.)
- ☐ *New Line* - specifies a line break; should be supported by all multi-line signs
- ☐ *New Page* - allows a single message to consist of multiple pages (e.g., if the message is large)
- ☐ *Page Time* - identifies duration to display a given page; should be supported when above is supported
- ☐ *Spacing - Character* - allows a message to alter the number of pixels between characters

☐ *Multi Error Configuration, as defined in NTCIP 1203*

The Multi Error Conformance Group enables the user to determine what errors might have been contained in the MULTI codes (i.e., in the body of the message display text). This group should be supported for technologies that allow for the remote definition of messages (i.e., technologies other than blank-out signs and other fixed message signs).

□ *Illumination/Brightness Control, as defined in NTCIP 1203. The following list indicates the modified object requirements for this conformance group.*

OBJECT	*Object Range Limits*	*Possible Project Requirements*
dmsIllumControl	*1-4*	*2, 4*
dmsIllumBrightnessValues	*Table of up to 255 rows each row defining a brightness level*	*Table must support at least 3 rows*

The illumination control values have the following meanings:
1 - other
2 - photocell
3 - timer
4 - manual

The 'possible project requirements' for the 'dmsIllumBrightnessValues' indicates that at least 3 different brightness levels (low, medium, high) must be supported.

This conformance group provides features to control and report the status of brightness and illumination of DMS devices. It is should be used for all light emitting technologies.

□ *Scheduling, as defined in NTCIP 1203. The following list indicates the modified object requirements for this conformance group.*

OBJECT	*Object Range Limits*	*Possible Project Requirements*
numActionTableEntries	*1-255*	*100*

The Scheduling Conformance Group enables the user to display messages based on a time-of-day schedule. If this group is supported, the Time Management and Timebase Event Schedule Groups must also be supported.

□ *Auxiliary I/O, as defined in NTCIP 1203*

This conformance group allows the user to monitor the Auxiliary I/O port of the controller, if one exists. This includes reading inputs and setting outputs. If such external device control/monitoring is desired, this feature should be selected.
Note that, in order to achieve interchangeability, the specification writer must either
a.) Avoid the use of this function, or
b.) Precisely define the function including the definition of each input and output. In this case, the agency has to ensure that no exceptions are granted.

□ *Sign Status, as defined in NTCIP 1203*

This conformance group includes objects to monitor the sign status (e.g., door open and watchdog failure) as well as a number of parameters that may be used as fields in sign displays (e.g., current speed of the traffic stream). In general, support for this group is not recommended unless the latter functionality of the sign is desired; instead, the door open and watchdog objects should be specified individually.

□ *Status Error, as defined in NTCIP 1203*

This conformance group includes various sign error codes (e.g. controller errors and actual sign error codes). Support for this group is highly recommended.

□ *Pixel Error Status, as defined in NTCIP 1203*

This conformance group indicates pixel errors (e.g. how many pixels are stuck open, etc.). This group is recommended for pixel-based technologies such as fiberoptic, LED, fiberoptic hybrid, LED hybrid, and bulb matrix signs.

□ *Lamp Error Status, as defined in NTCIP 1203*

This conformance group provides object definitions that relate to DMS lamp errors (i.e., lamp stuck on or off) and activation testing of the lamps. This group is recommended for fiberoptic technologies.

□ *Power Status, as defined in NTCIP 1203*

This conformance group provides object definitions that relate to the status of power at the DMS device (voltage readings, fuel levels, line volts). This conformance group is generally recommended.

□ *The NTCIP Component shall also implement the following optional objects.*

The specification writer has to indicate for each of the following objects whether the implementation must support the object.

Support of Object Required	*OBJECT*	*Possible Project Requirements*
□	*globalSetIDParameter*	*FSOR*
□	*eventConfigLogOID*	*FSOR*
□	*eventConfigAction*	*FSOR*
□	*eventClassDescription*	*FSOR*
□	*defaultFlashOn*	*The DMS shall support the full range of these objects with step sizes no larger than 0.5 seconds*
□	*defaultFlashOff*	*The DMS shall support the full range of these objects with step sizes no larger than 0.5 seconds*
□	*dmsMessageBeacon*	*FSOR*
□	*dmsSWReset*	*FSOR*
□	*dmsMessageTimeRemaining*	*FSOR*
□	*dmsShortPowerRecoveryMessage*	*FSOR*
□	*dmsLongPowerRecoveryMessage*	*FSOR*
□	*dmsShortPowerLossTime*	*FSOR*

Support of Object Required	*OBJECT*	*Possible Project Requirements*
☐	*dmsResetMessage*	*FSOR*
☐	*dmsCommunicationsLossMessage*	*FSOR*
☐	*dmsTimeCommLoss*	*FSOR*
☐	*dmsPowerLossMessage*	*FSOR*
☐	*dmsEndDurationMessage*	*FSOR*
☐	*dmsMemoryMgmt*	*The DMS shall support the following Memory Management Modes:* *- normal* *- clearChangeableMessages*
☐	*dmsMultiOtherErrorDescription*	*If the vendor implements any manufacturer-specific MULTI tags, the DMS shall provide meaningful error messages within this object whenever one of these tags generates an error*[3]
☐	*dmsIllumLightOutputStatus*	*FSOR*
☐	*dmsCurrentSpeed*	*FSOR*
☐	*watchdogFailureCount*	*FSOR*
☐	*dmsStatDoorOpen*	*FSOR*
☐	*fanFailures*	*FSOR*
☐	*fanTestActivation*	*FSOR*
☐	*signVolts*	*FSOR*
☐	*lowFuelThreshold*	*FSOR*
☐	*fuelLevel*	*FSOR*
☐	*engineRPM*	*FSOR*
☐	*lineVolts*	*FSOR*
☐	*tempMinCtrlCabinet*	*FSOR*
☐	*tempMaxCtrlCabinet*	*FSOR*
☐	*tempMinAmbient*	*FSOR*
☐	*tempMaxAmbient*	*FSOR*
☐	*tempMinSignHousing*	*FSOR*
☐	*tempMaxSignHousing*	*FSOR*

In addition to those conformance groups defined in NTCIP 1201 and NTCIP 1203, the following groups are defined for this procurement specification. In order to claim compliance to these conformance groups, all of the indicated objects shall be supported, even if they are marked optional in the base standard.

- ☐ *Flashing Text Conformance Group*
  - ☐ *defaultFlashOn* - indicates the default on time for flashing text.
  - ☐ *defaultFlashOff* - indicates the default off time for flashing text.

- ☐ *Beacon Conformance Group*
  - ☐ *dmsMessageBeacon* - indicates whether or not beacons will be activated for a given message.

[3] NOTE: See the subsection on 'Documentation' for a discussion on the use of manufacturer-specific objects and manufacturer-specific MULTI-tags. The use of manufacturer-specific objects and MULTI-tags should only be granted under certain circumstances.

- *Pixel Service Conformance Group*

  This conformance group allows the user to manage the servicing (i.e., periodic exercising) of pixels. Whether or not this conformance group is supported is largely dependent on the display technology used by the sign. If the sign is LED, the pixels do not need to be serviced; most other technologies (i.e., those involving mechanical components) should be exercised in order to prevent the pixels from becoming frozen in place. If this group is supported, then the Pixel Error Conformance Group must be supported.

  The Pixel Service Conformance Group shall include the following objects:
  - *dmsMessagePixelService* - indicates whether or not pixel service is activated during a given message.
  - *vmsPixelServiceDuration* - indicates how long a pixel service period will last. This parameter should be supported if the Pixel Service Conformance Group is selected.
  - *vmsPixelServiceFrequency* - The frequency at which pixel service is performed as measured from the pixel service time.
  - *vmsPixelServiceTime* - The time of day at which the pixel service starts.

- *Enhanced Sign Control Conformance Group*

  The Enhanced Sign Control Conformance Group shall include the following objects:
  - *dmsSWReset* - allows central to force a software reset of the controller.
  - *dmsMessageTimeRemaining* - identifies how much longer the current message will remain displayed.
  - *dmsMemoryMgmt* - allows a management station to clear portions of the message table.

- *Default Message Conformance Group*

  The Default Message Conformance Group enables the user to define default messages for certain conditions. For example, it allows the user to define what message to display after a power or communications loss. This group is generally recommended; otherwise, it is undefined what the sign will display, if one of the following events occur.

  The Default Message Conformance Group shall include the following objects:
  - *dmsPowerLossMessage* - indicates the message to be displayed after power is lost until power is restored.
  - *dmsShortPowerLossTime* - allows the user to specify what time distinguishes a short power loss from a long power loss.
  - *dmsShortPowerRecoveryMessage* - allows the user to specify a message that will appear after recovery from a short power loss.
  - *dmsLongPowerRecoveryMessage* - allows the user to specify a message that will appear after recovery from a long power loss.
  - *dmsResetMessage* - allows the user to specify what message will be displayed after the controller is reset.
  - *dmsTimeCommLoss* - identifies the maximum amount of time between subsequent communications prior to determining that communications have been lost.
  - *dmsCommunicationsLossMesssage* - indicates the message to be displayed when communications are lost.
  - *dmsEndDurationMessage* - indicates the message to be displayed after the duration of the current message expires.

- *Enhanced Error Conformance Group*

  The Enhanced Error Conformance Group shall include the following objects:

- *dmsMultiOtherErrorDescription* - this object provides additional data as to what caused the "other" error in the display text string.

- *Enhanced Illumination Conformance Group*

  The Enhanced Illumination Conformance Group shall include the following objects:
  - *dmsIllumLightOutputStatus* - indicates the current light output (i.e., brightness).

- *Speed Conformance Group*

  The Speed Conformance Group shall include the following objects:
  - *dmsCurrentSpeed* – indicates the current speed value as detected by the attached device in kilometers per hour (km/h).
  - *dmsCurrentSpeedLimit* – indicates the current speed limit in kilometers per hour (km/h).

- *Enhanced Sign Status Conformance Group*

  The Enhanced Sign Status Conformance Group shall include the following objects:
  - *watchdogFailureCount* – a counter that indicates the number of watchdog failures that have occurred.
  - *dmsStatDoorOpen* – indicates whether any of the doors to the controller cabinet or the sign housing are open.

- *Fan Conformance Group*

  The Fan Conformance Group shall include the following objects:
  - *fanFailures* – indicates whether each fan (system) within a DMS is capable of operating
  - *fanTestActivation* – indicates the state of the fan testing.

- *Battery Power Conformance Group*

  The Battery Power Conformance Group shall include the following objects:
  - *signVolts* – indicates the battery voltage by measurement in units of hundredth (1/100) of a volt.

- *Generator Power Conformance Group*

  The Generator Power Conformance Group shall include the following objects:
  - *lowFuelThreshold* – indicates the low fuel level threshold used to alert the user. The threshold is indicated as a percent (%) of a full tank.
  - *fuelLevel* – indicates the amount of fuel remaining, specified as a percent (%) of a full tank.
  - *engineRPM* – indicates the engine rpm in units of 100.

- *AC Power Conformance Group*

  The AC Power Conformance Group shall include the following objects:
  - *lineVolts* – indicates the DMS line voltage as measured in (1.0) volts.

- *Temperature Conformance Group*

  This conformance allows the user to monitor the temperature inside and outside of the DMS as well as inside the controller cabinet. This feature is recommended for temperature sensitive technologies (e.g., LED).

  The Temperature Conformance Group shall include the following objects:

- *tempMinCtrlCabinet* – indicates the current temperature for a single sensor, or the current minimum temperature for multiple sensors, within the DMS Control Cabinet in degrees Celsius.
- *tempMaxCtrlCabinet* – indicates the current temperature for a single sensor, or the current maximum temperature for multiple sensors, within the DMS Control Cabinet in degrees Celsius.
- *tempMinAmbient* – indicates the current outside ambient temperature for a single sensor, or the current minimum outside ambient temperature for multiple sensors in degrees Celsius.
- *tempMaxAmbient* – indicates the current outside ambient temperature for a single sensor, or the current maximum outside ambient temperature for multiple sensors in degrees Celsius.
- *tempMinSignHousing* – indicates the current temperature for a single sensor, or the current minimum temperature for multiple sensors in the sign housing in degrees Celsius.
- *tempMaxSignHousing* – indicates the current temperature for a single sensor, or the current maximum temperature for multiple sensors in the sign housing in degrees Celsius.

