
**NATIONAL TRANSPORTATION COMMUNICATIONS FOR ITS PROTOCOL (NTCIP)
CASE STUDY REPORT**

NTCIP 9003 v01.04

**Washington State DOT
NTCIP VMS Software Upgrade**

Version 01.04, September 29, 1999. A Recommended Information Report of the Joint Committee on the NTCIP.

© 1999 AASHTO/ITE/NEMA. All rights reserved. Permission to reproduce, distribute, and/or translate into other languages is granted provided that copyright is acknowledged and text is not edited or used out of context.

1. PURPOSE OF THE CASE STUDY

1-1 INTRODUCTION

Field deployment of NTCIP-conforming equipment has begun. State and local Departments of Transportation and their consultants are aware of the interoperability and interchangeability features promised by the NTCIP, and are including references to the NTCIP in their procurement documents. For all but a few, this is their first experience with the NTCIP.

The purpose of this project, sponsored by AASHTO, FHWA, ITE and NEMA, is to prepare a series of case studies that describe the lessons-learned by vendors, agencies, and consultants during three of the early projects that required NTCIP compliance. The objective is to compile an unbiased investigation of each case study that incorporates the perspectives from different implementation positions.

Two Variable Message Sign (VMS)¹ projects and one traffic signal control project were selected for this study during 1999. Additional projects may be investigated in FY 2000. The material for these case studies was drawn from interviews with individuals who were directly involved in the NTCIP implementation and from project-related documents such as specifications, test plans, and procurement documents. At least three individuals in different roles, such as agency champion, procurement specification writer, agency field technician and vendor representative, were interviewed. The interviews, conducted by individuals familiar with the NTCIP, were structured around a survey prepared for these case study investigations. Whenever possible, relevant project documents for each project are included in that case study report

¹ Variable Message Signs are considered a device subgroup addressed within the NTCIP Standard TS 3.6. The term dynamic message sign (DMS) refers to all sign types including variable message signs, changeable message or drum signs, and blank out signs.

This document focuses on the implementation of VMS devices using the NTCIP. It does not attempt to explain the details of the NTCIP. Additional information on the NTCIP, including specific NTCIP standards, is available on the NTCIP Website (www.ntcip.org)².

2. THE CASE STUDY

This report presents a case study of a Variable Message Sign (VMS) implementation by the Washington State Department of Transportation (WSDOT). The formal name of this project is the "NTCIP VMS Software Upgrade." The purpose of the project was to modify the existing traffic management system to support selected protocols from the NTCIP suite of protocols and to purchase two new NTCIP compliant variable message signs (VMS). The VENDOR was American Electronic Sign Co (AES). Additionally, the AGENCY hired a programming contractor (PROGRAMMER) to enhance the central system software.

This project was a change order to a larger project. As is customary with VMS implementation projects, an electrical contractor was awarded a contract with the AGENCY and acted as the prime contractor. This contractor then selected the VENDOR based on price and reputation. Originally, the contractor was to supply and integrate two new signs into the existing traffic management system. The traffic management system supported only a single proprietary protocol and all sign procurements required the use of this protocol³; thus, the signs were previously obtained sole-source from the sign vendor that supported this protocol.

In 1997, the contractor was able to secure a better price on hardware from a different vendor. Initially, the contractor planned to deliver these signs with a converter box. However, the AGENCY decided that it would be more appropriate to have the manufacturer support the NTCIP than to require support for the existing proprietary protocol using converter boxes that might become a maintenance problem. The AGENCY issued a no-cost change order to allow the delivery of NTCIP-compliant signs.

During the course of this VMS NTCIP Software Upgrade project, three fiberoptic flip disk signs were installed. In addition to these new NTCIP-compliant VMS, the central system would also control non-NTCIP compliant CCTV, ramp meters, and VMS. The NTCIP-compliant VMS were to be controlled on a separate communications channel using full duplex 1200 bps communications. These signs were temporarily controlled using proprietary protocols until the NTCIP software was ready.

