
**NATIONAL TRANSPORTATION COMMUNICATIONS FOR ITS PROTOCOL (NTCIP)
CASE STUDY REPORT
NTCIP 9002 v01.04**

Virginia DOT Statewide VMS Project

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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 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 were 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.

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.

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

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.

2. THE CASE STUDY

This report presents a case study of a Variable Message Sign (VMS) implementation by the Virginia Department of Transportation (VDOT). Other project participants include: Odetics ITS, successor to Viggen Corporation, who provided support to VDOT as the AGENCY CONSULTANT, and Daktronics, the VENDOR.

Seventy-seven (77) LED variable message signs will be installed to provide traveler information to motorists throughout Virginia’s transportation network. In addition to the NTCIP, VDOT specified LED displays and walk-in cabinets to minimize operations and maintenance burdens and to allow greater flexibility in using the signs. Dial-up communications over the public telephone network is used to communicate with the signs. Seventeen of the 77 signs are being installed during Phase I. The remaining signs will be installed during Phase II, after demonstrating successful implementation of Phase I.

Important milestones and dates for this project and the applicable NTCIP standards are shown in Table 1. Some delays were anticipated for this project. The advertisement of the project was delayed by about six months until the standard reached Recommended³ status. In addition, a one-year lapse in the project was needed to resolve some structural issues (wind loading) and “traditional” software issues. Construction of foundations and guardrails continued during this lapse.

Table 1: Project Milestones & Dates

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 (SNMP now mandatory and STMP optional)	5/97
Project advertised / Pre-qualification process for vendors described.			7/97
Sign vendors pre-qualified		TS 3.6 formally approved by SDOs through balloting process	9/97
Procurement due			10/97
Project awarded to competent low bid			12/97
	Product specification completed		5/98
	Outsourced NTCIP stack		6/98
	Began software development	Additional amendments for OER, time differential, and dynObj Table recommended and incorporated with previous Technical Revisions	8/98
Cooperative review of NTCIP software status			11/98
	Class B stack complete		12/98
	Class D stack complete		4/99
Acceptance test (First)			3/99

³ See Annex D for explanations of the standards development process and the various status states.

AGENCY	VENDOR	NTCIP Standards Status	Date
	Install Signs (not yet completed)		5/99
Acceptance Test (second)			5/99
		Amendments formally Approved by SDOs through balloting process	10/99 (expected)

3. PROJECT PROCUREMENT

In most cases, the AGENCY ensures that products used on contracts comply with specifications by requiring the prime contractor to select products from a “Qualified Products List.” However, the AGENCY was concerned that the construction contractor could select a vendor with limited qualifications for producing NTCIP-compliant variable message signs. The AGENCY used a low-bid process for this project that required the prime contractor to select the VMS vendor from a list of pre-qualified vendors. VMS vendors were required to participate in a pre-qualification to be eligible to submit a bid. The process used to procure the VMS is described below, while the process used to develop the specifications is described in Section 4.

3-1 PRE-QUALIFICATION

The AGENCY developed a two-part test to pre-qualify vendors. This test consisted of:

- A written statement of qualifications to ensure that the vendor had sufficient experience in delivering the desired product to the transportation industry, and
- A test of a small number of NTCIP features using the NTCIP Exerciser to ensure that the vendor had a reasonable understanding of the NTCIP and could produce a competent bid.

The pre-qualification test consisted of connecting the NTCIP Exerciser⁴ to a sign provided by the VENDOR and running a limited series of tests to demonstrate basic functionality of the sign. The pre-qualification test did not perform full NTCIP-compliance testing because few vendors (if any) could deliver fully NTCIP-compliant devices in time for the pre-qualification test. It would also be difficult to judge vendors’ knowledge of the NTCIP using a written test.

3-2 ADVERTISEMENT / REQUEST FOR PROPOSAL

When the decision was made to require the NTCIP as the primary communications protocol, the AGENCY delayed advertising the project until the NTCIP Standard for Dynamic Message Signs (TS 3.6) was made a Recommended Standard. The advertisement for this project was issued in July 1997; three months after TS 3.6 became a Recommended Standard. The objective of this delay was to ensure that the standard was fairly stable. The NTCIP-relevant portions of the Request for Proposal (RFP) are included in Annex B: VMS Specifications.

⁴ The NTCIP Exerciser was developed with funding from FHWA and others to test data packets containing data elements (called objects) 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.

3-3 SELECTION & AWARD

Six VMS vendors submitted responses to the pre-qualification request. Four of these vendors were pre-qualified prior to release of the RFP. The prime contractor selected the vendor who submitted the low bid.

4. SPECIFICATIONS

The software functionality specifications included the following requirement:

“Both the computer and the field controller software shall comply with the National Transportation Communications for ITS Protocol documents and all related errata sheets by July 1, 1998 as referenced herein. If the ISO OIDs⁵ have been assigned by this date, they shall be used rather than the NEMA-based OIDs for each of the object definitions needed within the sign control software”⁶.

Section 9 of the procurement specifications further refined this statement. Section 9 required compliance with the NTCIP standards listed in Table 2, and defined the mandatory and optional object definitions (data elements) to be used. In addition, Section 10 of the RFP included project-specific specifications for the use of dial-up communications⁷. The NTCIP-relevant portions of the RFP are included in Annex B.