3.1.4.5.1 Documentation

It is necessary for agencies to keep and maintain copies of the software as well as full documentation of the software. One of the purposes of maintaining this information within the agency is to be able to identify what functions the vendor has provided and how those functions have been provided (i.e., which object definitions and communications protocols). There is a possibility that vendors may have added manufacturer-specific objects that are not defined within the NTCIP standards to address specified functional requirements[4]. These objects must be identified and the purpose of the manufacturer-specific objects be understood by the agency personnel for data processing. By maintaining copies of the Management Information Base (MIB[5]) and documentation[6], the agency will also be able to reference version numbers in the event of an upgrade or if for some reason the MIB has been damaged within the hardware, it can be reinstalled to the device or to the system.

Software shall be supplied with full documentation, including 3.5" floppy disk(s) and a CD-ROM containing ASCII versions of the following Management Information Base (MIB) files in Abstract Syntax Notation 1 (ASN.1) format:

[4] However, the agency/specification writer is advised to consider the following for interchangeability reasons:

a.) Either require that those vendor-specific objects can be re-used by the agency for future procurements, or

b.) Consider disallowing any vendor-specific objects by either

i. Not requiring the associated non-standardized function or

ii. Developing and requiring agency-specific objects that address the desired functions.

[5] A MIB is the collection of data elements supported within the sign's database and within the central computer. The data elements supported within a sign may be contained in one or more MIBs. The MIBs enable the central system and the sign controller to have a common understanding or definition of the functions supported by the sign and how they can be managed.

[6] It is recommended to require that the above-mentioned PICS statements for the implemented communications protocols be provided to ensure that future procurement provide interchangeable DMS (by including those PICS into these future procurement specifications).

☑ *The relevant version of each official standard MIB Module referenced by the device functionality.*
Note: The agency should ensure that the MIB provided with this implementation includes only the objects necessary to address the required and specified functions. It may be a good idea to include this MIB (and the MIBs identified in the next bullets) in any subsequent procurement documents.
This statement also includes the provision of objects required by the underlying communications profiles. For example, NTCIP 2101, 2102, and 2103 define and/or reference a number of objects allowing a central system to determine communications-related status information. Many of those objects are mandatory within their standard and must be supported in any conformant implementations.

☑ *If the device does not support the full range of any given object within a Standard MIB Module, a manufacturer-specific version of the official Standard MIB Module with the supported range indicated in ASN.1 format in the SYNTAX and/or DESCRIPTION fields of the associated OBJECT TYPE macro shall be provided. The filename of this file shall be identical to the standard MIB Module, except that it will have the extension ".man".*
Note: If the procuring agency has specified sub-ranges for any objects, as suggested for certain objects in the above statements, the agency must check whether these sub-ranges have been implemented by comparing the specification statements with the SYNTAX of the corresponding objects within this vendor-provided ".man" MIB file. Discrepancies must be discussed with the vendor to determine whether the manufacturer-specific subranges or the agency-specified subranges are being used. If the conclusion is to use the manufacturer-specific subranges, the agency must update the specifications to ensure that additional devices procured later using the same specifications are compatible with the devices procured first.

□ *A MIB Module in ASN.1 format containing any and all manufacturer-specific (or agency-specific) objects supported by the device with accurate and meaningful DESCRIPTION fields and supported ranges indicated in the SYNTAX field of the OBJECT-TYPE macros.*
Note: There are certain issues associated with manufacturer-specific and agency-specific objects. The main issues are discussed here to clarify these issues.

1.) Replacement of standardized functionalities and their corresponding standardized objects:
While it may be true that manufacturer-specific objects are more efficient to address standardized functions, it is also true that accepting these manufacturer-specific replacements will lead to non-interoperable and non-interchangeable systems. This should **be avoided under all circumstances**, if the benefits of using open standards are to be achieved.

2.) Addressing of agency-specific functions with manufacturer-specific objects:
This method is one method to address non-standardized, but agency-required functions. The vendors typically know their equipment best and understand how to develop corresponding objects to enable a particular non-standardized function. However and in order to achieve interoperability and interchangeability, the agency has to ensure via appropriate specification language that it has access, publication, and distribution rights to these manufacturer-specific objects. After accepting these manufacturer-specific objects, the agency must then include these manufacturer-specific objects in their specification documents for future procurements.

3.) Addressing of agency-specific functions with agency-specific objects:
In order to address agency-specific functions that are not standardized in the NTCIP standards, this method may be the most effective one to avoid tailoring a procurement to a particular vendor (naturally, it is much cheaper for a vendor to bid on a follow-on procurement, if its manufacturer-specific objects are being specified, as detailed in the

previous method). The method is very much the same as the manufacturer-specific object method; however, it requires that the agency has an in-depth knowledge of the NTCIP standards and understands how objects are developed.

□ *A MIB containing any other objects supported by the device.*
Note: This clause is intended to provide a final catch-all for any other objects that may be in the device. For example, if someone uses off-the-shelf software in their development efforts and this software supports objects not covered by the aforementioned standard, this statement requires the manufacturer to disclose them. This would typically apply to communications profile-related objects.

3.1.4.5.2 Intellectual Property Rights

The NTCIP standards are open standards. While the standards are copyrighted, the objects defined in the MIBs can be copied and added to any procurement specification, as deemed necessary, but no object can be modified under the terms of the copyright statements contained in the standards.
To maintain this spirit and to ensure interoperability and interchangeability, the agency must ensure that the manufacturer-specific/agency-specific objects are also considered 'open'. In order to ensure this openness, the agency has to add wording to the procurement documentation that provides the agency with the right to re-use and distribute any and all manufacturer-specific objects. The following statement provides procurement language to be added that facilitates this need.

The manufacturer shall allow the use of any and all of this documentation by any party authorized by the Procuring Agency for systems integration purposes at any time initially or in the future, regardless of what parties are involved in the systems integration effort.

If the current DMS procurement is a second or follow-on procurement, the agency is advised to add the following statement to the procurement specifications to ensure that the devices are interoperable and interchangeable. As mentioned above, the agency/specification writer must add the same procurement language as ACCEPTED (which may be different as originally SPECIFIED) to the procurement documents of this second or follow-on procurement including the completed PICS statements provided with the first procurement.

The manufacturer shall utilize and implement all items included in the attached PICS statements. Additionally, the manufacturer shall implement the attached MIB files. Any responses to these specifications will only be accepted, if these requirements are fulfilled. No exceptions will be allowed to ensure interoperability and interchangeability with the existing system.

3.1.5 Maintenance / Diagnostics Computer/Laptop Requirements

The DMS shall be furnished with a Maintenance/Diagnostics Laptop, which shall be able to execute all commands and monitor/modify all settings available within the sign controller regardless of whether these are available to the DMS Central Computer System. The vendor shall identify whether the same NTCIP Communications Profiles (and their selected options) are supported. Additionally, all cabling and other equipment to connect the Maintenance/Diagnostics Laptop to the DMS Sign Controller shall be provided.

The maintenance laptop should be part of every delivery of a DMS sign system. If several signs of the same type and model are purchased, it may be sufficient to only require one laptop with

this software depending on the purchasing agency's desires. The maintenance computer should be able to perform ALL the commands available within the sign system including running detailed diagnostics. For example, an ATMS might only need to know that a power supply has failed, while the maintenance laptop must be able to identify which one is faulty. For all intents and purposes, it may not be necessary to require that the communications between the Maintenance/Diagnostics Laptop and the DMS Sign Controller use the NTCIP Standards, since this particular software must be tailored to the sign functionality. However, it is the responsibility of the procuring agency to specify how the communications between the sign controller and the maintenance laptop is to be done. For example, it could require the use of the same NTCIP protocols specified for the communication between the central system and the sign controller, or it could allow a proprietary protocol (however, in this case the provision of different ports may also need to be specified).

3.1.6 Central Computer System Requirements

The DMS Central Computer System shall support all (some (as specified below)) of the requirements for DMS components as identified above. In addition, the Central Computer System shall support the requirements identified in this section.

The DMS Central Computer System shall support up to ( ) DMSs that are compliant with the above requirements. It shall be able to support at least ( ) communications channel(s) of the defined subnet profiles.

The developer of the central computer system software shall provide a timing analysis of the communications network to demonstrate that sufficient bandwidth is available.

The purchasing agency has to determine what type of DMS Central Computer System it wants to acquire. There are basically two types:

a.) A system that can control all functions available within the sign. This type of software is typically provided by the sign vendor to provide access to the sign from an office, and is often the same as (or very similar to) the software running on the Maintenance/Diagnostics Laptop.

b.) An integrated ATMS system that uses the sign(s) as part of an overall integrated transportation management strategy. This type of software is typically provided by a third party system integrator. The purpose of this software is not to perform detailed diagnostics of a sign, and therefore, this type of software might not need to support all of the objects available within the DMS Sign Controller. Requiring support of all objects available might increase the cost of this type of software drastically. If diagnostics software is to be provided as part of the ATMS software, similar procurement language as used under a.) must be added to the procurement specifications.

3.1.7 Acceptance Testing

An agency has several options to ensure a device or central system is compliant with the selected communications profiles and data dictionaries (and the options selected within these standards). The most common ones are:

- Test procedures are provided by the vendor
- Test procedures are provided by the system integrator, if present
- Test procedures are provided by the system design company (this is rather rare)
- Test procedures are provided by the procuring agency (this is also rather rare)

- Test procedures were performed as part of a voluntary or required certification process, and the agency accepts the tests provided. Note that this used to be a good way of doing it. However, in conjunction with standards conformance, this option must be applied very carefully because the certification tests are typically performed for a particular set of communications profiles and data dictionaries (and the selected options within these standards). Thus, an agency needs to ensure that the tested set of ITS Standards (and options) are the same as the ones selected for the project, before accepting the NTCIP-conformance certification.

At the present time, no 'official' test procedure guidelines exist. Test procedures to test the NTCIP-conformance for NTCIP have been developed for the previously mentioned ENTERPRISE consortium. Instead of redeveloping these test procedures, they have been added in Annex B. It should be noted that these test procedures do not address the NTCIP 2104 (Ethernet Subnetwork Profile).

Another source for test procedure development is the Battelle Memorial Institute who was tasked by the Federal Highway Administration to perform testing of the standards in real-life settings. Due to the lack of other testplans and the very large number of possible tests, this effort had to develop a process to test the 'core business' functionalities of the tested standards. These test procedures may not be suitable for every implementation, but they might provide a starting-point for agencies seeking to develop their own test procedures.

Additionally, the NTCIP effort has recently established a Working Group that will develop the guidelines for NTCIP standards implementation. However, currently there are no recommendations, guidelines, or documents available from this WG.

Development (or acceptance) of test procedures must be based on traceability of required functional requirements to particular test procedures. Thus, it is mandatory that the Project Engineer (or her/his consultants) develop/review the test procedures considering the functional requirements.

At the present time, the most appropriate wording that should be added to a procurement specification to address and require NTCIP-specific acceptance testing is as follows (Please see Section 4 for additional issues that must be addressed in Acceptance Test Plans):

If the test procedures are to be provided by the DMS Vendor, the following should be added:

Test Procedures shall be provided to the Project Engineer by the DMS Vendor. The Project Engineer will review and accept these test procedures within (___) weeks. Any comments shall be addressed and the test procedures shall be re-submitted for re-review.

If the test procedures are to be provided by a system integrator, the following should be added:

The Test Procedures shall be provided by the Project Engineer. The test procedures were developed by the (AGENCY). The test procedures shall be witness tested, and be executed by (_____) (i.e., DMS Vendor, Agency, System Integrator).

Additionally, the following statement for both types of test plan provisions must be added:

The acceptance test shall use the NTCIP Exerciser, or other authorized testing tool, and shall follow the guidelines established in the ENTERPRISE Test Procedures. The (_____) (i.e., AGENCY) reserves the right to enhance these tests as deemed appropriate to ensure device conformance to the NTCIP and compliance with these procurement specifications.

3.1.8 Training and Warranties

The DMS component developer shall provide ( ) hours of training on the

- *DMS Field System (DMS Sign Controller, DMS Sign Display, DMS Sign Diagnostic Software and laptop)*
- *DMS Central Computer System*

In addition, the developer shall provide free software upgrades for a period of ( ) year(s) from acceptance of the components.

3.1.9 Interpretation Resolution

If the Project Engineer or DMS component developer discovers an ambiguous statement in the standards referenced by this procurement specification, the proper interpretation shall be decided by the relevant NTCIP working group.

In early implementations of the DMS-relevant NTCIP Standards, ambiguities associated with these NTCIP Standards led to interpretation problems either between DMS Vendor and System Integrator, or between DMS Vendor and third party testers. With the development of Amendment 1 of the NTCIP 1203 and NTCIP 1201, many of these ambiguities have been resolved. However, some problems might still occur, and it is very beneficial to identify within the specifications how this type of problem is to be resolved should it occur.