The AGENCY's objectives for using the NTCIP were to achieve interoperability and to increase competition on bids for these devices. The VENDOR's objectives in developing an NTCIP-compliant sign were to develop products with a common protocol that can be used in a broader market without adapting to agency-specific protocols, and to become a leading supplier of NTCIP-compliant signs. The VENDOR, who is based in Washington State, also saw this project as an opportunity to enter the Washington State market. The manufacturer has since been awarded other contracts with WSDOT for some 15 to 18 signs.

Project milestones and dates are shown in Table 1. The project, scheduled for completion in one year, required two years to complete.

Table 1: Project Milestones & Dates

AGENCY	VENDOR	NTCIP Standards Status	Date
		TS 3.2 and TS 3.3 approved as a Recommended Standard	5/96

² The White Paper "Understanding the NTCIP™ Class Profiles from an End User's Perspective," prepared by the NTCIP™ Profiles Working Group is an excellent example.

³ Specifying a controller indirectly specified the protocol for the signs.

AGENCY	VENDOR	NTCIP Standards Status	Date
		TS 3.6 approved as a Recommended Standard	3/97
		Modifications to TS 3.2 and TS 3.3 first published as Technical Revision	5/97
	Start NTCIP development		10/97
Started development			12/97
	Contract Submittal		4/98
	Simulator provided to Agency for integration testing		11/98
Simulator working with provisional central software			12/98
	Factory testing of VMS with Agency's central system via modem connection		3/99
	Signs converted to NTCIP		4/99

3. PROJECT PROCUREMENT

The contractor selected the VENDOR using a low-bid process. Signs were supplied on change order with an agreement to use proprietary software until the NTCIP could be implemented. The AGENCY released a separate contract for a programmer to develop an NTCIP device driver. This driver was integrated into the existing central system, which controls and monitors a variety of non-NTCIP compliant ITS devices such as CCTV, ramp metering controllers and VMS.

4. SPECIFICATIONS

The VENDOR and the AGENCY developed the specifications jointly in a somewhat unstructured manner. There were no formal project requirements for the various NTCIP options. The change order stated that the devices must be "NTCIP compliant" and required that new signs support the same features offered by existing signs. Additionally, the AGENCY and VENDOR agreed to implement TS 3.2-Amendment 1 (at that time called Technical Revision to TS 3.2) Conformance Level 1. This requirement states that SNMP⁴ but not STMP⁵ was to be implemented.

The AGENCY and VENDOR negotiated the details related to the implementation of the NTCIP compliant signs. The VENDOR produced a draft Management Information Base (MIB) that consisted of a subset of the full NTCIP MIBs with no proprietary objects. The AGENCY approved this MIB with minor changes⁶.

As would be expected, the NTCIP aspects of central control system were also not addressed in the specification. During the contract, the central system software programmer was directed to implement the features of the existing system within the NTCIP protocols and the associated MIB.

⁴ Simple Network Management Protocol, the primary network monitoring and control protocol used in Internet applications. Support for this protocol is nowadays provided in most computers; however, the end-application data elements are usually unique to the application.

⁵ Simple Transportation Management Protocol. A derivative of the SNMP that was compressed to run over bandwidth restricted communications lines. This protocol is new and originally no off-the-shelf software was available. The CPU requirements to process STMP commands were also increased in order to reduce bandwidth requirements.

⁶ Written documentation for this MIB is not available.

4-1 PROJECT-RELATED NTCIP STANDARDS STATUS

The March 1997 drafts of the NTCIP Standards (as well as some earlier drafts) were used in developing specifications; however, the final deliverable conformed to the approved documents. The VENDOR referred to and implemented the NTCIP Dynamic Message Sign Object Definitions draft TS 3.6 v01.14, as well as the TS 3.2 and TS 3.3 Standards, and the Technical Revisions to TS 3.2 and TS 3.3 that were published in May 1997.

One problem related to the NTCIP DMS standard was that during the development of the DMS Standard (i.e., the pre-'March 1997' drafts), several nodes were moved from one branch of the ISO⁷ tree to another. As a result of this modification, the unique identifiers (OIDs⁸) for some object changed. These changes required changes to the software, which was still under development.

Definitions

Interchangeability: the capability to exchange devices of the same device type (e.g., a signal controller from different vendors) without changes to the software beyond updating the appropriate parameters and variables. Some non-standard functions and features might not be available.

Interoperability: the capability to operate devices from different manufacturers, or different device types (e.g., signal controllers and VMS) on the same communications wire/channel.