Table 2: NTCIP-Related Standards & Specifications for the VDOT Implementation

Standard	Description
NEMA 3.2 1996 and Amendment 1	Simple Transportation Management Framework (STMF) Conformance Level 2 ⁸ .
NEMA 3.3 1996 and Amendment 1	Class B Profile
NEMA 3.4 1996	Global Object Definitions
TS 3.6 – Pending 1997	NTCIP Joint Standards Committee Recommended Standard for Object Definitions for Dynamic Message Signs (dated March 31, 1997 or as approved)
Dial-up Communication Protocol	Physical Layer – as specified in TS 3.3, Clause 3.2.1.1. Data Link Layer – Point-to-point protocol (RFC 1334, RFC 1661, RFC 1662); Network/Transport Layer – NULL Layer Session/Presentation Layer definition – NULL layers; Application layer definition – as specified in TS 3.2

⁵ ISO OID – International Standards Organization– Object Identifier

⁶ Section 9, Special Provision for Variable Message Sign System, Virginia DOT (See Annex B: VMS Specifications)

⁷ No NTCIP standard for dial-up communication existed at that time.

⁸ Only Conformance Level 1 (SNMP) was ultimately implemented. Interpretation problems within the NTCIP Standards caused the AGENCY not to require the implementation of STMP.

4-1 PROJECT-RELATED NTCIP STANDARDS STATUS

There was some confusion about the status of the NTCIP standards used for the project, and to some extent, the stages of the standards development process.⁹

After the project advertisement (or RFP) was issued in July 1997, the following changes were made to the NTCIP standards:

- **November 1998:** TS 3.2 – Simple Transportation Management Framework. The Octet Encoding Rules (called PER in TS 3.2-1996) were renamed and further refined; and various other non-project relevant modifications were made. *The NTCIP Joint Committee also reaffirmed the Technical Revisions (TRs) that received a status of 'Recommended' from the NTCIP Joint Committee in May 1997. These TRs changed the Conformance Level assignments (SNMP was made mandatory, and STMP became optional).* All new modifications and Technical Revisions were combined into TS 3.2 – Simple Transportation Management Framework – Amendment 1.
- **November 1998:** TS 3.4 – Global object definitions. A time object was added to account for Greenwich Mean Time, the object definitions that address the db-Management mechanism were changed, and “security” object definitions were added. All new modifications and Technical Revisions were combined into TS 3.4 – NTCIP Global Object Definitions – Amendment 1.
- **November 1998:** TS 3.6 – DMS specific object definitions. Editorial changes were made, and a statement was added to require amendments to the standard to be posted on the NTCIP web site.

The VENDOR felt that the modifications introduced in November of 1998 had a significant impact on the project, even though the project specification¹⁰ required support of Conformance Level 2, as defined within NEMA TS 3.2-1996. The November 1998 modification reaffirmed the previous Technical Revision and, consequently, should have had no effect on the implementation since both standards still needed to be supported. However, the VENDOR felt it added additional development costs.

The VENDOR believed that TS 3.6 (the DMS Standard) was a “User Comment” version, when the project began and that it was approved as a Recommended Standard during the course of the project¹¹. During the interviews, it was also evident that the difference between a “Recommended Standard” and “Published Standard” was not clearly understood at the beginning of the project.

The status of the specification for dial-up communications was not clear to the individuals interviewed. The NTCIP effort had not developed a standard for dial-up communications when the specification for this project was written. The dial-up specification (Section 10) was neither an NTCIP standard nor an NTCIP draft standard. It was a project-specific requirement unique to this project. Subsequently, this specification was submitted to the NTCIP Profiles Working Group (WG) for consideration, where it was used as the basis for the first draft version of SP-PPP (the official name for the dial-up specification). The NTCIP Profiles WG expects to issue a ‘User Comment Draft’-version of SP-PPP prior to the end of 1999.

4-2 SPECIFICATIONS DEVELOPMENT

The AGENCY and an AGENCY CONSULTANT concurrently developed the specifications for this project. The AGENCY developed the hardware and software functionality specifications using existing VMS specifications, and the AGENCY CONSULTANT developed the NTCIP-related specifications.

⁹ The “seven stage” standards development process (Proposal, Working Draft, User Comment, Review, Recommended, SDO ballot, SDO Approval, and Publication) is described in Annex D.

¹⁰ See Annex B, IV, clause 9, second paragraph.

¹¹ The project specifications spelled out the version of the draft standard to be used.

While everyone interviewed thought the specifications for this project thoroughly defined the NTCIP, there were a few instances where the functional requirements were ambiguous, or, depending on how the clause was interpreted, conflicted with the NTCIP. Some features were not standardized within NTCIP, but addressable as a proprietary feature. A few examples are cited in Section 5-1.

The AGENCY and VENDOR interpreted the roles and responsibilities described in specifications differently. The AGENCY assumed that that they and their CONSULTANT would develop and execute the test plans. The VENDOR, however, noted a line item in the specifications that required them to develop the test plan to be approved by the AGENCY. Another example is the use of the NTCIP Exerciser. The AGENCY thought use of the Exerciser was clearly specified, while the VENDOR did not.

This and other minor inconsistencies were discussed and resolved to the satisfaction of all involved parties. No formal contract modifications were made to the specifications. The only formal change within the project was a structural modification to account for truck-induced wind loading, and was not related to the NTCIP.

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 and are also described in Section 9 of the project specifications (see ANNEX B).

5-1 OBJECTS & CONFORMANCE GROUPS

All of the devices integrated into the system are NTCIP-compliant¹² for the functions and corresponding NTCIP object definitions and communications protocols specified and used within this project. The VMS control software implemented all of the Mandatory Conformance Groups defined in TS 3.4 - 1996, and Recommended Standard TS 3.6 – 1997, as well as many of the Optional Conformance Groups. See Table A1 of Annex A for a complete list of the supported Conformance Groups. Unless otherwise noted, the RFP required all of the standardized object ranges¹³ to be supported. Any exceptions are listed in Table A2 of Annex A.

The VENDOR identified the following issues related to the standardized object definitions of the "Recommended Standards TS 3.6".