It should be noted however that the 'proper interpretation' of any ambiguities might take quite some time resulting in project delivery delays. The following statement is meant to provide the specification writer with additional wording that can be added to the procurement specifications, but it also needs to be noted that this statement may lead to another, more serious problem. If a project-specific solution is being chosen, it needs to be understood that the implementation, while fulfilling its schedule obligations, may have ultimately led to a non-compliant implementation. This situation may occur if the problem addressed in the project-specific solution differs from the NTCIP WG solution that is being chosen at a later time.

If a resolution to an ambiguous statement cannot be obtained from the relevant NTCIP Working Group with (..) weeks, the Project Engineer and the DMS component developer shall jointly determine how to address this problem to avoid schedule delays.

4 FRAMEWORK FOR DMS PROCUREMENT

4.1 GENERAL SECTION / UP-FRONT MATTER

Each submission for a DMS system should include the following generic, yet detailed information such as:

- ☐ Firm Identification – company name, contact name and info
- ☐ Qualification and Experience Statement – list of projects where the proposed item has been deployed.
  Requiring a company or vendor to have in place a Quality Assurance program and/or possess an ISO 9000 certification can be used as good indicators that the selected company can provide high-quality products.
  Consider adding wording such as the following (delete non-applicable items from table):

  In order to ensure that the experience of the offeror is relevant to the specified highway application, the following will <u>not</u> be considered "qualifying experience":

  - toll plaza signing
  - billboard and any other type of advertising signs
  - construction related temporary signs
  - airport information signs
  - indoor information signs (including buildings and enclosed tunnels, parking garages and parking lots)
  - lane control signals

- ☐ Executive Summary (not always necessary, but recommended for more complex systems such as an ATMS)
- ☐ Project Management Plan
  - Include requirements for the submitter to provide a description of the proposed methods for planning, organizing, scheduling, controlling and coordinating the total construction and testing effort.
  - A requirements walk-through and quality assurance activities such as mock screen development/prototyping should be addressed in the management plan.
  - A requirement for the submitter to identify staff members who will have management responsibility for:
    - Construction
    - Hardware
    - Software
    - System Integration (Note: in certain procurements only signs without central software is procured. The agency needs to identify whether signs-only, stand-alone system, or integrated system is being required).
    - Testing
    - On-site Support
    - Training
    - Documentation
  - The management plan should also require the provision of an Organizational Chart identifying relationship among the prime Contractor, their suppliers, and their subcontractors. This chart(s) must also show the key personnel of each such organization.

- Name and address of each subcontractor, and supplier.
- Experience within last X years for the discipline for which the subcontractor/ supplier is being considered.
- A statement indicating the name(s) of the subcontractor, or supplier who will furnish and install each of the portions of the work.

☐ Project Schedule and monthly/weekly meetings

☐ Software Licensing and Intellectual Property Rights
This part needs to address what access rights the purchasing agency will have towards the software implemented in the signs and the central software (the NTCIP-specific issues regarding Intellectual Property Rights are addressed in Section 3.1.4.5).

☐ Insurance Statements

☐ Deliverables such as

a. **Shop Drawings** Support Structure Information Submittal within, for example seven days after Notice to Proceed. The remainder of the shop drawings to be submitted within for example sixty (60) days after Notice to Proceed.

b. **List of equipment and materials, description of equipment and software, system theory of operation, high-level block diagram showing** all proposed equipment and connections, and **mechanical drawings** which the Contractor proposes to install within for example forty (40) days after Notice to Proceed. The provision of the implemented MIBs should be required as part of this submittal.

c. **Test Plans** – there are a number of different test plans that should be required within the procurement specifications. The procuring agency should consider detailing the topics to be addressed in each of the test plans within the procurement specifications. These different test plans are as follows:

i. **Preliminary Test Plan** within for example sixty (60) days after Notice to Proceed. This preliminary test plan must address the general topics for hardware, software, NTCIP conformance, and communications that will be addressed in the subsequent testplans.

ii. **Factory Acceptance Test (FAT) Plan** within for example thirty (30) days after approval of the Preliminary Acceptance Test (this test plan needs to be further detailed to include the aspects that are to be tested as well as NTCIP Standards conformance testing. This test determines whether the type of sign conforms to the requirements stated in the procurement specifications. The test plan should address issues such as water tightness, vibration issues, workmanship, visual inspection items, communication from controller to sign modules, NTCIP-requirements testing. Any issue that would require an adjustment of all signs procured under this contract, because if the signs are delivered and installed it is very difficult to address these types of issues).
NOTE: include requirements that clarify who pays what if re-testing is necessary.
Also note that only after successful passing of this test should the vendor be allowed to send the field equipment to the installation site.

iii. **Stand-alone Acceptance Test Plan** within for example thirty (30) days after approval of the Factory Acceptance Test (these test plan needs to be further detailed to include the aspects that are to be tested as well as NTCIP Standards conformance testing. For the DMS, this test should include visual inspection again with a particular focus on the connection between sign and structure, connectivity between controller cabinet and sign housing, access to sign housing, soundness of sign structure. Additionally, communications should be re-tested to ensure that the controller software is the same as tested and passed during the FAT.).

NOTE: include requirements that clarify who pays what if re-testing is necessary.

iv. **System Acceptance Test Plan** within for example thirty (30) days after approval of the Stand-alone Acceptance Tests (these test plan needs to be further detailed to include the aspects that are to be tested as well as NTCIP Standards conformance testing. This test should include communications and NTCIP conformance testing.).
NOTE: include requirements that clarify who pays what if re-testing is necessary.
Also note that only after successful passing of this test for each component (field devices, communications devices, and central system) should the System Acceptance Test be performed to avoid any finger-pointing about which component failed when the System Acceptance Test reveals any problems.

v. **Network Conditional Acceptance Test Plan** within for example thirty (30) days after approval of the System Acceptance Test (these test plan needs to be further detailed to include the aspects that are to be tested as well as communications connectivity diagrams and indications as to where the specified NTCIP Standards are being used/tested. This test should include NTCIP communications from the central system to the sign controller and may require field personnel at the sign to determine performance measures such as how long does it take to display a message from the time the operator entered and sent a message until it's display).
NOTE: include requirements that clarify who pays what if re-testing is necessary.

d.) **Test Result Submittals** within for example seven (7) days after conducting any acceptance test.

e.) **Manufacturer installation manuals** (as-built) for all electrical and mechanical subsystems, equipment, or modules at a minimum of sixty (60) days prior to the installation of said equipment.

f.) **Maintenance and users' manuals;** identify the number of sets that are to be provided, i.e., five sets.

g.) **Training Course outlines and samples of all training aids and manuals**; define what is supposed to be addressed in these outlines, defined the delivery (i.e., thirty (30) days prior to the proposed start of the training sessions) and number of trainees at each session. Also define how many manuals and the media (i.e., hardcopies and/or electronic including allowed formats if electronic).

Naturally, issues such as the following also need to be included and addressed as required and/or desired by the procuring agency.

- Instructions for cost proposal submission including content and format
- Submission requirements
- Pre-proposal conference, if needed
- Evaluation criteria and bid selection process possibly including oral presentation and/or product demonstration
- Contract award formalities
- Payment Terms such as the following **EXAMPLE**.
  The resultant contract will be a performance-based contract. Payments will be made according to the following schedule:

DESCRIPTION	*PAYMENT SCHEDULE*
DMS Field Device Components	
Overhead Dynamic Message Sign (DMS)	These components to be paid as follows: • 40% Delivery • 30% Field Acceptance • 30% Final Acceptance[7]
Dynamic Message Sign (DMS) Controller	
DMS Power Cable	
DMS Control Cable	
Power Conditioner	
Maintenance Laptop Computer	
Maintenance and Movement Traffic Protection	100 % at Final Acceptance
Central Computer/Communications System	
Dynamic Message Sign (DMS) Central Computer	These components to be paid as follows: • 80% at Network Acceptance • 20% at Final Acceptance
CSU/DSU	
CSU/DSU Bank	
Un-Interruptible Power Supply	
Workstation Monitor	
Miscellaneous	
DMS System Training Program	100% upon completion
Spare Parts	100% after Delivery and Acceptance
System Start-Up Support	40% shall be paid thirty (30) days prior to the completion of the Burn-in-Period. 40% shall be paid in 24 equal monthly installments (less any liquidated damages charged that month) beginning 30 calendar days after all requirements of the Dynamic Message Sign Network Acceptance Procedure have been met. The final 20% shall be paid upon the Engineer's approval of the delivery of the spare part inventory required by this special provision in good working order, at the completion of the 24-month System Start-up Support period.
Additional Items (Itemize)	To be determined based upon submission

4.2 TECHNICAL APPROACH

The inclusion of a Technical Approach section will allow an agency to include provisions to trace their requirements against deliveries by the offeror. The procuring agency should consider including the following two items:

[7] The agency may want to use different payment schedules. Final acceptance as used here would mean that the device passed the final acceptance test, any 'punch list items' have been resolved, and any 'burn-in' periods have passed. Most implementations include a warranty period which should have elapsed without failures before the final payment is made.

4.2.1 System Block Diagram

Required the submission of a block diagram showing all proposed equipment to be installed, including all interfaces between components.

4.2.2 Requirements Matrix / Checklist

Prepare a complete list of all requirements and add this list to the procurement documentation. Require that the offeror respond to the requirement matrix in the following manner, but also allow the offeror to propose additional capabilities in the system design:

4.2.2.1 Mandatory Requirements ('Must-Have's)

The Mandatory Requirements are defined as those requirements that the AGENCY has deemed critical to the deployment of the DMS system. Any proposal that does not clearly demonstrate compliance with the mandatory requirements (these need to be defined somewhere preferably in the Requirement Matrix/ Checklist) or that proposes to provide functionally equivalent capabilities shall be deemed unresponsive and shall not be considered for Contract award. Particularly:

1. Each proposal must list, by requirement number as indicated in the Requirement Matrix, each requirement, and shall indicate where the capability currently exists in an installation currently deployed by the offeror, or where the capability will be developed for this Contract.
2. Should a functional equivalent be proposed by the offeror, the proposal must include a justification as to why the proposed functionality is equal to or better than the required capability.
   Note: It must be understood by the Procurement Writer that certain exceptions such as deviations from the communications protocol standards, NTCIP Object definitions, or MULTI Tags must be ***very carefully*** *evaluated before granting this type of exception to avoid additional software development for the existing Central Computer software and/or communications infrastructure modifications. Granting exceptions without this careful review will most likely lead to interoperability problems. As indicated in earlier sections, this careful review of NTCIP-related options is especially true for secondary or later purchases of additional equipment of the same type.*

4.2.2.2 Requested Requirements ('Like to Have's)

These types of requirements define capabilities that are desired by the AGENCY, but which are not absolutely required, i.e., non-support will not lead to exclusion from Contract Award. However, the more of these Requested Requirements are being supported, the higher the evaluation criteria score in terms of Technical Approach. As with the mandatory requirements:

1. Each proposal must list, by paragraph number, each requested requirement, and must indicate whether the offeror intends to provide the capability. Where the capability is being offered, the proposal must indicate where the capability currently exists in an installation deployed by the offeror, or if the capability will be developed for this Contract.
2. Should a functional equivalent be proposed, the proposal must include a justification as to why the proposed functionality is equal to or better than the requested capability.
   Note: It must be understood by the Procurement Writer that certain exceptions such as deviations from the communications protocol standards, NTCIP Object Definitions, or MULTI Tags must be very carefully evaluated before granting to avoid additional

software development for the existing Central Computer software and/or communications infrastructure modifications. Granting exceptions without this careful review will most likely lead to interoperability problems. As indicated in earlier sections, this careful review of NTCIP-related options is especially true for secondary or later purchases of additional equipment of the same type.

4.2.2.3 Additional Capabilities

Additional points may be awarded in the evaluation of the technical proposals for capabilities offered that have not been required or requested, but which the AGENCY deems, at their sole discretion, to be beneficial with respect to the operational objectives of the DMS system.

4.3 DMS PROCUREMENT SPECIFICATION SETUP

Each identifiable, individually replaceable component that is part of this DMS Procurement should have its own section, regardless of length to describe the functional requirements. For example, a section on a dial-up modem might be relatively short, while the requirements section for the sign housing might be relatively long.