5. NTCIP FUNCTIONS AND FEATURES

This section discusses the NTCIP functions and features implemented. NTCIP Conformance Groups, Optional Object Definitions, and the required "MULTI Tags" specified for the VMS are listed in ANNEX A.

5-1 OBJECTS & CONFORMANCE GROUPS

Project specifications required that the new signs provide the same functions as the existing signs. The VENDOR related these functions to conformance groups and to the standard MIBs. The NTCIP standards defined the necessary objects. The VENDOR produced a standard product for multiple clients and therefore delivered support of additional features not required by this AGENCY.

Sub-ranged values were not specified; however, the delivered project included the following limitations, which were acceptable to the agency:

- The scheduled memory type was not implemented (nor was the scheduling conformance group)
- The colors were limited to two values to reflect a monochrome display
- 32 permanent messages, 125 changeable messages, 1 volatile message, and 1 current buffer message were supported.

These sub-ranged values are not defined in a separate MIB⁹.

No proprietary objects were implemented on this project. However, the VENDOR needed to add an interpretive function; the message "zero" was sent to blank the sign.

⁷ International Standards Organization

⁸ Object ID is a globally unique number associated with a particular object definitions or data element. These numbers are needed for any NTCIP implementation.

⁹ The VENDOR suggested they most likely should have been.

Some system performance was sacrificed because of bandwidth limitations. The amount of time to display a message has increased. The old system required 10 seconds and the new system requires 35 seconds on a good day. This exceeded the AGENCY's 20-second polling interval and caused system problems that required additional development time. This problem could not be attributed solely to the protocol¹⁰, but also to the design of the central software. However, the numbers of signs per communications line / channel (at a fixed speed) decreased from 8 signs per channel (using the proprietary protocol) to 4 signs per channel (using NTCIP).

5-2 INTERCHANGEABILITY & INTEROPERABILITY

The communications protocol used provides interoperability for this project. However, this interoperability could not yet be tested because only one manufacturer and one type of device were implemented¹¹. The system should be able to support other device types, but the appropriate (standard) MIBs have not been implemented in the AGENCY's central system.

The project used only standard objects, so it should also provide interchangeability. The controller is an integral part of the VMS. Therefore, it is impossible to change out just the controller, and it is impractical to change out an entire sign.

5-3 THE LEARNING CURVE

AGENCY staff was knowledgeable about information technology (IT), although SNMP concepts were relatively new to them. AGENCY personnel also served on the NTCIP DMS Working Group (WG) and the NTCIP Joint Committee. Like the AGENCY, the VENDOR was a member of the NTCIP DMS WG, but had little experience with SNMP.

6. TESTING COMPLIANCE

The testing procedures were developed as a cooperative effort between VENDOR and AGENCY, and were approved by AGENCY. The VENDOR developed a field device simulator compatible with the central system. The specifications required the VMS to be tested using the NTCIP Exerciser¹² and the NTCIP Field Device Simulator (FDS)¹³. Final acceptance was based on the functionality of the signs within the central system.

Both the NTCIP Exerciser (version 1) and the NTCIP FDS were utilized during the project. While the AGENCY felt that these tools were useful, they were used only at the beginning of the project for preliminary investigations to verify the direction of the project. They were not used for further testing. In general, the Exerciser did NOT perform as expected. From the VENDOR's perspective, the Exerciser would have been much more useful, if the error codes were more informative and the graphical user

¹⁰ At the time of this interview, the AGENCY was trying to decrease the delay within their central system. After the interview, they demonstrated a time of 19 seconds for message download, activation and display.

¹¹ In order to verify interoperability, the agency would like to obtain and test another vendor's product.

¹² The NTCIP Exerciser was developed with funding from FHWA and others to test data packets contained data elements (called object definitions) that are sent in direct-connect multidrop communications. The Exerciser compiles so-called Management Information Bases (MIBs), which are database descriptions that have been developed following a specific defined setup.

¹³ The FDS was developed with funding from FHWA to simulate a field device, i.e., respond to requests. The FDS supports a hard-coded subset of Global Object Definitions as defined in TS 3.4-1996 and was not updated after TS 3.4-Amendment 1 was issued. Additionally, the FDS does not support the functionality associated with the supported object definitions.

interface (GUI) was user-friendlier. In addition, the Exerciser did not reliably parse responses received from device¹⁴.