- The Lamp Error status objects were not large enough to handle large sign matrices¹⁴. The pixel and lamp nodes seemed redundant because it was not apparent that the lamp node was meant for Fiber Optic VMS.
- The message table does not support the use of message names as a means to identify a message (a method that the VENDOR was accustomed to using).¹⁵

¹² The possible implementation of two protocols within a sign controller was discussed within the industry. This would allow a transition to the NTCIP when the infrastructure or devices are updated. The VENDOR, however, indicated that a dual mode system (NTCIP and non-NTCIP) would be extremely difficult to implement.

¹³ A maximum size, a value range, or an enumerated listing defines object definition ranges.

¹⁴ Author's Note: Apparently the VENDOR used the Lamp Error Status object for Pixel Error Status purposes. While the Pixel Error Status table indicates up to 65535 pixel errors, the lamp error status object was designed for Fiber optic signs where far fewer lamps are used. However, the VENDOR does not work with Fiberoptic technologies and their clients often refer to pixels as lamps. The VENDOR thought that the intention was to offer two ways to address pixel errors.

¹⁵ Author's Note: NTCIP is a communications protocol with certain bandwidth requirements. The VENDOR recognized that activating messages using names instead of numbers would add more bytes to the transmission. However, this feature is desired by their clients, it would enhance the standard and it would only require adding another standard object.

- The DMS Standard object definitions provide limited display functionality. Therefore, the VENDOR developed and implemented a proprietary state-machine based file transfer mechanism as well as a mechanism to simulate thumb-wheel switches. The thumb-wheel mechanism allows a user to point to a message within the message table and to 'scroll' from that message.
- The VENDOR felt that NTCIP required too much overhead, and that it could be made more efficient. A small protocol (about 100 bytes) could provide the control needed in DMS. The SNMP just adds more bytes to deal with¹⁶.

To address these issues, the VENDOR added a private MIB to accommodate a small number of proprietary object definitions to enable file transfer, configuration and intensity control for the LED¹⁷s. The associated globally unique Object Identifiers (OIDs) controlling these non-standardized features were located under the VENDOR's name (node). The AGENCY has the rights to re-use the VENDOR provided MIB for re-distribution within future contracts¹⁸.

5-2 INTERCHANGEABILITY & INTEROPERABILITY

Both the AGENCY and VENDOR feel that the system meets the definitions for interoperability and interchangeability. However, this could not be fully demonstrated without full deployment of all potential devices. There were no apparent instances where interoperability was desired but not fully achieved. The same applies to interchangeability.

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.

5-3 THE LEARNING CURVE

The AGENCY CONSULTANT was well acquainted with the NTCIP; however, NTCIP was new to both the AGENCY and the VENDOR.

The AGENCY CONSULTANT was involved in the development of the NTCIP from its beginning. Staff was and still is involved in the design of the protocol, provides technical expertise and editorial services to the NTCIP. The NTCIP Exerciser was also designed and developed by AGENCY CONSULTANT staff. In addition to its NTCIP Expertise, the AGENCY CONSULTANT is experienced in transportation and information technology services.

The AGENCY staff had significant experience developing specifications for VMS and signal systems, and prior to initiating the project, attended NTCIP awareness workshops. The staff, however, had limited experience with the LED VMS technology used in this implementation, and it was their first experience with implementing the NTCIP. Consequently, the AGENCY depended heavily on their consultant to help

¹⁶ Author's Note: The developers of the NTCIP were aware of the significant bandwidth requirements of SNMP; however, it is not unusual for the benefits of standards to be associated with certain costs. SNMP was selected because of its wide use within the Internet community (and thus extensive technical support) coupled with the flexibility it provides (i.e., selection of SNMP enabled the VENDOR to develop and use the customized objects listed above). A bandwidth- efficient variant of SNMP was developed by the NTCIP effort to accommodate those links where bandwidth is a critical issue.

¹⁷ LED = Light Emitting Diode. LED is a particular DMS technology.

¹⁸ Author's Note: Locating object OIDs under the vendor's node is appropriate and feasible. However, if an agency requires the development of 'special' objects and/or entire MIBs, it may be more feasible to place them under an agency node to ensure that the control of the object lays within the agency (otherwise, the agency might need an agreement with the vendor to maintain the objects until both sides agree to dismiss them).

them understand the NTCIP, as well as to develop the NTCIP specifications and to test compliance for the items defined in the specifications.

While the VENDOR was accustomed to working with protocols used in other VMS applications, the NTCIP was new to them. The VENDOR researched the NTCIP in order to fully understand it and the complications that it presented. Initially, the VENDOR found the standards complex and intimidating. While the Global object definitions (TS 3.4-1996) were understandable, the documentation did not clearly describe some of the DMS object definitions. The use of these object definitions was unclear and open to interpretation. The complexity of the NTCIP standards and the short time-frame available for development lead the VENDOR to outsource the development of the communications stack.

6. TESTING COMPLIANCE

The testing requirements described in the specifications include factory demonstration/ acceptance tests, software tests, system acceptance tests, an operational test period, and specific NTCIP testing. The VENDOR was contractually required to develop a test plan for the deliverable, which was approved by the AGENCY with help from their AGENCY CONSULTANT. The AGENCY estimated that NTCIP-compliance testing would require 5 days to test both central and field devices. Testing performed by the VENDOR included an initial 4-day effort, followed by a 2-day effort to be conducted before the end of the project. The VMS testing procedures¹⁹ and test plans provide step-by-step instructions for testing each NTCIP Conformance Group using the NTCIP Exerciser. The procedures for testing the VMS and those for testing the central control software²⁰ are included in Annex C. NTCIP testing was conducted by the AGENCY, AGENCY CONSULTANTS, and by the VENDOR.