It should be noted that the DMS procurement specification should be written in terms of measurable performance specifications, not in specifying hardware 'down to the bolt'. While this statement is not included to prohibit an agency from specifying which sign technology (LED, FO, LED/Flip, FO/Flip, bulb, etc), communications infrastructure, housing structure, or other general items are preferred, performance requirements are a means to allow an agency to avoid specifying a particular vendor.
Additionally, getting too detailed on certain requirements will either

a.) preclude vendors from bidding,
b.) require alternative design reviews,
c.) lead to exception requests,

These issues have the potential to increase valuable review and may possibly delay the deployment. For example, instead of detailing how a walk-in sign housing is ventilated, it could be sufficient to state that the design shall provide a certain air exchange within the housing and shall avoid any condensation on any parts within the housing.

4.4 DYNAMIC MESSAGE SIGN (DMS) CONTROLLER

This section has been singled out, because the NTCIP requirements are applicable to the communications device and the processing entity (CPU) within a DMS Field Device system. It should be noted that all requirements stated below including the NTCIP statements are included as **AN EXAMPLE**. Values mentioned in the NTCIP requirement statements such as minimum number of supported messages are included **as examples**. The project requirements should determine the value (indicated by bold, italic lettering) that need to be specified. The deviations of hardware setups that do not have an effect on the data that is being exchanged can be very great, and any requirements pertaining to the hardware configuration can only serve as an example.

The requirements for the Central Computer may be the same as those stated below, but they might also exclude certain requirements (reserved for execution from the Maintenance Laptop

only) or include other requirements (such as support of a timebased scheduling feature or an event logging feature, which may possibly not be supported within the DMS controller).

The requirements for the Maintenance Laptop are often the same as those stated below. However, often the Maintenance Laptop's functionalities provide more details on diagnostics and maintenance status information. Examples for diagnostics features are the ability to test communications between controller and sign, test each display module, test each pixel, and test each ventilation fan. It should be noted that often the communications between the Laptop and the DMS Controller is based on manufacturer-specific objects or even a proprietary communications protocol. The procuring agency should specify what it desires (or allows) in terms of functionalities, communications protocols and options, and manufacturer-specific objects, as well as in terms of communications protocol used between the maintenance laptop and the sign controller.

4.4.1 DESCRIPTION

This section specifies the requirements for furnishing, installing and testing of a Dynamic Message Sign (DMS) Controller. All Controller system components supplied for this project shall be identical models from the manufacturer.

4.4.2 GENERAL REQUIREMENTS

The Contractor shall furnish and install a fully functional Dynamic Message Sign Controller as indicated in the Plans and these Contract documents. Each DMS Controller shall be fully compatible with the DMS Central Computer and the Dynamic Message Sign display components.

4.4.3 CONSTRUCTION AND MATERIAL DETAILS

The Dynamic Message Sign (DMS) Controller shall be constructed according to the specifications detailed in the following sections

4.4.3.1 National Transportation Communications for ITS Protocol (NTCIP) Software Standards

The DMS Controller software shall comply with the National Transportation Communications for ITS Protocol (NTCIP) Standards, as defined in greater detail below, when installed. The software shall comply with the versions of the relevant NTCIP standards and all related amendments and errata sheets that are current at the date of contract notice to proceed (NTP). The DMS Controller software shall comply with the NTCIP Requirements defined in this section and identified elsewhere in the document.

Dispute and Interpretation Resolution – NTCIP standard interpretation disputes between the Engineer and the Contractor will be resolved by requesting a clarification from the NTCIP working group that developed the standard in question. If the resolution is simply a clarification and does not require a normative change to the standard, the decision of the working group shall be implemented. If the resolution requires extensions to the standard, the Contractor shall (use one of the following two wordings: *develop manufacturer-specific* or *inquiry with the agency and use agency-specific*) objects as may be necessary to meet the requirements of these specifications. Manufacturer-specific / agency-specific objects shall be developed in accordance with any guidance as may be provided by the NTCIP working group.

For each NTCIP-compliant implementation, at least one NTCIP Standard needs to be selected for each of the following Levels:

4.4.3.1.1 Application Profile Level – there are currently three different choices in terms of Application Profile standards, but only one is currently being used in conjunction with DMS applications. NTCIP 2301 defines the Simple Network Management Protocol (SNMP) that allows exchanging the objects (or data elements) defined in the data dictionaries (see Subclause 3.1.4 and following).
Note: Use of the file transfer profiles (NTCIP 2302 [TFTP] and NTCIP 2303 [FTP]) should currently not be considered as protocols due to the undefined content structure that would have to be used inside these transfer file types.

4.4.3.1.1.1 The software shall comply with the NTCIP 2301 - Simple Transportation Management Framework (STMF) - Application Profile.

4.4.3.1.1.2 The software shall comply with the NTCIP 11018- Simple Transportation Management Framework (STMF)+Amendment 1, and shall meet the requirements for (select one)

- ☐ Conformance Level 1 (SNMP => recommended for DMS)
- ☐ Conformance Level 2 (SNMP plus STMP)
  Note that this level is typically not necessary for DMS.

4.4.3.1.2 Transport Profile Level – there are two possible NTCIP Protocols that can be selected for this level.

4.4.3.1.2.1 NTCIP 2201 (Transportation Transport Profile) is a non-routable profile that must be used in conjunction with low-speed, high frequency communications lines. It has been designed for use in conjunction with NTCIP 2101 and NTCIP 2102, but may also be used with NTCIP 2103 (See Subclause 3.1.3).

4.4.3.1.2.2 NTCIP 2202 (TCP/UDP/IP) is the Internet community's routable protocol, which must be used in conjunction with NTCIP 2104 and may be used with NTCIP 2103 (see Subclause 3.1.3).

4.4.3.1.2.3 The software shall comply with NTCIP 2201 – Transportation Transport Profile, as defined in the attached PRL for NTCIP 2201.
Note: The PICS/PRL statement associated with this NTCIP Standard (See Annex A2) must be completed. For the first implementation, either the AGENCY or the vendor needs to complete it. Any follow-on installation using the same software, the same communications link, and the same communications protocols MUST use the same completed PRL.

4.4.3.1.2.4 The software shall comply with NTCIP 2202 – Internet (TCP/UDP/IP) Transport Profile, as defined in the attached PRL for NTCIP 2202.

[8] Note that NTCIP 1101 is being replaced by NTCIP 1102, NTCIP 1103, and NTCIP 8004. As soon as these standards are published, NTCIP 1101 will be deprecated and does not need to be referenced anymore. These three standards should be available as recommended standard very soon (please monitor the NTCIP homepage http://www.ntcip.org frequently).

Note: The PICS/PRL statement associated with this NTCIP Standard (See Annex A3) must be completed. For the first implementation, either the AGENCY or the vendor needs to complete it. Any follow-on installation using the same software, the same communications link, and the same communications protocols MUST use the same completed PRL.

4.4.3.1.3 Subnetwork Profile Level – there are four possible NTCIP Protocols that can be selected for this level.

1. NTCIP 2101 (PMPP/232 Subnetwork Profile) is a point to multipoint, direct connect profile that is typically used with serial communications lines.
2. NTCIP 2102 (PMPP/FSK Subnetwork Profile) is a point to multipoint, direct connect profile that is used in conjunction with FSK modem-enabled communications lines.
   => Note: NTCIP 2101 and NTCIP 2102 are very similar, and instead of NTCIP 2102, NTCIP 2101 can be tested on the serial connections leading into the FSK modems; thus, requiring NTCIP 2101 instead of NTCIP 2102 is sufficient, even if FSK modems are used. However, the FSK modems must still be specified in the hardware part of the specifications.
3. NTCIP 2103 (PPP/232 Subnetwork Profile) is a point-to-point profile that is used for dial-up communications lines.
4. NTCIP 2104 (Ethernet) is the Local Area Network (LAN) / Wide Area Network (WAN) protocol used in most Internet communications today.

4.4.3.1.3.1 The software shall comply with NTCIP 2101 – PMPP/232 Subnetwork Profile, as defined in the attached PRL.
Note: The PICS/PRL statement associated with this NTCIP Standard (See Annex A4) must be completed. For the first implementation, either the AGENCY or the vendor needs to complete it. Any follow-on installation using the same software, the same communications link, and the same communications protocols MUST use the same completed PRL.

4.4.3.1.3.2 The software shall comply with NTCIP 2103 – PPP/232 Subnetwork Profile, as defined in the attached PRL.
Note: The PICS/PRL statement associated with this NTCIP Standard (See Annex A5) must be completed. For the first implementation, either the AGENCY or the vendor needs to complete it. Any follow-on installation using the same software, the same communications link, and the same communications protocols MUST use the same completed PRL.

4.4.3.1.3.3 The software shall comply with NTCIP 2104 – Ethernet Subnetwork Profile, as defined in the attached PRL.
Note: The PICS/PRL statement associated with this NTCIP Standard (See Annex A6) must be completed. For the first implementation, either the AGENCY or the vendor needs to complete it. Any follow-on installation using the same software, the same communications link, and the same communications protocols MUST use the same completed PRL.

4.4.3.1.4 Data Dictionaries – these NTCIP standards define the 'words' that are being used to control and monitor the functions within an NTCIP-compliant field device. Several data dictionaries have been defined, but only two are applicable for DMS systems.

4.4.3.1.4.1 The software shall implement all mandatory objects of all mandatory conformance groups as defined in NTCIP 1203 - Object Definitions for Dynamic Message Signs (DMS) and Amendment 1. All following statements referring to NTCIP 1203 shall automatically include reference to Amendment 1 or other approved errata and amendments.

4.4.3.1.4.2 The software shall also implement all mandatory objects of the following optional conformance groups in addition to the following list of optional objects for each conformance group as defined in NTCIP 1201-Global Object Definitions + Amendment 1 *(check all that are desired)*.

- ☐ Time Management
- ☐ Time Base Event Schedule[9]
- ☐ Report
  - ☐ Event Log Configuration Object Identifier Parameter
  - ☐ Event Log Configuration Action Parameter
  - ☐ Event Class Description Parameter
- ☐ Security

4.4.3.1.4.3 The software shall also implement all mandatory and optional objects of the following optional conformance groups as defined in NTCIP 1203 - Object Definitions for Dynamic Message Signs (DMS) *(check all that are desired)*.

- ☐ GUI Appearance
- ☐ Font Configuration
- ☐ VMS Sign Configuration
- ☐ MULTI Configuration
- ☐ Pixel Service Control
- ☐ MULTI Error Control
- ☐ Scheduling
- ☐ Status Error
- ☐ Pixel Error Status

4.4.3.1.4.4 The software shall also implement all mandatory objects of the following conformance groups in addition to the following list of optional objects for each conformance group as defined in NTCIP 1203 - Object Definitions for Dynamic Message Signs (DMS):

4.4.3.1.4.5 Message Table conformance group *(check all that correspond and/or are identified in the project requirements)*

- ☐ Message Beacon Parameter (only needed, if beacons are located on the sign)
- ☐ Message Pixel Service Parameter (only needed, if a pixel service or exercise should be performed while a message is being displayed)

[9] Please note that requiring this Conformance Group assumes that the scheduling function is implemented at the sign controller level. Many implementations perform this function at the central level only, which would not require the support of this Conformance Group.

4.4.3.1.4.6 Sign Control conformance group *(check all that correspond and/or are identified in the project requirements)*

- ☐ Software Reset Parameter (needed to reset the controller)
- ☐ Message Time Remaining Parameter (needed, if the remaining message display time is to be queried from the device)
- ☐ Message Memory Management Parameter (needed to remotely clear changeable or volatile messages from the message table; if required, all possible values should be supported)

4.4.3.1.4.7 Default Message Control conformance group *(check all that correspond and/or are identified in the project requirements)*

- ☐ Short Power Loss Recovery Message Parameter (message to be displayed after a short power loss)
- ☐ Long Power Loss Recovery Message Parameter (message to be displayed after a long power loss)
- ☐ Short Power Loss Time Definition Parameter (needed to define the time separator between short and long power loss)
- ☐ Reset Message Parameter (message to be displayed after a controller reset)
- ☐ Communications Loss Message Parameter (message to be displayed after a communications loss)
- ☐ Communications Loss Time Definition Parameter (needed to define the time that, if exceeded, constitutes a communications loss)
- ☐ End Duration Message Parameter (message to be displayed after the duration to display a message has expired)

4.4.3.1.4.8 Illumination/Brightness Control conformance group *(check all that correspond and/or are identified in the project requirements)*

- ☐ Status of Illumination Light Output Parameter *(indicates the current light output level)*

4.4.3.1.4.9 Sign Status conformance group

- ☐ Door Open Status Parameter (indicates whether a door on the sign housing or the control cabinet is open)
- ☐ Watchdog Failure Count Parameter (indicates the number of controller failures counted since the last reset)

4.4.3.1.4.10 Fan Error Status conformance group *(check all that correspond and/or are identified in the project requirements)*

- ☐ Fan Failure Parameter

4.4.3.1.4.11 Temperature Status conformance group *(check all that correspond and/or are identified in the project requirements)*

- ☐ Minimum Ambient Temperature Parameter

- ☐ Maximum Ambient Temperature Parameter (*Note: support recommended)*
- ☐ Minimum Temperature of Sign Housing Parameter (*Note: support recommended)*
- ☐ Maximum Temperature of Sign Housing Parameter (*Note: support recommended)*
- ☐ Minimum Temperature of Sign Cabinet Parameter
- ☐ Maximum Temperature of Sign Cabinet Parameter

4.4.3.1.4.12 The DMS Controller shall support each object maximum ranges as defined in NTCIP 1203 *(see Section 3 for suggested subranges)*.