Two other field device simulators, one developed by the VENDOR and the other by a third party, were used to perform integration work. These simulators provided a more complete object definition set than the Exerciser, and they supported the associated object definition functionality as well. These simulators were not intended to test compliance, but to perform integration work.

Issues associated with the meaning or interpretation of specific object definitions were generally resolved by negotiation between the VENDOR and the AGENCY. The ultimate decision was always left to the AGENCY.

Formal acceptance tests of the VMS were not conducted. Instead, the VENDOR and the AGENCY worked together to integrate the two components according to their interpretation of the standards. Any problems were resolved through discussion. This process was actually joint software integration rather than compliance testing. The AGENCY had final approval.

These procedures for testing compliance were considered satisfactory because the project concluded successfully¹⁵.

7. USING THE NTCIP

The AGENCY and VENDOR representatives were asked to briefly describe the “NTCIP experience.”

7-1 FROM THE AGENCY’S PERSPECTIVE

While it is too early to confirm success, it appears that progress has been made towards the AGENCY’s goals of interoperability and increased competition. The sole-source vendor used by the AGENCY in the past has reduced its prices.

From the AGENCY’s perspective, their experience with the NTCIP was acceptable, but not as good as they had hoped for. The project took longer and cost more than expected (in this case, about three times higher than the cost estimate). For the final cost, the AGENCY could have added three proprietary high performance protocols achieving the goal to increase competition in the market. The added costs of a few additional communication circuits/channels to accommodate these protocols occurred anyway due to increased bandwidth requirements.

Bandwidth, CPU¹⁶ requirements, and memory requirements were the primary technical concerns the AGENCY considered before deciding to use the NTCIP. The AGENCY was also concerned that the NTCIP standards might change during the project, and that the product delivered might not be compatible with the final approved standards. Extra bandwidth was required, but this did not pose a problem because extra communications channel(s) to run NTCIP were needed in any case. While overloading the CPU has not been a problem yet, the AGENCY remains concerned that extra workload at the central computer may cause problems in the future. No memory problems have appeared, and the AGENCY believes the delivered products are compliant with the appropriate NTCIP standards.

¹⁴ The most current version of the NTCIP Exerciser is Version 3.3, in which the reliability and stability problems are solved, according to the software developer. However, the graphical user interface has not changed.

¹⁵ However, both AGENCY and VENDOR acknowledged that this process may not work well on every project, and, especially, it does not result in a universal recognition of acceptance.

¹⁶ Central Processing Unit

The project would have gone smoother if the current versions of the Exerciser and Field Device Simulator had been available from the start, were stable, and had supported the DMS MIB¹⁷. The AGENCY plans to purchase NTCIP VMS signs and adjust central software as necessary, but there are no plans to implement other NTCIP-compliant device types.

7-2 FROM THE VENDOR'S PERSPECTIVE

The VENDOR described the NTCIP experience as stressful, but successful. Their objectives and expectations were fairly realistic when they began the project. The VENDOR's primary concern was that the NTCIP protocols utilized for this project had not been field-tested and field proven. The question was would it work?

While it is still too early to determine how successful these efforts are, the VENDOR believes the NTCIP standards are necessary. This project allowed the VENDOR to develop a standard product instead of developing and implementing many project-specific protocols. They believe their ability to supply NTCIP compliant products will increase their market share¹⁸. The VENDOR plans to incorporate this suite of NTCIP protocols into all of their portable and stationary VMS product lines.

8. LESSONS LEARNED

8-1 FOR AGENCIES

During the interviews, the following recommendations were made for an AGENCY preparing for an implementation:

- **Recognize that the communications infrastructure needs to be analyzed.** There were some bandwidth limitations; the amount of time to display a message has increased; and there was a reduction in the number of signs per line.
- **Plan for increased costs for initial software development.** In this case, the actual cost for the project was about three times higher than the expected cost.
- **Allow increased development time for initial efforts.** The AGENCY expected that implementation of the NCTIP would take 6 months; the VENDOR thought it might be as long as 12 months. It actually took 24 months.
- **Expect few immediate benefits.** While the long-term benefits have not yet been proven, the AGENCY has seen some indication that competition in the market is beginning to decrease sign costs.
- **Install fiber cable.** Fiber-optic cable is the best way to communicate with the field devices.
- **Recognize that early implementations will experience more problems.** Consider waiting to use the NTCIP until there are more competing products available and there is industry compliance testing.