The specifications required use of the NTCIP Exerciser to test NTCIP-compliance²¹. The original version of the NTCIP Exerciser software (Version 3.2 Beta) did not support the dialup communications infrastructure used in this project, nor did it perform functionality testing. The AGENCY CONSULTANT²² modified the NTCIP Exerciser to support dial-up communications and to allow the Exerciser to act as a field device. This version was then used to test required NTCIP-compliance of the VMS²³. The VENDOR used in-house software development tools including a WinNT-based NTCIP VMS simulator to test software during development without connecting to actual devices..

The AGENCY and the VENDOR found the NTCIP Exerciser useful, and in general felt it performed as expected. New users found the software difficult to use; however, this improved as the user became more familiar with it. The NTCIP Exerciser (version 3.3) worked well for the Class B Profile, which included direct connect and multidrop environment without networking capabilities. The dial-up feature was new and had not been tested independently. Consequently, a few bugs in the dial-up feature were discovered at the time the interviews were conducted. . According to the AGENCY CONSULTANT, all known bugs have now been corrected; but the dial-up feature still has not been rigorously tested. The VENDOR also had difficulty installing the new version of the NTCIP Exerciser and running it in conjunction with a modem setup, which is crucial for dial-up communications.

7. USING THE NTCIP

During the course of the project, there were instances where the AGENCY and the VENDOR interpreted the NTCIP standards or the specifications differently. For example, the AGENCY thought the AGENCY

¹⁹ Test Plan for NTCIP Compliance of Daktronics Vanguard TM Variable Message Signs (VMS)

²⁰ Daktronics Field Controller Test Procedure.

²¹ Section VI – F: NTCIP Testing, Virginia DOT

²² These modifications were funded by the AGENCY.

²³ The modified software is now available as version 3.3 beta.

and the AGENCY CONSULTANT were responsible for the development and execution of the test procedures. The VENDOR referred to a line item in the specifications that required them to develop the testplan for approval by the AGENCY. In another case, the AGENCY thought use of the Exerciser was clearly specified, while the VENDOR did not.

7-1 FROM THE AGENCY'S PERSPECTIVE

When asked about their experience with NTCIP, the first spontaneous reaction of the AGENCY representative was "Lost In Space". This response was attributed to the fact that agencies generally are not (and do not need to be) familiar with the underlying communications protocol(s).

The philosophy underlying the NTCIP is very attractive to the AGENCY. The AGENCY expects the NTCIP to help them maximize the communications infrastructure by being able to connect devices of different types and those made by different vendors to the same communications lines.

The AGENCY was among the first to require NTCIP for an implementation. The risk factors that the AGENCY considered with using the NTCIP were that

- much of the NTCIP was in draft form or, in the case of dial-up communications, not yet available.
- it was not clear that industry would embrace the NTCIP.

The key factors that influenced their decision to use the NTCIP for this procurement were the recommendation of the AGENCY CONSULTANT, prior experience with the VENDOR, and encouragement from other agencies. The AGENCY staff had only a general understanding of the NTCIP obtained through awareness workshops. Because the AGENCY CONSULTANT was very familiar with the NTCIP, the AGENCY was confident that expertise was available to support use of the NTCIP for this project.

At this point, the AGENCY believes that the decision to specify the NTCIP was the correct one. When asked if they would specify NTCIP again, the answer was "YES".

7-2 FROM THE VENDOR'S PERSPECTIVE

While the VENDOR has worked with other communications protocols in a number of other applications (transportation is less than 5% of their business), the NTCIP was new to them. Like the AGENCY, the VENDOR also referred to outside experts to understand the NTCIP as well as for the development of the communications protocol aspects (i.e., the 7-Layer Reference Model aspect).

The VENDOR feels that the NTCIP is incomplete and not ready to be implemented. Data elements are missing, standards addressing additional communications infrastructures are not available, and documentation is needed to explain the purpose of each data element and the interaction between them²⁴.

The VENDOR described the NTCIP experience as painful and expensive. At this point it provides minimal return to the VENDOR. If, however, the NTCIP gains national acceptance and if the implementation works, then the development effort would be worth the cost. The VENDOR hopes the experience gained during this project may give them a competitive advantage on other projects²⁵.

²⁴ Author's Note: The parallel NTCIP effort to enhance the NTCIP Guide provides certain explanations and implementation details to users, implementors and vendors. However, it does not provide the level of detail requested by the VENDOR.

²⁵ The VENDOR has also won projects with Delaware Department of Transportation and the Illinois Tollway that require the use of the NTCIP

8. LESSONS LEARNED

8-1 FOR AGENCIES

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

- Have knowledgeable staff. Understand what the NTCIP is all about, how it is used, and whether the cost justifies the goal of mid- to long-term interoperability and interchangeability.
- Gain a thorough understanding of the NTCIP to ensure a “good” RFP and a successful project
- Consider hiring an NTCIP “expert” to provide guidance during the course of the project.
- Understand the standards development process, and the stability (and implications of instability) of standards at specific points in that process.
- Ensure that the functionality requirements, terminology, and descriptions are consistent throughout the specification, and are written clearly and precisely as possible. Avoid general language requiring the use of the NTCIP.
- Make sure agency personnel understand and consistently interpret the specifications.
- If the decision is made to use NTCIP, use it for all transportation devices. Upgrade old equipment for interoperability.
- Either automate testing or have it done by a consultant.
- Do not use a limited pre-qualification test. Many vendors have now implemented the full functionality of the NTCIP (i.e., a particular communications “stack” and many of the functions addressed within the Conformance Groups).

8-2 FOR VENDORS

- Take an active role in the standards development process. The implementation issues presented in this case study suggest that each vendor should be directly involved in developing and reviewing standards to ensure that the standards are understood (and understandable) and that their own product-specific requirements are met.²⁶
- Be prepared to spend a lot of time and money on your first implementation of the NTCIP. The learning curve is steep since you are bound to the standards and cannot “go the quickest route”.
- Consider contacting deploying agencies and/or knowledgeable consultants.