4.4.3.2 Central Computer and Maintenance Laptop Request Processing

The DMS controller shall process requests from the Central Computer (via the central control communications port), or Maintenance Laptop (via the local interface port). These requests shall include the following:

4.4.3.2.1 Download from the DMS Central Computer a message to display. This request shall preempt the display of scheduled messages. This function shall be achieved using the dialogs as defined in Section 4 of this document and the objects as defined in the 'message table conformance group' of NTCIP 1203.

4.4.3.2.2 Upload to the DMS Central Computer the current message on the display. This function shall be achieved using the objects as defined in the 'message table conformance group' of NTCIP 1203.

4.4.3.2.3 Download from the DMS Central Computer the message library. This function shall be achieved using the dialogs as defined in Section 4 of this document and the objects as defined in the 'message table conformance group' of NTCIP 1203.

4.4.3.2.4 Upload to the DMS Central Computer the current message library. This function shall be achieved using the objects as defined in the 'message table conformance group' of NTCIP 1203.

4.4.3.2.5 Download from the DMS Central Computer the message display schedule (Note: this needs to be deleted, if the DMS Controller does not support a local timebased scheduling function).

4.4.3.2.6 Upload to the DMS Central Computer the message display schedule (Note: this needs to be deleted, if the DMS Controller does not support a local timebased scheduling function).

4.4.3.2.7 Blank sign request. This function shall be achieved using value 7 of the dmsMessageMemoryType object as defined in NTCIP 1203.

4.4.3.2.8 Disable message display schedule request. If a scheduled message is being displayed, the DMS controller shall blank the sign. If supported, this function shall be achieved using the dialogs defined in Section 4 of this document and the objects and tables of the following conformance groups:
- time management (NTCIP 1201)

- timebase Event Schedule (NTCIP 1201)
- scheduling (NTCIP 1203)

4.4.3.2.9 Enable message display schedule request. If a scheduled message is being displayed, the DMS controller shall blank the sign. If supported, this function shall be achieved using the dialogs defined in Section 4 of this document and the objects and tables of the following conformance groups:
- time management (NTCIP 1201)
- timebase Event Schedule (NTCIP 1201)
- scheduling (NTCIP 1203)

4.4.3.2.10 Upload sign status. This function shall be achieved using the objects defined in the 'status error subconformance group' of NTCIP 1203.

4.4.3.2.11 Clock synchronization request. This function shall be achieved using the objects defined in the 'time management conformance group' of NTCIP 1201.

4.4.3.2.12 Communications watchdog message. This function shall be achieved using the dmsWatchdogFailureCount object as defined in NTCIP 1203.

4.4.3.3 Local and Remote Control Interface (EXAMPLE)

4.4.3.3.1 The DMS controller shall be controlled both remotely and locally (through communication ports and a user interface). As detailed in the following sections:

A. Local and Remote Serial Ports

B. Local and Remote Control Processing

C. Local Control User Interface

4.4.3.3.2 Local and Remote Serial Ports: The DMS Controller shall incorporate two EIA/TIA-232-E serial ports for communication designated for remote and local communications.

4.4.3.3.2.1 The Remote Communication Port shall be used to communicate with the DMS Central Computer System.

4.4.3.3.2.2 The Local Communication Port shall be used to connect a laptop computer allowing local control of the DMS.

4.4.3.3.2.3 The Local Communication Port connector shall be easily reached when the cabinet is opened from the front and shall be a DB 9 connector configured as a DCE.

4.4.3.3.2.4 If required, a Sign Control Switch located in the DMS Control Cabinet shall select either local control or remote control of the DMS. Either a hardware switch or a software "switch" controlled via either the controller front panel or the laptop GUI shall be acceptable.

4.4.3.3.2.5 Access to the DMS Controller through the Local Communication Port and User Interface shall be protected by a password. A second security level password shall be required to edit messages.

4.4.3.3.3 Local and Remote control processing – the status of the position of the control mode switch shall be reported to the Central Computer using the dmsControlMode Object as defined in NTCIP 1203.

4.4.3.3.3.1 **Remote Processing:** When the Sign Control Switch is positioned on remote control, the DMS Controller shall function as follows:

- The DMS Controller shall execute all commands received from the Remote Communication Port.
- The DMS Controller shall execute only monitoring commands received from the Local Communication Port.
- All other local control interfaces shall be disabled when the Sign Control Switch is positioned on Remote Control.

4.4.3.3.3.2 **Local Processing:** When this Sign Control Switch is positioned on Local Control, the DMS Controller shall function as follows:

- The DMS Controller shall execute all commands received from the Local Communication Port.
- The DMS Controller shall execute monitoring commands received from the Remote Communication Port.
- The DMS Controller shall inform the DMS Central Computer whenever the Sign Control Switch is switched to the Local Control position and of any other changes to the DMS subsystem.

4.4.3.3.4 Local Control User Interface[10] A front panel display and keypad shall be located on the DMS controller to provide a local control user interface at the DMS Control Cabinet for the selection and display of messages (Note: As stated earlier in this document use of a maintenance laptop may mean that no front panel or keypad is necessary. However, this is a project-specific requirement that should be determined via the functional requirements). The user interface shall meet the following requirements:

4.4.3.3.4.1 Message Display

1. The local control user interface shall allow an operator to preview and select any of the pre-programmed messages to be displayed.
2. To allow previewing of messages prior to display, the interface shall display complete message frames; display scrolling will not be allowed.
3. The previewing and selection of message(s) shall not affect the currently displayed message on the DMS.
4. The local control user interface shall allow the operator to select any of the display testing patterns.

[10] The specification writer could use this section to describe the 'look and feel' of the local interface.

4.4.3.3.4.2 **Dimming Control:** The local control user interface shall be provided at the DMS Control Cabinet that allows an operator to select manual dimming of the DMS pixels. Manual dimming of the pixels shall meet the following requirements:

1. The number of manual dimming level shall be as indicated in section 3.6. These number of levels shall be indicated using the dmsIllumNumBrightLevel object as defined in NTCIP 1203.
2. The manual dimming range shall extend from lamps off to full intensity.

4.4.3.3.4.3 **Reset Switch:** The DMS Controller shall incorporate a reset switch that, when activated, resets the DMS Controller and LED drivers.
Note: This is a physical device in opposite to the software function defined in the dmsSWReset object.

1. The reset switch shall be available at the local control user interface and shall be recessed to prevent accidental resets.

4.4.3.4 Message Display

4.4.3.4.1 Messages to be displayed on the DMS shall be configured according to the following specifications:

4.4.3.4.2 The DMS Controller shall provide a minimum storage capability of *32* pre-programmed messages in non-volatile read and write memory using Number of Changeable Messages Parameter and Maximum Number of Changeable Messages Parameter as specified in NTCIP 1203[11].

4.4.3.4.3 When downloading a message to display from the DMS Central Computer, the request must include a display duration, after which period of time the message is removed from the sign.

4.4.3.4.3.1 If a message display schedule was active when the message was received, the DMS controller should resume the message display schedule when the preemptive message expires. Otherwise, the DMS controller should blank the sign when the preemptive message expires. *Note: this may be an optional requirement because either no schedule is supported at the local level or because this particular behavior is not required even if a local scheduler is required.*

4.4.3.4.4 Each message shall include a minimum of *three (3)* display frames (pages). This function shall be achieved by implementing the "np" MULTI Tag as specified in NTCIP 1203.

4.4.3.4.5 The DMS Controller shall support embedded graphic is each message display frame. This function shall be achieved by defining a graphic font *(Note: The 'graphics' type mentioned here only reference small pictograms that are an integral part of a font,*

[11] Please note that this entire section contains an example. The specification writer will have to customize the language to address their functional requirements. For example, in the past, some implementations did not store any messages at the local level. However, if NTCIP is used, at least one message will need to be stored locally.

i.e., a small airplane symbol that is defined as Character A in Font 4. This type of graphic does not cover large graphic), or by implementing the "msx.y" manufacturer-specific[12] MULTI Tag as specified in NTCIP 1203.

4.4.3.4.6 Each message shall control activation of the DMS beacons by implementing the Message Beacon Parameter as specified in NTCIP 1203.
Note: this requirement would only be included, if external beacons (i.e., not integrated and addressable as part of the displayed message) are required.

4.4.3.4.7 The time each message frame (page) is displayed shall be independently configured. This function shall be achieved by implementing the "pt" MULTI Tag as specified in NTCIP 1203.

4.4.3.4.8 Each message frame (page) ON time shall have a minimum range from *2* seconds to *10* seconds in *0.5*-second intervals. This function shall be achieved by implementing the "ptxoy" MULTI Tag as specified in NTCIP 1203.

4.4.3.4.9 The DMS Controller shall display characters using proportional spacing.
Note: this is only possible if the sign display features a line- or full matrix pixel configuration.

4.4.3.4.10 A currently displayed message shall not be affected in any form as the DMS Controller performs other functions, except when displaying a new message or when blanking the DMS.

4.4.3.4.11 When flashing a message frame or displaying a message with two or more frames, the DMS Controller shall blank, change, or update the DMS display within *0.1* sec.

4.4.3.4.12 The DMS controller shall support multiple font sets

4.4.3.4.12.1 EXAMPLE: The DMS Controller shall contain the following minimum sets of fonts using the Font tag and Default Font Definition object as specified in NTCIP 1203:

1. Standard Triple Line Alphanumeric (5 x 7 nominal pixel resolution per character)
2. Compressed Triple Line Alphanumeric (4 x 7 nominal pixel resolution per character)
3. Double Stroke Triple Line Alphanumeric (6x7 nominal pixel resolution per character)
4. Double Line Alphanumeric (7x10 nominal pixel resolution per character)
5. Single Line Alphanumeric (11x24 nominal pixel resolution per character)
6. Graphic characters (minimum of 40 units)

[12] Please note that the use of the 'manufacturer-specific MULTI Tag' may lead to interoperability issues when purchasing additional signs. It is recommended to use the exact same definition of the 'manufacturer-specific MULTI Tag' as implemented with the initial implementation to avoid interoperability and interchangeability issues (the specifications have to require that the agency has the right to use this manufacturer-specific MULTI Tag though).

4.4.3.4.12.2 Each alphanumeric font shall include the following characters as a minimum:

"A" through "Z" All upper case
"0" Through "9" All decimal digits
Special characters: . , / ? ; ' : " < > @ # & * - ← → ↑ ↓ ↖ ↗ ↙ ↘

4.4.3.4.12.3 The DMS Controller shall allow editing of the fonts using the objects defined in the 'font definition conformance group' of NTCIP 1203.
Note: Only include this statement, if the functional requirements determined that editing of fonts is desired.

4.4.3.5 Message Scheduling

4.4.3.5.1 The DMS Controller shall have a real time clock, which meets the following minimum requirements:

4.4.3.5.1.1 In case of power failures, the backup battery shall provide the DMS clock with a minimum of ***twenty-four (24)*** hours.

4.4.3.5.1.2 The clock battery shall have a minimum ***ten (10)*** year life expectancy.

4.4.3.5.1.3 The DMS clock shall keep track of leap years.

4.4.3.5.1.4 The DMS clock shall be accurate to within one second per day.

4.4.3.5.2 The DMS Controller shall have the capability of storing a minimum of twenty (20) preset message display schedules in non-volatile read and write memory. The Controller shall allow schedule entries by either a date and time (i.e., Month/Day/Year, Hour/minutes), or by a weekday and time (i.e., Weekday + Weekday + Weekday…, at Hours/minutes). The DMS message display schedule data shall be exchanged using the objects defined in the 'scheduling conformance group' (NTCIP 1203) and the 'time management' and 'timebase event schedule' conformance groups (both NTCIP 1201).
Note: the human display / graphic user interface to enter the schedules may be completely different than the highly compressed and complex setup used to transmit this data.