¹⁷ Author's Note: The NTCIP Exerciser supports any MIB, while the FDS only supports certain global objects.

¹⁸ The VENDOR has been awarded other contracts with the AGENCY for 15 – 18 signs.

- **Thoroughly understand what NTCIP is**, what it does, and what it is capable of. This will help avoid conflicts between functionality features and NTCIP requirements within the specifications¹⁹.
- **Use a standard definition of compliance.**
- **Require pre-certification with AGENCY's existing implementation(s).**

While a loosely structured process worked for this implementation, neither the AGENCY nor the VENDOR recommends this approach for future projects. This project is successful because the manufacturer and the state worked closely and effectively together. The AGENCY stated that future specifications should be (and will be) much more specific. If possible, the precise NTCIP requirements should be documented in the original contract rather than on a change order.

8-2 FOR VENDORS

- **Don't try to rush the implementation.** It is complex. Design for a product line that can be used on multiple projects, rather than for a single project.

8-3 RECOMMENDATIONS FOR IMPROVEMENTS TO THE NTCIP STANDARDS

The NTCIP standards were created without any real field experience; thus, problems arose. This project implementation identified several shortfalls in the standards that the VENDOR hopes will be addressed in the next version of the NTCIP standards, and in the DMS standard in particular.

- **Improvements to the Standards**
 - ⇒ Provide an unambiguous way to blank the sign within the DMS standard.
 - ⇒ Add graphics to the DMS standard.
 - ⇒ Allow more than 1 message to be activated at a time (e.g., when alternating between pages, each page could contain a separate message). The current DMS standard allows only one message to be displayed.
 - ⇒ Add additional features to the DMS MIB, such as heating and ventilation objects.
 - ⇒ Provide better descriptions of error conditions. For example, describe the error codes to be returned when modifying the illumination.
 - ⇒ Clarify descriptions. For example, describe the messages displayed after power recovery, and explain how to point to the previous message displayed if another message is displayed when power is lost.²⁰
 - ⇒ Develop standards that are easier to code.
 - ⇒ Develop standards that require less bandwidth²¹.

¹⁹ On another project that the manufacturer is working on, the specification contained conflicts between the features required by the sign and the NTCIP requirements.

²⁰ Author's Note: In fact, existing object definitions allow to point to messages that are to be displayed after certain conditions have occurred. When a power failure occurs, the DMS displays a specific, pre-defined message. The actual problem the VENDOR describes here was to re-display the message that was displayed prior to the power failure, when power is again restored. The solution is to 'load' the previous message into the dms Short Power Recovery Message-object.

²¹ Author's Note: This is the issue that is most often stated in conjunction with NTCIP. The framers and developers of the NTCIP standards felt that complying with the Internet standard was needed to create an open, widely used standard. Any standardized approach comes with a price, made higher, if the transportation community cannot agree on common message sets. The challenge is to provide a means of

-
- ⇒ Develop standards that enable more cost effective devices and system implementations.
 - **Develop an end device simulator** that sets the base line for testing²².
 - **Improving the NTCIP Exerciser:**
 - ⇒ Add a mode where the NTCIP Exerciser can listen on the wire while a real management system talks to a real device.
 - ⇒ Include an emulator that supports all levels of compliance.
 - ⇒ Improve the graphical user interface (GUI) to reduce the “clicks” (steps) needed to get to the objects, and to make line monitoring more understandable.
 - ⇒ Improve the stability of the software.
 - ⇒ Provide automated routines to perform agreed to test procedures.
 - ⇒ Reflect changes and interpretations in revised standards.
 - ⇒ Add a field agent to run in an NT environment.
 - **Enhance the NTCIP Guide.** Include more material concerning specifications and include a universally accepted procedure for compliance testing.
 - **Develop standard or universally accepted test procedures.**
 - **Make NTCIP useable for legacy systems.** The AGENCY’s legacy VMS system used 6 fixed message types to allow control and monitoring of the devices.