8-3 RECOMMENDATIONS FOR IMPROVEMENTS TO THE NTCIP STANDARDS

- **NTCIP Documentation:** Documentation of the existing NTCIP standards should be enhanced to include descriptions of the intended use of the communications protocols (e.g., difference between PPP and PMPP, for which (combination of) standards are off-the-shelf software packages available). A specific suggestion is to describe the use of object definitions (with examples).
- **Improving the NTCIP Exerciser.** Consider expanding the Exerciser to:
 - ⇒ Support all mandatory and optional items for all supported device types

²⁶ Author’s Note: An attempt was made to involve all vendors in the standards development effort. The DMS Working Group included six vendors and two ITS/NTCIP consultants. In addition, seven public agencies and two other firms provided comments on the User Comment Draft of the DMS standard.

- ⇒ Include the ability to enable or disable any one or groups of the object definitions/data elements.²⁷
 - ⇒ Include functionality, not just communications.
 - ⇒ Include other communications media, such as dial-up (based on the final SP-PPP standard), Ethernet and fiberoptics. Consider the integration of wireless communications, even though the NTCIP Suite of Protocols will NOT cover this topic.
 - ⇒ Include an automated testing process by linking sets of selectable functional requirements to the corresponding (set of) object definition(s).
- **Test Procedures.** Develop a set of modular test plans that can be used on all projects. A modular approach would allow requested NTCIP options to be tested on a project-by-project basis. Industry testing procedures would also clarify how object definitions should be used.²⁸.
 - **TCIP Compatibility.** Maintain compatibility with transit devices, and the Transit Communications for ITS Protocol (TCIP).
 - **Delay changes.** Delay changes in existing NTCIP standards for a year or two to see how the first projects go. Changes should be based on these implementation experiences.
 - **NTCIP Evolution.** Ensure that new versions of the NTCIP are backwards compatible.
 - **NTCIP Standards Development Participation.** Encourage more active participation of the vendor community in the standards development effort for DMS.

²⁷ Author's Note: This feature is available, but requires manual modifications of the initialization files.

²⁸ Author's Note: The interviewees did not indicate whether these test plans should be incorporated into the standard, or if "model" or "standard" test plans should be published as stand-alone documents. The NTCIP is a suite of communication standards. Appropriate test plans must address both communications and device functionality. It is questionable if it would be possible to develop "standard" test procedures for the many combinations of these communications and device functionality standards, or if the industry is ready to develop device functionality standards yet.

ANNEX A: NTCIP EQUIPMENT DESCRIPTIONS

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

Table A1: Supported DMS Functions and NTCIP Conformance Groups

CONFORMANCE GROUP	Reference Standard	Conformance Status	CAPABILITIES	
			Requested	Implemented
Configuration	TS 3.4	Mandatory	A	V
Database Management	TS 3.4	Optional		
Time Management	TS 3.4	Optional	A	V
Timebase Event Schedule	TS 3.4	Optional	A	V
Report	TS 3.4	Optional	A	V
STMF	TS 3.4	Optional	A	
PMPP	TS 3.4	Optional	A	
Sign Configuration	TS 3.6	Mandatory	A	V
GUI Appearance	TS 3.6	Optional		
Font Configuration	TS 3.6	Optional	A	V
VMS Sign Configuration	TS 3.6	Optional	A	V
Multi Configuration	TS 3.6	Optional	A	V
Message Table	TS 3.6	Mandatory	A	V
Sign Control	TS 3.6	Mandatory	A	V
Default Message Control	TS 3.6	Optional	A	V
Pixel Service Control	TS 3.6	Optional	A	V
MULTI Error Control	TS 3.6	Optional		V*
Illumination/Brightness Control	TS 3.6	Optional	A	V
Scheduling	TS 3.6	Optional	A	V
Auxiliary I/O	TS 3.6	Optional	A	V
Sign Status	TS 3.6	Optional	A	V
Status Error	TS 3.6	Optional		

Annex A – Project-Specific NTCIP Items

CONFORMANCE GROUP	Reference Standard	Conformance Status	CAPABILITIES	
			Requested	Implemented
Pixel Error Status	TS 3.6	Optional	A	
Lamp Error Status	TS 3.6	Optional		V
Fan Error Status	TS 3.6	Optional	A	V
Power Status	TS 3.6	Optional		V*
Temperature Status	TS 3.6	Optional		V*

Note: A = Requested by AGENCY
 V* = Implemented without specification requirement.

Table A2: Project-Specific, RFP-Required Object Definition Value Ranges

Object	NTCIP Standard	Min Requirement
maxTimeBaseScheduleEntries	TS 3.4	7
maxDayPlans		7
maxDayPlanEvents		7
maxEventLogConfigs		50
eventConfigMode		2,3,4
maxEventLogSize		200
maxEventClasses		7
maxGroupAddress		1
numFonts	TS 3.6	2
defaultBackgroundColor		0
defaultForegroundColor		At least one of 2, 7, 8, or 9
defaultJustificationLine		2, 3, or 4
defaultJustificationPage		2, 3, or 4
dmsNumPermanentMsg		0
dmsMaxChangeableMsg		0
dmsMaxVolatileMsg		21
dmsFreeVolatileMemory		5kb
dmsControlMode		2, 4, and 5
numActionTableEntries		15