4.4.3.6 Lamp Dimming

4.4.3.6.1 The DMS Controller shall control the intensity of the DMS display LEDs with a minimum of *10* brightness levels. This function shall be achieved by implementing the Illumination/Brightness Conformance Group as specified in NTCIP 1203.

4.4.3.6.2 The Contractor shall preprogram the DMS Controller to set the pixel light output levels to be twice as bright as the highest light level measured from the *three* photocells located in the sign.

4.4.3.6.3 The highest photocell reading shall be used as the value for the Status of Illumination Photocell Level Parameter as defined in NTCIP 1203.
Note: while Amendment 1 of NTCIP 1203 states that the value of the photocell level

reading may be determine using some algorithm, a specification can require how this is to be done.

4.4.3.6.4 The DMS Controller shall be capable of reading a minimum of *250* light levels from each photocell.

4.4.3.6.5 DMS Diagnostics and Error Reporting
Note: the functional requirements should determine what actions such as a dial-back function or paging a technician should be taken. These actions would then need to be added under this section.

4.4.3.6.5.1 **Error Reporting:** The DMS Controller shall log all errors, all failures, and all warnings by implementing all of the mandatory objects under the Report Parameter Node as defined by NTCIP 1201, the Validate Message Error Parameter, Activate Message Error Parameter, and all objects of the Multi Error Conformance group as defined by NTCIP 1203, and the following optional objects as defined by NTCIP 1201:

- Event Log Configuration Object Identifier Parameter
- Event Log Configuration Action Parameter
- Event Class Description Parameter

4.4.3.6.5.2 The error and failure log shall incorporate a time and date stamp.

4.4.3.6.5.3 All DMS errors, failures, and warnings shall immediately be reported to the Local Communication Port.

4.4.3.6.5.4 All DMS errors, failures, and warnings shall immediately be logged by the DMS controller.

4.4.3.6.5.5 **DMS Warnings**: The following shall be classified as DMS Warnings

4.4.3.6.5.5.1 The DMS Controller shall detect a Password Warning when a user settable number of failed attempts to enter a password occurred.

4.4.3.6.5.6 **DMS Errors** The following shall be classified as DMS Errors:

4.4.3.6.5.6.1 The DMS Controller shall incorporate a Communication Time Out Error by implementing the Communications Loss Time Definition Parameter as define by NTCIP 1203.

4.4.3.6.5.6.2 The DMS Controller shall use the Description of Other MULTI Error Parameter as defined by NTCIP 1203 when implementing manufacturer-specific error message descriptions[13].

4.4.3.6.5.6.3 The DMS Controller shall sense a Communication Error when it receives a message that cannot be processed using the Short Error Status Parameter as defined by NTCIP 1203.

4.4.3.6.5.6.4 The DMS Controller shall track controller errors by implementing the Controller Error Status Parameter as defined by NTCIP 1203.

[13] Note that the use of any manufacturer-specific errors, as with any non-standardized object definitions or MULTI Tags, bears challenges in terms of interoperability and interchangeability. The specification writer is advised to carefully evaluate whether to allow or accept the manufacturer-specific or non-standardized functions.

4.4.3.6.5.7 **DMS Failures** The following shall be classified as DMS Failures:

4.4.3.6.5.7.1 **Pixel Failure**: The DMS Controller shall continuously monitor, detect, and locate any pixel failure (single or multiple pixels) by implementing the Pixel Failure Table Parameter as specified in NTCIP 1203:

4.4.3.6.5.7.2 A Pixel Failure shall be detected by the DMS Controller, if a LED strings within a pixel stays ON when the LED string should be OFF (stuck on).

4.4.3.6.5.7.3 A Pixel Failure shall be detected by the DMS Controller, if a LED strings within a pixel stays OFF when the LED string should be ON (stuck off).

4.4.3.6.5.7.4 The Pixel Failure detection routine shall test all sign pixels.

4.4.3.6.5.7.5 The Pixel Failure detection routine shall not affect the display of a message.

4.4.3.6.5.7.6 The Pixel Failure detection routine shall not be visible to the driver.

4.4.3.6.5.7.7 The Pixel Failure monitor and detection functionality shall be implemented by using the following Parameters as specified in NTCIP 1203:

- Pixel Service Duration Parameter
- Pixel Service Frequency Parameter
- Pixel Service Time Parameter

4.4.3.6.5.7.8 At a minimum, the DMS Controller shall have the following display test patterns for visual inspection of DMS pixels. The Contractor may submit alternative test sequences[14] for approval by the Engineer:

1. SET TEST: All pixels are on.
2. RESET TEST: All pixels are off.
3. SET RESET TEST: Set and resets all pixels continuously.
4. COLUMN TEST: Walking set column
5. ROW TEST: Scrolling set row

4.4.3.6.5.8 The DMS Controller shall have a hardware watchdog, which shall reset the DMS in case of software failure. A counter shall be provided to keep track of the number of reset events using Watchdog Failure Count Parameter as defined by NTCIP 1203.

4.4.3.6.5.9 The DMS Controller shall monitor the temperature values (minimum and maximum) within the sign controller, sign housing, and the ambient temperature using the objects defined under the 'temperature status configuration group' in NTCIP 1203.
Note: it is important for LED-based technologies to monitor the temperature inside the sign housing because the life cycle of LEDs will be reduced severely if the temperature exceeds particular thresholds. The vendor will typically factory-configure this value. However, an agency might be interested in remotely viewing this value and also be

[14] Note that allowing the contractor to submit 'alternative test sequences' may lead to interchangeability challenges. To avoid these challenges, the specification writer may be advised to remove this statement.

able to determine when the display was blanked (better turned off) due to exceeding this temperature threshold. Problem is that there are no standard NTCIP objects to achieve this.
An agency would have to require a vendor to propose and provide corresponding objects, or develop its own object and require the inclusion AND utilization of these agency-specific objects in the DMS software.

4.4.3.6.5.10 The DMS Controller shall monitor, and detect an LED Power Supply Failure when an LED power supply unit fails.
Note: as with the excess temperature thresholds, there are no standard objects to determine which LED power supply failed. Either vendor or agency can develop and use non-NTCIP standard objects to achieve this functionality[15].

4.4.3.7 Configuration Variables

4.4.3.7.1 All configuration variables in the DMS Controller shall be stored in non-volatile read and write memory.

4.4.3.8 Electrical (EXAMPLE)

4.4.3.8.1 Quality Provisions: The DMS Controller shall not include components for which the component's manufacturer product literature indicates that the component has an MTBF of less than 43,800 hours.

4.4.3.8.1.1 All fuses shall be easily accessible without having to remove any DMS component and shall be replaceable without the use of any tools.

4.4.3.8.1.2 All light indicators shall have a minimum 60-degree viewing angle.

4.4.3.8.1.3 All light indicators, switches, connectors, wiring, and knobs shall be clearly labeled.

4.4.3.8.1.4 Power service "brown-outs" or "surges" shall not damage any system, subsystem and components or impair future system performance.

4.4.3.8.1.5 All electrical circuits conducting power shall contain a circuit breaker or a fuse. The circuit breaker trip or fuse blow current rating shall not exceed twice the operational current of the circuit.

4.4.3.8.2 Printed Circuit Boards (PCB)

[15] Please note that there is a difference between manufacturer-specific and agency-specific objects. Manufacturer-specific objects are typically proprietary, while agency-specific objects are in the public domain. However, if the requirements specify (and subsequent submittal documents confirm this requirement) that manufacturer-specific objects can be used by the agency for distribution to anyone they deem necessary, they become almost like agency-specific objects. If non-standardized functions are deemed necessary to an agency, it is important for this agency to realize that the corresponding objects are available to them without any limitations to ensure that interoperability and interchangeability can be maintained without being bound to a particular vendor.

4.4.3.8.2.1 All PCBs shall comply with NEMA FR-4.

4.4.3.8.2.2 Direct soldering of jumper wires to PCB will not be permitted.

4.4.3.8.2.3 All devices dissipating more than 250 mW or whose operating case temperature is 50°F above ambient temperature shall be mounted to prevent direct contact with the PCB.

4.4.3.8.2.4 Conformal coating shall be applied to protect the PCB and its components from mildew and moisture. The conformal coating shall be listed on the Qualified Products List for MIL-I-46058C, and shall be UL approved. The water vapor transmission of the conformal coating when tested following ASTM E96 method shall be 0.045 gms/hrs-m^2 or less.

4.4.3.8.3 Discrete Components

4.4.3.8.3.1 Vacuum or gaseous tubes or electromechanical devices within the equipment shall not be used except for circuit breakers and thermostat.

4.4.3.8.3.2 Sole source components shall be identified in the offerors proposal. This requirement shall also apply to all programmable components (EPROMs, PLAs, ROMs, or any other such components).

4.4.3.8.3.3 All transistors, integrated circuits, and diodes shall be standard type listed by EIA.

4.4.3.8.3.4 All semiconductor components used at input and output lines shall be protected from electrostatic discharges.

4.4.3.8.3.5 Any component that may be loosened or damaged due to vibration or shock shall be restrained properly.

4.4.3.8.3.6 No devices shall be placed in sockets except for Integrated Circuits. All integrated circuit sockets shall meet MIL-S-83734.

4.4.3.8.3.7 All components shall be new, and their manufacture date shall not be older than one year from the Contract Notice to Proceed.

4.4.3.8.3.8 All components shall be used according to manufacturer's specifications.

4.4.3.8.4 Connectors

4.4.3.8.4.1 All connectors shall be keyed to prevent improper insertion when mating with the wrong connector or PCB.

4.4.3.8.4.2 All connectors and designated mates shall have unique reference designations and shall be clearly labeled.

4.4.3.8.4.3 All connectors shall incorporate a strain relief.

4.4.3.8.5 **Wiring, Circuit Breakers, Switches, and Terminal Blocks**: Control Cabinet shall meet the following requirements:

4.4.3.8.5.1 All wiring shall end on terminal blocks or in shrouded connectors.

4.4.3.8.5.2 All wiring shall be permanently labeled at both ends.

4.4.3.8.5.3 All wiring harnesses shall be properly bundled and tie-wrapped with external protection. All harnesses shall be neat, firm, spaced properly, out of the way, and clearly labeled.

4.4.3.8.5.4 Adequate length shall be allowed for all harnesses to allow any conductor to be connected properly to its associated connector or termination point.

4.4.3.8.5.5 All power conductors shall be bundled separately from signal and logic conductors. In addition, all signal wiring shall be bundled in such a fashion as to minimize cross talk.

4.4.3.8.5.6 All terminal blocks and terminal block positions shall be clearly and uniquely labeled.

4.4.3.8.5.7 All circuit breakers shall be clearly labeled.

4.4.3.8.5.8 Circuit breakers shall be listed by UL and shall have the trip and frame size plainly marked on the breaker. The trip ampere rating shall be visible from the front of the breaker.

4.4.3.8.5.9 All DMS Control Cabinet circuit breakers shall be quick-break.

4.4.3.8.5.10 All switches and switch positions shall be clearly labeled as to their function.

4.4.3.8.5.11 All wiring shall be routed through conduits or cable trays.

4.4.3.9 Environmental

4.4.3.9.1 The DMS system shall operate without degradation in performance under environmental conditions as specified herein. No separate payment will be made for the cost of environmental compliance, any environmental testing and/or documentation / submittals. Costs for such service shall be covered under payment of associated equipment and/or subsystems. All DMS system equipment provided under this contract installed outside of the Central Computer office location (such as dynamic message sign display, modems, DMS controllers, Power Conditioners, etc.) shall be protected (i.e., field cabinet and/or sign housing) and shall operate without functional or integral performance degradation or sustained damage under these environmental requirements:

- Operating temperature range: -30 °F to +165 °F
- Operating humidity up to 98 % relative, non-condensing
- Operating and transporting vibration of 5 to 30 cycles per second up to 0.5 gravity applied in each of three mutually perpendicular planes.
- Operating and transporting shock of 30 g's, 11ms duration in any axis under non-operating conditions.

4.4.3.9.2 **Quality Provisions:** The Contractor shall submit documentation of test results or field performance verifying the performance of the proposed components and subsystems in regards to the above environmental requirements.

4.4.3.9.3 All requirements are to be met under worst-case conditions.

4.4.4 Requested Requirements:

The capabilities outlined in this section are not requirements of the system, but the functionality described is considered highly desirable. The technical proposal of each offeror will be scored, in part, based on the number of these capabilities, or functional equivalents, that are provided by their proposed system.
Note: the following listing is an example. The functions can be moved to the Mandatory Requirements section above, if so desired by the procuring agency.