8-4 THE NTCIP JOINT COMMITTEE AND FHWA

The following are recommendations provided by the participants of this case study to the NTCIP Joint Committee and FHWA:

- Outreach efforts should address the concerns of those implementing the NTCIP. This is particularly important for standards that apply to signal controllers.
- Assistance in developing specifications would be nice for future projects.
- Development of a universal acceptance test would help ensure interoperability.

creating additional data elements within the framework, while providing a set of standardized objects and communications protocols that can be implemented.

²² Author’s Note: This request requires a large software development effort. Simulators would need to be developed for each device type (such as DMS, Ramp Meter, traffic signal controller) and for different communications infrastructures (such as direct-connect-non-networked, direct-connect-networked, dial-up-non-networked, dial-up-network).

ANNEX A: NTCIP EQUIPMENT DESCRIPTIONS

The communications technologies used for the DMS field devices are described below.

Table A1: Existing NTCIP and Non-NTCIP Equipment

<i>Technology (LED, flip disk, etc.)</i>	<i># of devices</i>	<i>Manufacturer</i>	<i>Communications type</i>	<i>Type (e.g., CMS, VMS, BOS)²³, Size</i>
2x15 LED Flip	4	Telespot	Multi-drop / 1200 bps	VMS
2x22 Fiber Flip	27	Telespot	Multi-drop / 1200 bps	VMS
3x8 Flip Disk	8	Matrix / Telespot	Multi-drop / 1200 bps	VMS
2x8 Flip Disk	12	Telespot	Multi-drop / 1200 bps	VMS
1x22	2	Telespot	Multi-drop / 1200 bps	VMS

Table A2: New NTCIP Devices

<i>Technology (LED, flip disk, etc.)</i>	<i># of devices</i>	<i>Manufacturer</i>	<i>Communications type</i>	<i>Type (e.g., CMS, VMS, BOS), Size</i>
Fiber Flip	3	American Electronic Sign	PMPP / 1200	VMS 2x22
Fiber Flip	1	American Electronic Sign	PMPP / 1200	VMS 1x12

Table A3: Supported DMS Functions and NTCIP Conformance Groups

<i>Conformance Group</i>	<i>Reference Standard</i>	<i>Conformance Status</i>	<i>CAPABILITIES</i>	
			<i>Requested</i>	<i>Implemented</i>
Configuration	TS 3.4	Mandatory	Not specified	X

²³ CMS – Changeable Message Sign, VMS – Variable Message Sign, BOS – Blank out sign. For the purpose of the NTCIP, these groupings of signs are all organized under the term ‘dynamic message signs’ (DMS).

Annex A – Project-Specific NTCIP Items

Conformance Group	Reference Standard	Conformance Status	CAPABILITIES	
			Requested	Implemented
Database Management	TS 3.4	Optional	Not specified	
Time Management	TS 3.4	Optional		X
Timebase Event Schedule	TS 3.4	Optional		
Report	TS 3.4	Optional		
Sign Configuration	TS 3.6	Mandatory		X
GUI Appearance	TS 3.6	Optional		X
Font Configuration	TS 3.6	Optional		
VMS Sign Configuration	TS 3.6	Optional		X
Multi Configuration	TS 3.6	Optional		X
Message Table	TS 3.6	Mandatory		X
Sign Control	TS 3.6	Mandatory		X
Default Message Control	TS 3.6	Optional		X
Pixel Service Control	TS 3.6	Optional		X
MULTI Error Control	TS 3.6	Optional		X
Illumination/Brightness Control	TS 3.6	Optional		X
Scheduling	TS 3.6	Optional		
Auxiliary I/O	TS 3.6	Optional		
Sign Status	TS 3.6	Optional		X
Status Error	TS 3.6	Optional		X
Pixel Error Status	TS 3.6	Optional		
Lamp Error Status	TS 3.6	Optional		X
Fan Error Status	TS 3.6	Optional		
Power Status	TS 3.6	Optional		X
Temperature Status	TS 3.6	Optional		X