Annex A – Project-Specific NTCIP Items

Table A3: Supported MULTI Tags²⁹

Tag Name	Description	Requested	Support
Color – Background	The background color for a message		V
Color - Foreground	The foreground color for a message		V
Field	The information to embed within a message that is based on data from some device, e.g., clock calendar, temperature sensor, detector, etc.		V
Flash	Activate flashing of the text, define the flash on and off times, and the order of flashing (on/off or off/on)	A	V
Font	Select a font number (as specified within the font table) for the message display.	A	V
Hexadecimal Character	The hexadecimal value of the character to display. Value of a character for display		V
Justification - Line	Specify line justification: left, center, right, or full	A	V
Justification - Page	Specify page justification: top, middle, or bottom	A	V
Manufacturer Specific Tag(s)	Specifies a manufacturer specific tag		V
Moving Text	Specify the parameters of a horizontal moving (scrolling) text	A	V
New Line	Specify the start of a new line	A	V
New Page	Specify the start of a new page	A	V
Page Time	Specify the page times (t = on , o = off)	A	V
Spacing Character	Specify the spacing between characters		V

Table A4: Supported Communications Object Definitions

Conformance Group	Reference Standard	Conformance Status	CAPABILITIES	
			Requested	Implemented
RFC 1213-MIB – data elements	TS 3.3	Mandatory	A	V
atTable data elements				V
netToMediaTable-data elements				
RFC 1317-MIB – data elements	TS 3.3	Mandatory	A	V

²⁹ 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	A	V
Support of Traps	TS 3.3	Optional		V
STMP	TS 3.4	Optional		
PMPP	TS 3.4	Optional		V

Table A5: 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							AGENCY specified but without speed or indication of half or full duplex
Multi-drop, full duplex	V	V	V	V	V	V	V – Any rate
Dial-up - Wire-line	V	V	AV	A* V	A* V	V	V – Any rate
Dial-up – Wire-less	V	V	V	V	V		V - Cellular

Note: A* = Agency requirement within specification

ANNEX B: VMS SPECIFICATIONS

The following contains only the NTCIP-relevant portions of the “VDOT Statewide VMS Project” - RFP (Section 9 and 10). The complete specifications/RFP developed for this project is available for distribution to interested parties by the VDOT. Please contact Emiliano Lopez (VDOT, ITS Division) at 800-220-9076.

VIRGINIA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION FOR
VARIABLE MESSAGE SIGN SYSTEM

Date:

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IV. VARIABLE MESSAGE SIGN FIELD CONTROLLER

A. General - Each sign shall include an associated controller which shall be installed in a cabinet near the sign. **Laptop computer and necessary equipment to program sign controllers shall be provided by the Contractor and remain property of the Contractor.**

Controller hardware and software shall permit the communication with the central computer in either of the following modes which shall be user selectable:

- X Polled Multidrop Operation in which the sign controller **informs** the **central computer** of its current status in response to a query from the **central computer**; or;
- X Event-Driven Operation in which the sign controller not only responds to queries from the **central computer** but also calls the **central computer** by telephone whenever **it detects: restoration of AC power at the sign controller and/or internal VMS temperature exceeds programmed safety limit.** If the line is busy, it shall retry the call at an interval which can be selected by the operator until it connects with the **central computer.**

Annex B – VMS Specifications

Controllers shall be installed to operate over dial-up telephone lines.

Controllers shall be a microprocessor based intelligent unit, capable of controlling and monitoring the variable message sign functions as described in Section III (L). Controllers shall be integral units with their own power supplies. Controllers shall be housed in durably fabricated painted metal enclosures (24 gauge minimum). Controller's volume, and power supplies, shall not exceed five cubic feet and shall fit inside the controller cabinet.

- B. Memory** - Controllers shall have both permanent and changeable memory. Permanent memory shall be in the form of plug-in PROM integrated circuits and shall contain the software. Changeable memory shall be in the form of RAM integrated circuits with a lithium battery backup that retains the data in memory for a minimum of one year following a power failure. Changeable memory shall contain the library of messages, the message display schedule and changeable operating parameters. **Message requirements such as minimum number of messages are specified under Section IV. E. 9 (NTCIP Requirements) Additionally each message shall have the capability to be defined and stored as a three (#) page message.**
- C. Data Transmission Requirements** - Each controller shall have a **EIA/TIA-232E** communication port. **This port shall be capable of operation at a maximum speed of 19,200 bits per second.** Controllers shall be initially installed to operate over dial-up telephone lines. The Contractor shall install a modem conforming to specifications herein and shall connect it to this port and a dial-up telephone line. **The modem shall also automatically detect and adjust to other lower speeds.** Each controller shall also be equipped to readily accommodate an internal Model 400 Modem conforming to the requirements in Chapter 7 of the latest edition of *Traffic Signal Control Equipment Specifications* published by CalTrans.
- D. Clock** - Controller shall contain a computer-readable time-of-year clock with a lithium battery backup. Battery shall keep the clock operating properly for at least 10 years without external power. Clock shall automatically adjust for daylight saving time and leap year through hardware or software or a combination of both. It shall be set by the sign controller's microprocessor. Clock shall be accurate to within 1 minute per month.
- E. Sign controller password** - **Sign controller shall be provided with a eight character (minimum) password, for access to sign controller. Controllers shall be initially shipped with the password (VMSSIM). User shall be able to select a new password once he has accessed sign controller.**

F. Controller Software

1. **Display Presentation** - VMS controller shall control the driver modules in such a way as to create the desired display on the sign. At a minimum, the signs shall be able to display the characters as described in Section III(M). Space allocated to each character shall be proportional to the character's true width. Software shall handle such details as centering text on a line, right justification, left justification, and appropriate spacing of letters and words. **Software include a mechanism to allow the selection of a particular font (single-stroke vs double-stroke).**

Software shall also control flash and alternating between pages of a three-page display. For flashing displays, the flash rate shall be selectable in half-second increments. Any line of a page shall be able to be set to flash while the rest remains steady. For alternating displays, the amount of time each page is displayed shall be selectable in half-second increments. **Software shall be designed to provide/include a default value for each parameter supported. The Contractor shall pre-load these default parameters with either values that have been provided thirty days (30) prior to the first installation or values that the Contractor deems reasonable and as approved by the Engineer.**

2. **Display Selection** - In the absence of instructions to the contrary from the remote control port, the controller shall implement a display selected from those stored in its memory based upon date and time **as specified in the schedule**. It shall use a schedule stored in random access memory plus its time-of-year clock to select the proper display.