4.4.4.1.1 The capability for the DMS Controller to allow the Central Computer System to overwrite Local Control mode. This function should be achieved by implementing the Control Mode Parameter as specified in NTCIP 1203 by supporting the following options (*check the required functions*):

- ☐ Other (1) – rarely necessary
- ☐ **Local (2) – highly desired**
- ☐ External Control – rarely necessary
- ☐ **Central (4) – highly desired**
- ☐ *Central Override (5) – desired*
- ☐ Simulation – rarely necessary

4.4.4.1.2 Log message authors or the last editor using the Message Owner Parameter as specified in NTCIP 1203.

4.4.4.1.3 Light Indicators: Light indicators should be provided to inform maintenance personnel of the power status for each the DMS Control Cabinet power circuits and DMS power circuits. At a minimum, the following number of power light indicators should be provided (if multiple circuits, one light indicator per circuit):
Note: this is a local function that is not transmitted to the Central Computer.

4.4.4.1.3.1 Controller Power

4.4.4.1.3.2 Fan status for air venting system

4.4.4.1.3.3 Fan status for air circulation system

4.4.4.1.3.4 Power status for each LED power supply bank.

4.4.4.1.4 Support for the Software Reset Parameter as specified in NTCIP 1203.

4.4.4.1.5 Override of proportional spacing using the character spacing MULTI Tag “scx”.

4.4.4.1.6 The ability to right, center, and left justify each line individually. This function is achieved by implementing the “jlx” MULTI Tag as specified in NTCIP 1203.

4.4.4.1.7 The ability to top, middle, and bottom vertically justify each message frame (page). This function is achieved by implementing the "jpx" MULTI Tag as specified in NTCIP 1203.

4.4.4.1.8 The capability to flash entire message frames or portions of each message frame (page). Flashing portions should be user selectable and should be as small as a character and as large as a line. The flashing ON and OFF rate should be user selectable per message. This function is achieved by implementing the "fltxoy" MULTI Tag as specified in NTCIP 1203.

4.4.4.1.9 Default flashing On and Off rate should be implemented by using the Default Flash On Time Parameter and Default Flash Off Time Parameter as specified in NTCIP 1203.

4.4.4.1.10 The capability to display current day and/or time (in United States format) anywhere in the text as part of a message. This function is achieved by implementing the "fx,y" MULTI Tag as specified in NTCIP 1203.

4.4.4.1.11 The value of each photocell available for monitoring at the Local Communication Port.
Note: The current version of the NTCIP 1203 standard only supports one value. Thus, either manufacturer- or agency-specific objects need to be used to achieve this functionality[16].

4.4.4.1.12 The time it takes the DMS Controller to report a failure, error, or warning to the Local Communication Port should not exceed ***30*** seconds.

4.4.4.1.13 Continuous monitoring of the DMS housing door and DMS ground mounted cabinet door and reporting Door Open Warnings shall be provided. The Door Open Warning shall be implemented by using the Open Door Status Parameter as defined in NTCIP 1203.

4.4.4.1.14 A light indicator provided at the DMS Control Cabinet to denote the DMS housing internal lighting status shall be provided.
Note: The current version of the NTCIP 1203 standard does not supports this function. Thus, if either manufacturer- or agency-specific object(s) need to be used to achieve this functionality.

[16] Again, please be aware that the use of manufacturer-specific objects can lead to interoperability and interchangeability challenges. The specification must include requirement statements allowing the agency to re-use and distribute any implemented manufacturer-specific objects to anyone they deem necessary.

5 DIALOGS

The following section is a preliminary draft from the new NTCIP 1203 version 2 standard[17]. While this Standard development effort is still 9-12 months away from 'Recommended Standard' and while this part may still change within the standard, inclusion of this material here at this time, will provide the reader with an understanding of the sequence of events/data exchanges (termed 'dialogs') that need to take place to achieve certain functions.

The need to specifically develop and include dialogs was determined during the first implementations attempting to deploy the NTCIP standards. While the concepts were defined in the original NTCIP standards via the conformance groups in which all related data elements were organized, it was difficult to decipher them. The vendor and user community requested that the interrelationships between data elements and any particular sequences be specifically stated. *Note: In Version 2 of the NTCIP DMS Standard, the conformance groups will most likely be replaced by functional requirements listing and the traceability matrix in which the procuring agency has to specify which requirements are to be implemented for a particular project. The traceability matrix will include dialogs and a listing of all data elements needed to accomplish the functional requirement.*

The only dialogs/data exchanges included here are those functions contained in NTCIP 1203 and Amendment 1. Additional dialogues/data exchanges will most likely be added to the NTCIP 1203 Version 2 standard.
This section defines the rules and procedures related to each of the features defined in Section 3. All of the operations defined in this standard are derived from those defined for NTCIP 2301**,** but some features impose special constraints upon these fundamental rules.

5.1.1 Download a Message to the sign

In order to download a message to a sign, a number of steps have to be performed, which are described in detail in the next subsections.

The message table is a database that needs to be populated, and several fields (or columns) within the message table need be filled out. While most of these fields are needed (mandatory), some are optional (optional) because they are applicable only if a particular technology or a particular external device (beacons) is used. The required fields within this table that the user has to populate are:

- Message text – to be displayed but including the MULTI tags, even though those are not displayed.
- Message Owner – the person or agency that downloaded the message to the sign's local message library.
- Message CRC – a unique checksum for the message
- Message Run Time Priority parameter – a priority value assigned to the message. There are two parameters dealing with priority, the run time priority, and the activation priority parameters. As the names indicate, the activation priority parameter contains the priority that is used to activate a new message, while the run time priority is the priority value associated with the current message, if any. In order to overwrite the current message, the activation priority value has to be higher than the run time priority value.

[17] **Reprinted from preliminary draft to "NTCIP 1203 Version 2 – DMS Object Definitions" by permission of NEMA. Excerpt © 2002 AASHTO / ITE /NEMA.**

- Message Status – the indicator for the message that determines whether the message can be used.

Two other fields associated with each message (this row of the message table) are the message type (users can determine whether the message is to be stored in volatile, changeable, or permanent memory) and the message number. Both are only indirectly settable by the users, since these values are the indices into the table, i.e., in order to enter something into the table, one has to state what memory type and which message number within a particular memory type the message is to be written.

The steps to download a message are as follows (see below for detailed descriptions and the parameters involved):

a.) Open a particular row of the message table by changing the value of the message status. This needs to happen in a separate data exchange because SNMP does not guarantee that the parameters within a data packet are processed in sequence.
b.) Enter the values for all fields / columns as desired. Be careful about the value of the run time priority parameter since it should not be too high, because otherwise it cannot be replaced by a new message.
c.) Close this particular row of the message table by changing the value of the message status again to verify that the downloaded contents of this message are proper.
d.) Check the value of the message status object to ensure that this message is available for use. This is an optional step but can prove useful since the time it takes to verify the message contents is not pre-determinable.

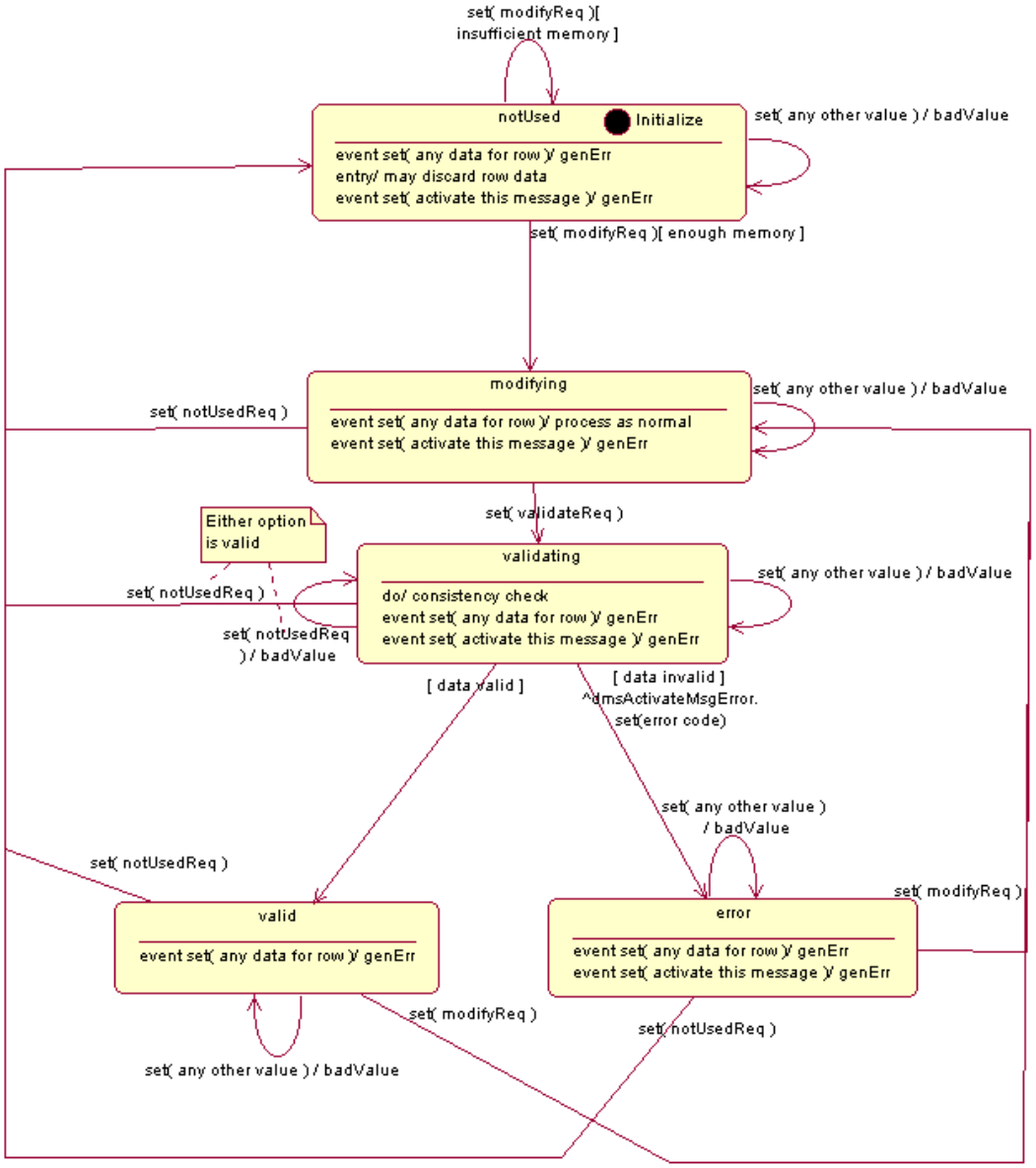

Figure 4-1: The Message Table State Machine

5.1.1.1 Download a Message Sequence Diagram

Figure 4-1 indicates the process required to download a message to the sign.

According to the NTCIP paradigm, no message can be displayed, unless it is defined in the message table within the sign controllers memory. The process for downloading a message into the sign's message table (dmsMessageTable) is as follows:

1. Set the dmsMessageStatus object to a value of *modifyReq*.
2. Check the value of the dmsMessageStatus object to determine whether the value is *modifying*. If the value is anything other, retry setting the value to *modifyReq*.
3. Set the values of the following objects to the desired values: dmsMessageMultiString, dmsMessageOwner, dmsMessageCRC, dmsMessageRunTimePriority. The index values

into this table have to be valid. For example, dmsMessageType has to have a value of other, volatile, or changeable and dmsMessageNumber has to have be a valid number (if an already used number is used, it will overwrite the existing message).
Additionally, set the dmsMessageBeacon and dmsMessagePixelService objects, if the associated functions are supported within the signs. For example, if the sign has no beacons, support of the dmsMessageBeacon object is not necessary.

4. Set the value of the dmsMessageStatus object to a value of *validateReq*. This will cause the controller to initiate a consistency check on the message contents to ensure that the MultiString is valid and the status will then automatically change to either the *valid* or *error* based on the results of this check.
5. Check the value of the dmsMessageStatus object until the value is either *valid* or *error*.
   If the value is *error*, check the dmsValidateMessageError object to determine the reason the message was not implemented.
   If the value is *valid*, the message can be activated using the 'Post a Stored Message' Dialog.