Table A4: Supported MULTI Tags²⁴

Tag Name	Description	Requested	Support
Color – Background	The background color for a message	Not specified	Yes
Color - Foreground	The foreground color for a message		Yes
Field	The information to embed within a message that is based on data from some device, e.g., clock calendar, temperature sensor, detector, etc.		Yes
Flash	Activate flashing of the text, define the flash on and off times, and the order of flashing (on/off or off/on)		Yes
Font	Select a font number (as specified within the font table) for the message display.		Yes
Hexadecimal Character	The hexadecimal value of the character to display. Value of a character for display		No
Justification - Line	Specify line justification: left, center, right, or full		Yes
Justification - Page	Specify page justification: top, middle, or bottom		Yes
Manufacturer Specific Tag(s)	Specifies a manufacturer specific tag		No
Moving Text	Specify the parameters of a horizontal moving (scrolling) text		No
New Line	Specify the start of a new line		Yes
New Page	Specify the start of a new page		Yes
Page Time	Specify the page times (t = on , o = off)		Yes
Spacing Character	Specify the spacing between characters		Yes

Table A5: Supported Communications Object Definitions

Conformance Group	Reference Standard	Conformance Status	CAPABILITIES	
			Requested	Implemented
RFC 1213-MIB – data elements	TS 3.3	Mandatory	Sort-of	Yes, but not tested
atTable data elements			Sort-of	Yes, but not tested
netToMediaTable-data elements			Sort-of	Yes, but not tested
RFC 1317-MIB – data elements	TS 3.3	Mandatory	Sort-of	Yes, but not tested

²⁴ The MULTI and all tags are defined within TS 3.6. All tags are optional to be implemented.

Annex A – Project-Specific NTCIP Items

Conformance Group	Reference Standard	Conformance Status	CAPABILITIES	
			Requested	Implemented
RFC 1381-MIB –data elements	TS 3.3	Mandatory	Sort-of	Yes, but not tested
Support of Traps?	TS 3.3	Optional	No	No
STMP	TS 3.4	Optional	No	No
PMPP	TS 3.4	Optional	Sort-of	Yes, but not tested

Table A6: Supported Communications Technologies and Speeds

Technology	1200 bps	2400 bps	9600 bps	14.4 Kbps	19.2 Kbps	56 Kbps	Comments
Multi-drop, half duplex	XX						
Multi-drop, full duplex							
Dial-up - Wire-line							
Dial-up – Wire-less							

ANNEX B: VMS SPECIFICATIONS

This contract was issued using change orders. There were three different change orders but the text was very similar. The text for one of these change orders is provided below.

The Contractor will install the VMS signs with the existing AES protocol and provide a PC program to control the signs as stage 1 of this change order. The Contractor will design and install a NTCIP software update to the VMS signs as stage 2. The software will be based on the most recent draft version of the specification and be mutually agreed upon by the State and the Contractor. The State will write a modification to the existing TSMC VAX computer system to operate the signs. The final product shall support the existing features of the WSDOT VMS system based on Model 2001 FP Electronics controllers.

Please contact Mike Forbis at the Washington State Department of Transportation (206-440-4475) for further details.

ANNEX C: TEST PLANS

No written test procedures were developed for this project. The testing was performed during integration testing with 'on-the-fly' tests.

Please contact Mike Forbis at the Washington State Department of Transportation (206-440-4475) for further details.

ANNEX D: THE NTCIP STANDARDS PROCESS

During the standards development process, all NTCIP standards progress from one stage to another, each of which are described below:

- **Proposal** - someone submits an idea.
- **Working Draft** - The idea is reviewed in committee and goes through an iterative editing process.
- **User Comment** – When the Working Group reaches a reasonable level of consensus on the draft, it is submitted to the Joint Committee and upon their approval, it is distributed for user comments.
- **Recommended** - The Working Group has reached consensus on the document and the Joint Committee elevated the standard to this level by a 2/3rds vote. Typically, the Joint Committee also decides to send to ballot at this point.
- **Approved** - All three Standard Development Organizations balloted the standard, received enough affirmative votes, and have approved the document through their legal department, the standard reaches this level.
- **Published** - After a standard is approved, it then goes to the editorial group who is responsible for proper formatting and copyright statements. Once it is available in published form, the file is removed from the Web Site and the SDOs start charging a fee for it.