The display of the scheduled message may be overridden by instructions sent from the remote control port. A remote computer shall be able to cause the controller to implement a particular display selected from the messages stored in its memory, or a new display **entered through the remote computer**. The remote computer shall also be able to edit or completely replace a message stored in the controller's memory, or revise the message schedule. In addition, it shall be able to cause the controller to report its schedule or the text of any message stored in its memory.

Software shall incorporate fail-safe procedures to check messages received and shall not change a message stored in memory, the display currently on the sign, the schedule stored in memory, or the current time unless the message is received correctly.

Normally, a display shall remain on the sign until either a command to change the current display or the schedule in the controller's memory indicates that it is time for a different display. However, it shall be possible to confer a "priority" status to each stored message. **If the priority status is higher than the status of the message that it is to replace, the new message shall be posted and shall remain on the sign indefinitely until a new command rescinds the priority.** When the

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controller receives a command to change the sign display while a priority display is on the sign, the controller shall transmit a response indicating that the new command was ignored because of the priority status of the current display.

3. **Dimming System** - With each VMS display and controller, the Contractor shall furnish and install a system which shall sense the background ambient light level and provide a minimum of sixteen field adjustable intensities (dimming). Dimming shall be implemented with high frequency variation of the display duty cycle (pulse width modulation). The frequency shall be selected to minimize any detrimental flickering.

The dimming system shall conform to the following minimum requirements:

- A. **Photo-Electric Sensors** B. The dimming system shall contain three commercially available photo-electric sensors installed in water-tight metal enclosures on the VMS housing. The photo-electric sensors shall have a 0.25 inch (minimum) photo-sensitive area. The photo-electric sensors shall be capable of being continually exposed to direct sunlight without impairment of performance. The water-tight metal enclosure shall have a 1.00 square inch (minimum) glass window area. The photo-electric sensors shall be placed so that they sense the ambient light levels striking the front, and rear of each sign. **Sensors shall be located on cabinet to provide access from side of cabinet with walkway. Access to sensors for replacement shall be available to workers from the walkway.**

- B. **Dimming Levels** B The dimming system shall select one of sixteen levels from the sensed ambient light. The set points for each of the sixteen ambient light levels shall be set within user adjustable software.

Manual dimming shall be accomplished locally and remotely. Local control shall be with a laptop computer connected to the port furnished in the field controller. Remote control shall be achieved by calling the field controller with the central or remote computers.

Both dimming modes, manual and automatic shall be provided enabling the user to select the desired mode of operation.

- C. **Interference** B The dimming circuit and VMS power system shall have electrical devices installed to minimize RFI noise generated by the VMS both on the power line and radiated by sign circuitry.

4. **Communication** - The sign controller shall be able to communicate with the central computer via the remote control port in either of two ways: polled multidrop operation or event-driven dial-up operation. This system shall be initially installed as a dial up system. The future communication medium for the polled multidrop shall be fiber or a dedicated hardwired cable. In polled multidrop operation, there is constant communication between each sign controller and the central computer. **Several sign controllers may be on the same communication channel, with each controller assigned a unique ID number. ID numbers for controllers shall conform to the NTCIP requirements for address numbers**

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as indicated in section IV. E. 9 and shall respond only to messages labeled with its ID or to the broadcast address ID. In this system, controllers never initiate communication, but merely transmit their responses to commands or queries from the central computer. The central computer queries each controller frequently about its current status in order to detect problems.

In event driven dial-up communication, communication occurs much less often. Communication is over the public telephone network. Each sign shall have a unique telephone number, which the central computer dials when it wants to issue a command or check on the status of the sign. The controller shall also be able to call the District and central computer, and shall do so whenever it detects a malfunction. If the central computer's line is busy, the sign controller shall keep trying at intervals selectable by the operator until it gets through. When it does connect with the central computer, it shall transmit a status message that includes an identifying number for the sign controller.

The sign controller shall support both modes of operation sequentially, meaning if one mode is working than the functionality of the other cannot be provided.

In either mode of operation, it shall be possible for a maintenance technician to connect a laptop computer to the remote control port, and carry out all operations that could be carried out by the central computer. Connection of a laptop without disconnecting the sign controller shall be accomplished with an additional control port.

All other communication requirements such as checksum and parities are specified under Section IV. E. 9.

5. **Controller ID** - An 8 byte ID code shall be assignable to each controller.
6. **Diagnostic Test** - Upon command from a remote computer, the controller shall test the electrical operation of all drivers and the over current, under current and normal current of the pixels. Field controller shall analyze the pixel current and determine whether the pixel is operating with Anormal \cong , Aunder \cong , or Aover \cong , current and shall **communicate the result using an NTCIP compliant method that can be transmitted according to the NTCIP Class B profile from the VMS to the District and central computers.**
7. **Power Interruptions** - The contents of the controller's memory shall be preserved by battery power during power interruptions and the controller shall resume operation automatically when power is restored. Upon recovering from a power interruption, the controller shall leave the current display on the sign until it receives a command to change it, or until a message change is called for by its schedule. Also, the controller shall report to the **District and central computers** that it has just recovered from a power interruption.
8. **Software Duplication Rights** - The Department shall have the right to duplicate the sign controller software as needed for use in controlling signs under its jurisdiction.

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- 9. NTCIP Requirements** - Both the central computer and the field controller shall comply with the National Transportation Communications for ITS Protocol (NTCIP) documents and all related errata sheets by July 1, 1998 as referenced herein. If the ISO OID's have been assigned by this date, they shall be used rather than the NEMA-based OID's for each of the object definitions needed within the sign control software.