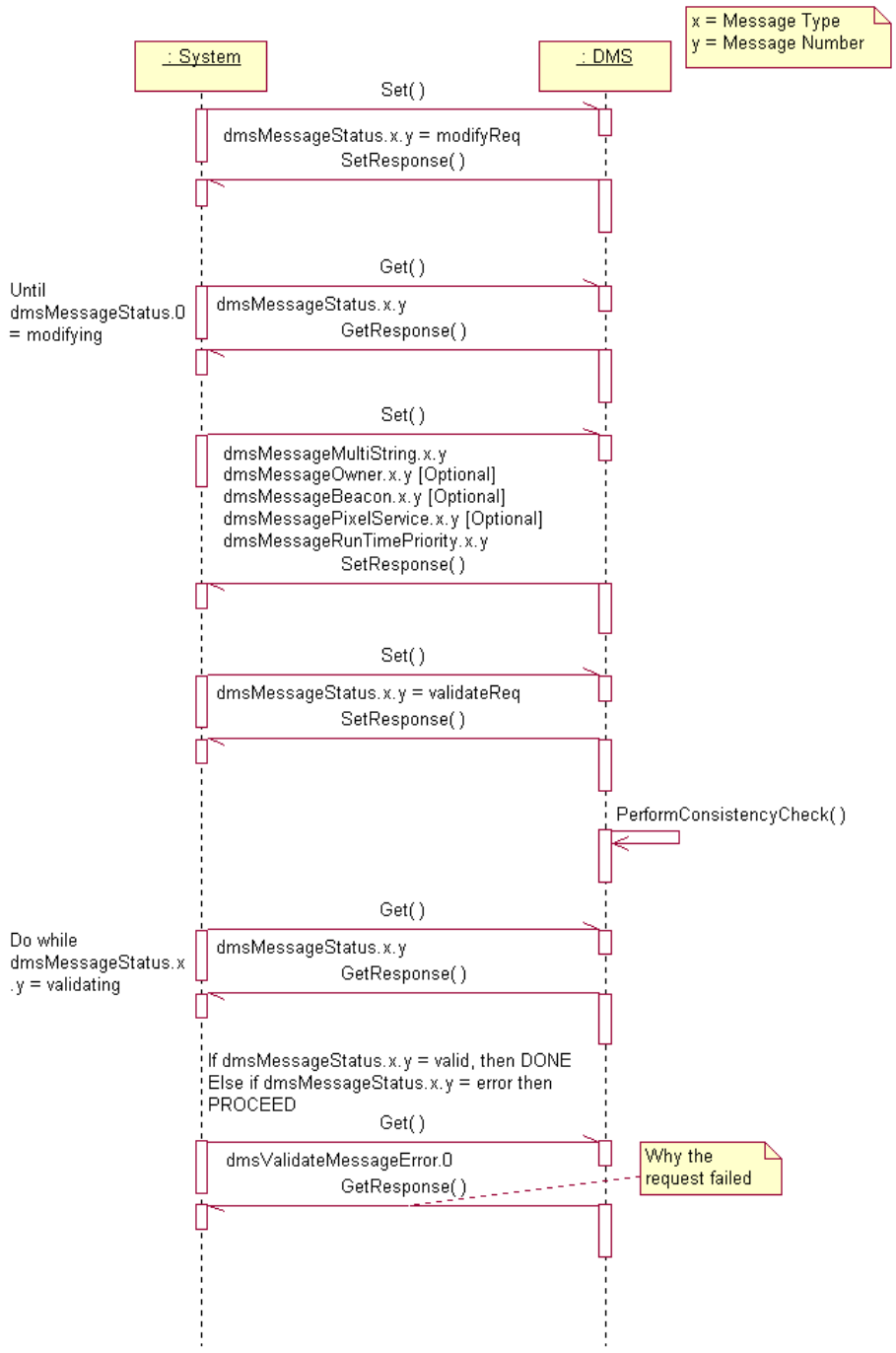

Figure 4-2: Sequence Diagram for Downloading a Message to the Sign

5.1.2 Change the Sign Display

Several different methods can be used to display a stored message. Some of them are described below. Others include the use of singular objects such as the dmsEndDurationMessage which would indicate the message to be displayed after the duration of a commanded or scheduled message has expired.

It should be noted that the NTCIP 1203 standard does not allow to directly display a message, but instead that each message will first need to be stored locally. This requirement and the associated activities are transparent to the user. Requirements such as 'shall allow for immediate display of a message' can be fulfilled with this requirement, even though technically the display is not 'immediate'.

5.1.2.1 Post a Stored Message

The process to change a sign display message on a sign uses the normal SNMP SET process with a consistency check applied before the set response is returned. The consistency check is performed as follows:

1. If the requested message type is not supported by the sign, the DMS returns a genErr and sets the dmsActivateMsgError to *memoryType*.
2. If the requested message number is not supported by the sign, the DMS returns a genErr and sets the dmsActivateMsgError to *messageNumber*.
3. If the requested message is supported by the sign but is not currently in the valid state, the DMS returns a genErr and sets the dmsActivateMsgError to *messageStatus*.
4. If the requested message is in the valid state but has a different CRC value than indicated in the set request, the DMS returns a genErr and sets the dmsActivateMsgError to *messageCRC*.
5. If the request is valid, but the sign is in local control, the DMS returns a genErr and sets the dmsActivateMsgError to *localMode*.
6. If the request is valid, but has insufficient priority to override the current message, the DMS returns a genErr and sets the dmsActivateMsgError to *priority*.
7. If the request is valid and has sufficient priority to override the current message, but cannot be displayed due to some error in presenting the MultiString on the display panel, the DMS returns a genErr and sets the dmsActivateMsgError to *syntaxMULTI*. In addition, the DMS will set proper values for the dmsMultiSyntaxError, dmsMultiSyntaxErrorPosition and dmsMultiOtherErrorDescription objects.
8. If the request does not result in posting the requested display for any other reason, the DMS returns a genErr and sets the dmsActivateMsgError to *other*.
9. Otherwise, the DMS shall display the requested message, return noError, and set dmsActivateMsgError to *none*.

The process for posting a stored message is as follows:

1. Set the dmsActivateMessage object to a value of MessageActivationCode.
2. If a SNMP genErr is returned, check the value of the dmsActivateMsgError object to determine error caused the genError.

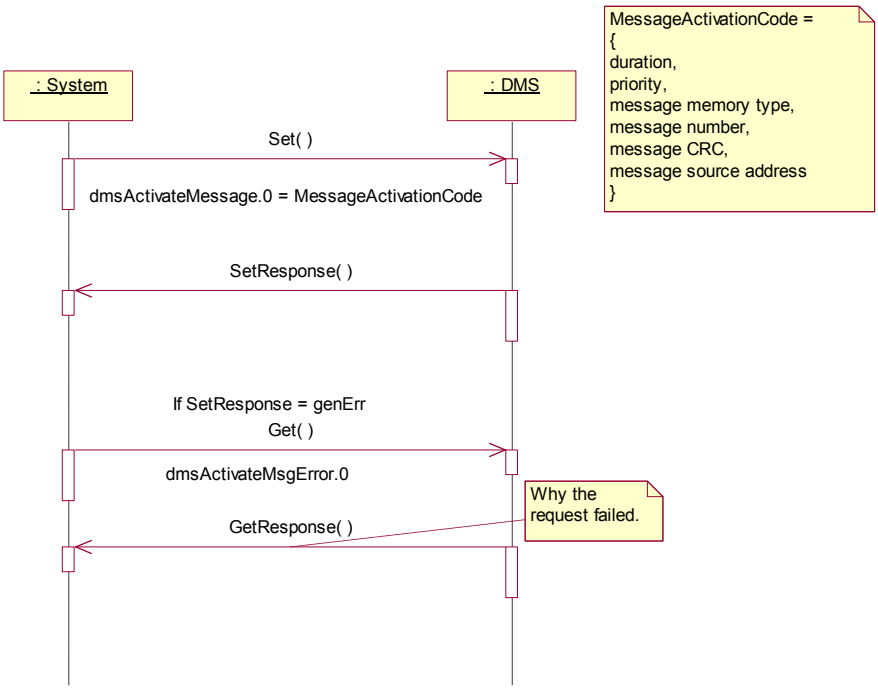

Figure 4-3: Sequence Diagram for Posting a Stored Message

5.1.2.2 Blank the Sign

The process for blanking the sign is identical to that for 'posting a stored message', except the message type shall be 'blank', the message number shall reflect the requested run-time priority, and the CRC shall be 0x0000.

5.1.3 Implementing a Schedule

This function is only used when a scheduling function is implemented locally within a sign controller. This does NOT pertain to a scheduling function installed in the central computer, because if the central computer runs the scheduling function, and it determines a particular message is to be posted due to a scheduled event, the actions to be taken are the same as in 'downloading a message' and 'posting a stored message' (see Sections 5.1.1 and 5.1.2.1).

5.1.3.1 Populate the Scheduling Objects

Several tables need to be populated prior to the use of the scheduling function. These tables are timeBaseScheduleTable (NTCIP 1201), timeBaseDayPlanTable (NTCIP 1201), and dmsActionTable (NTCIP 1203). Additionally, the time management objects, as defined in NTCIP 1201) must be supported, since a real-time clock within the sign's controller is required to support this function.

These tables are interrelated in that the timeBaseScheduleTable references a row in the timeBaseDayPlanTable via the timeBaseScheduleDayPlan object. The timebaseDayPlanTable references a row in the dmsActionTable via the dayPlanActionNumberOID.

If a scheduled event is to be programmed within the sign controller, the following steps have to be taken.

1. Check the maxTimeBaseScheduleEntries, maxDayPlans, maxDayPlanEvents, and numActionTableEntries objects to determine how many events and actions can be defined.
2. Set the values of one or more rows within the timeBaseScheduleTable, timeBaseDayPlanTable and dmsActionTable. Note that the timeBaseDayPlanTable uses a double index allowing several programmed actions to take place simultaneously.
3. If several schedules are to be defined, be sure to configure overlapping scheduled events correctly. The event with the most specific date will be activated. The scheduler will determine this by first looking at the MONTH value, then 'Day of Month' value, and then at the 'Day of Week' value. If all of these values are the same, then the first entry into the table according to the timeBaseScheduleNumber value will be activated.
4. No consistency check is currently included in the NTCIP Standards.

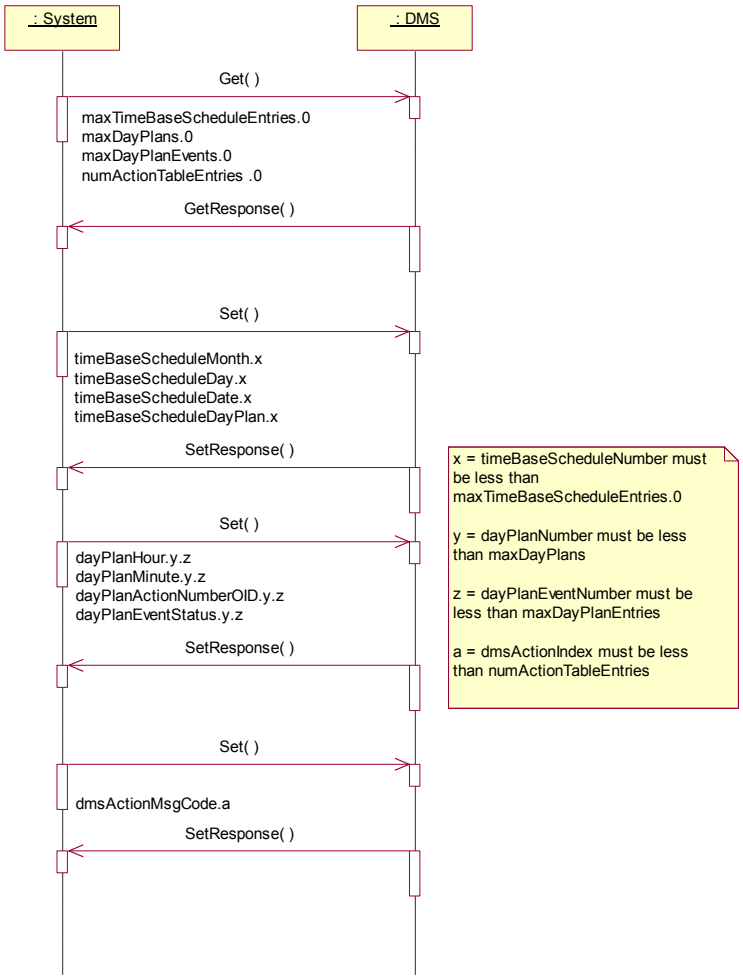

Figure 4-4: Sequence Diagram for Populating a Schedule

ANNEX A – PROFILE REQUIREMENTS LISTS (PRLS)

INSTRUCTIONS:
Insert the attached documents numbered A1 thru A6 here.

ANNEX B – TEST PROCEDURES

INSTRUCTIONS:
Insert the attached documents numbered B1 thru B6 here (all PDF files).