Software shall comply with NEMA TS 3.2 1996, the Simple Management Framework (STMF), and shall conform to Compliance Level 2.

Software shall conform with NEMA TS 3.3 1996, Class B Profile and the Class D Profile as required in Section IV E. 10. All serial ports on the device shall support communications according to these standards. Each port shall support an assignable 1 byte Data Link layer address.

Software shall implement all mandatory objects of all mandatory conformance groups as defined in NEMA TS 3.4 1996, Global Object Definitions, and the NTCIP Joint Standards Committee Recommended Standard for Object Definitions for Dynamic (Variable) Message Signs dated April 1997 or as approved by the Engineer.

Software shall also implement all mandatory objects of the following optional conformance groups as defined in NEMA TS 3.4 1996, Global Object Definitions, and the NTCIP Joint Standards Committee Recommended Standard for Object Definitions for Dynamic (Variable) Message Signs dated April 1997 or as approved by the Engineer.

NEMA TS 3.4 - 1997, NTCIP - Global Object Definitions:

- Time Management
- Timebase Event Schedule
- Report
- STMF
- PMPP

NTCIP Joint Committee Recommended Standard - 1997, NTCIP - DMS Object Definitions:

- VMS Sign Configuration
- Font Configuration
- Multi Configuration
- Default Message Control
- Pixel Service Control
- Illumination/Brightness Control

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- Scheduling
- Auxiliary I/O
- Sign Status
- Pixel Error Status
- Fan Error Staus

Software shall also implement the following optional objects as defined in NEMA TS 3.4 1996, Global Object Definitions, and the NTCIP Joint Standards Committee Recommended Standard for Object Definitions for Dynamic Message signs dated March 1997 or otherwise approved by the Engineer.

- dmsSWReset
- dms Message-Time-Remaining
- dmsMemoryMgmt
- dmsShortPowerRecoveryMessage
- dmsLongPowerRecoveryMessage
- dmsShortPowerLossTime
- dmsResetMessage
- dmsCommunicationsLossMesssage
- dmsTimeCommLoss
- dmsPowerLossMessage
- dmsEndDurationMessage
- dmsMulti-Other-Error-Description
- dmsIllumLightOutputStatus
- watchdog-Failure-Count
- dmsStat-Door-Open
- fanFailures
- fanTest-Activation
- lineVolts

All objects required by these procurement specifications shall support all values within its standardized range. The standardized range is defined by a size, range, or enumerated listing indicated in the objects SYNTAX field and/or through descriptive text in the object's description field of the relevant standard.

The following provides the current listing of known variances for this project.

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OBJECT	MINIMUM PROJECT REQUIREMENTS
TS 3.4-1996	
Max Time Base Schedule Entries	7
Max Day Plans	7
Max Day Plan Events	7
Max Event Log Configurations	50
Event Configuration Mode	2,3, and 4
Max Event Log Size	200
Max Event Classes	7
Max Group Address	1

OBJECT	MINIMUM PROJECT REQUIREMENTS
TS 3.6 Pending-1997	
Number Fonts	2
Max Font Characters	255
Default Background Color	0
Default Foreground Color	Must support at least one of 2, 7, 8, or 9
Default Justification Line	2, 3, 4
Default Justification Page	2, 3, 4
DMS Num. Permanent Msg	0
DMS Max. Changeable Msg	0
DMS Max. Volatile Msg	21
Volatile Memory	5 KB
DMS Control Mode	2, 4, and 5
Number Action Table Entries	15

The software shall implement the following tags (opening and closing where defined) of MULTI as defined in the NTCIP Joint Standards Committee Recommended Standard for Object Definitions for Dynamic Message signs dated April 1997 or as approved by the Engineer.

- Flash

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- Font
- Justification Line
- Justification Page
- Moving Text
- New Line
- New Page
- Page Time
- Scrolling

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:

- The relevant version of each official standard MIB Module referenced by the device functionality.
- 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 field of the associated OBJECT TYPE macro. The filename of this file shall be identical to the standard MIB Module, except that it will have the extension “.man”.
- A MIB Module in ASN.1 format containing any and all manufacturer-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.
- A MIB containing any other objects supported by the device.

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

10. Class "D" Profile Communication Protocol - shall conform to the following requirements:

A. Physical Layer shall conform to the EIA/TIA 232-E interface defined in NEMA 3.2.1.1 and support the following modem command sets:

- Hayes AT - Command Set
- MNP5
- MNP10

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- V.42bis

B. Data Link Layer shall conform to the Point-to Point Protocol (PPP) service as defined in:

- RFC 1334, *PPP Authentication Protocols*
- RFC 1661, *The Point-to-Point Protocol (PPP)*
- RFC 1662, *PPP in HDLC-like Framing*

The IPI shall be indicative of the following format. Implementations shall support the functionality indicated by the following formats as indicated within the PPP packet:

Format	IPI Value	Reference
CHAP	0 x'C223'	RFC1334
STMF	0x'C1'	TS 3.2

C. Network layer Definition: The Network Layer shall be a NULL layer.

D. Transport Layer Definition: The Transport Layer shall be a NULL layer

E. Session / Presentation Layer Definitions: The session and presentation layers shall be NULL layers.

F. Application Layer Definitions: - The application layer shall conform to the protocol referenced by the lower layer. These protocols shall conform to the standards indicated in the table below.

Protocol	Standard
STMF	NEMA TS 3.2

ANNEX C: TEST PLANS

The test procedures developed by the VENDOR for this project are shown below. For further information, please contact Emiliano Lopez (VDOT, ITS Division) at 800-220-9076, or Brian Iwerks / Layne Mostad (Daktronics Inc.) at 888-325-8766.

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.
- **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.