NATIONAL TRANSPORTATION COMMUNICATIONS FOR ITS PROTOCOL

CASE STUDY REPORT

NTCIP 9008 v01.06

Minnesota DOT Statewide R/WIS Project

version 01.06, January 2003. A Recommended Information Report of the Joint Committee on the NTCIP.

PREFACE

When early adopters began using the NTCIP in their deployment activities, there was limited guidance available. Since then, *The NTCIP Guide* (NTCIP 9001) has been developed to help users understand, specify, and deploy the family of standards. NTCIP 9001 version 03 was completed in 2002 and is available.

Early NTCIP deployments and the initial NTCIP case studies identified issues due to content ambiguities and shortfalls in the first version of several standards. Subsequent amendments addressed many of these issues.

Case study reports revealed that functional requirements within user specifications could be improved. As a result, a systems engineering approach to standards development has been adopted to help users better specify NTCIP-based systems. New versions of ITS standards will add sections on concepts of operation, functional requirements, traceability to the data dictionary, and dialogs and sequences.

Early adopters also revealed that testing was an issue in many of their deployments. An NTCIP working group on testing and conformity assessment was created in 2002 to further assess and define testing issues.

The case studies also revealed a general need for continued outreach, education, and training. These needs are being addressed through a variety of ongoing Standards Development Organization activities.

These NTCIP case studies have proved valuable to the ITS community and have facilitated the continued improvement of the standards. As a result of lessons learned from the case studies and improvements in the standards development process, future deployments are expected to face fewer challenges.

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:

a. Prepare a second series of case studies that describe the lessons-learned by vendors, agencies, and consultants during another five of the early projects that required NTCIP compliance, and

b. Update the existing three Case Study projects.

The objective is to compile an unbiased investigation that incorporates the perspectives from different implementation positions.

Two Environmental Sensor Systems (ESS)[1] projects, one Center-to-Center Project using NTCIP 2304 (DATEX-ASN), and two traffic signal control projects were selected for Phase 2 of the study. The two Variable Message Sign (VMS) projects and the one signal control project investigated during Phase 1 are to be revisited to update the status of these projects. Additional projects may be investigated in FY 2003.

The material for these eight case studies (5 new ones and 3 updates) 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. An attempt was made to interview at least three individuals that performed different roles in each project, such as agency champion, procurement specification writer, agency field technician, and vendor representative. The interviews, conducted by individuals familiar with the NTCIP, were structured around an updated 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 one of the ESS implementations using the NTCIP, but 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 an Environmental Sensor System (ESS) implementation by the Minnesota Department of Transportation (MnDOT). Other project participants include: Surface Sensor Inc. (SSI), the Vendor.

Seventy-six (76) ESS using the NTCIP standards were to be installed and placed into operation. The ESS were spaced on an approximate 60-kilometer grid throughout the State of Minnesota. Additionally, the following work items and services were to be provided:

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[1] Environmental Sensor Stations are considered a device subgroup addressed within the NTCIP Standard NTCIP 1204. The term ESS is used to address road weather information systems. ESS were previously termed RWIS.

[2] The 'NTCIP Guide' and the White Paper "Understanding the NTCIP Class Profiles from an End User's Perspective" are excellent sources of information.

- Incorporate the existing 17 road/weather ESS into the new RWIS network;
- Incorporate the existing 50 Automated Weather Observation Systems (AWOS) stations operated by the State Office of Aeronautics into the new RWIS network;
- Incorporate the existing Automated Surface Observing System (ASOS) systems operated by the Federal Aviation Administration into the new RWIS network;
- Incorporate the existing 10 agricultural weather system (CR 10) stations into the new RWIS network;
- Provide roadside equipment, communications systems, an RWIS database integration center, information delivery systems, and other elements that are required for the successful use, operation, and maintenance of the state of Minnesota's RWIS project;
- Incorporate road condition and weather information from all appropriate sources including other states and Canadian provinces, and share it with identified users, and interface with other related programs and systems;
- Provide real-time road and weather data to State Maintenance Area Supervisors; and
- Develop and conduct a successful training program for State staff, and other selected persons, in the operation, support, and maintenance of the integrated system.

The communication with several existing devices was accommodated by connecting the ESS Central System to the central system server of these existing systems. Those connections were dial-up, direct Ethernet, and/or Internet connections. The data from those systems was transmitted using proprietary formats within File Transfer Protocol (FTP) files for which the Vendor wrote 'data translators.' Since these connections and data transmissions were not NTCIP, we have not considered these links further within this report. However, two system diagrams of the overall system are provided in Figure 1 (highlighting the NTCIP links that are the subject of this report) and Figure 2.

Figure 1: MnDOT Statewide R/WIS Project – System Diagram

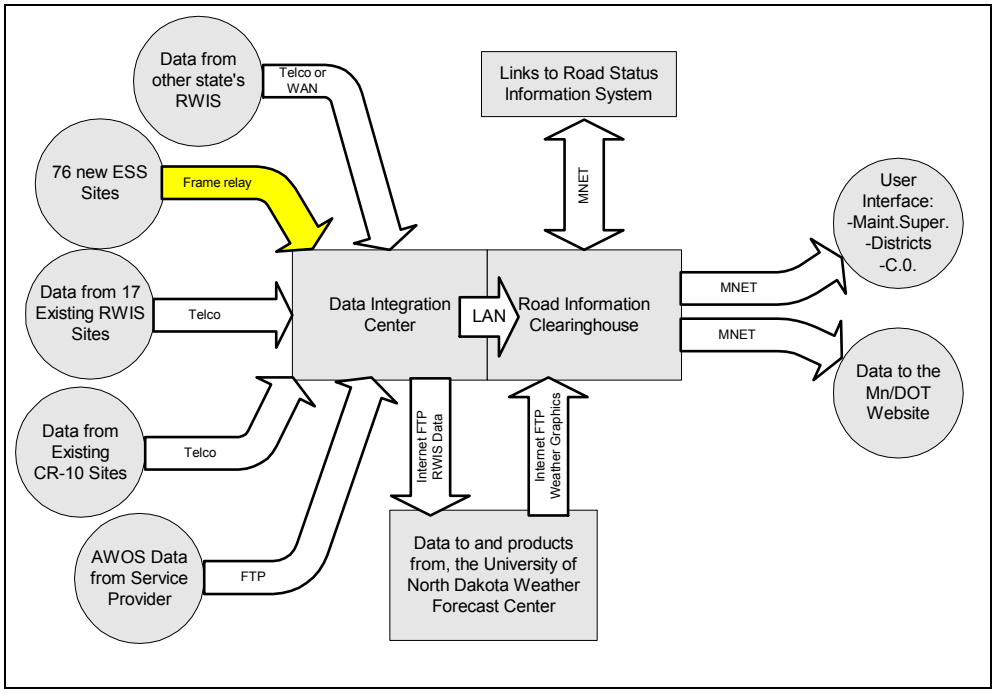
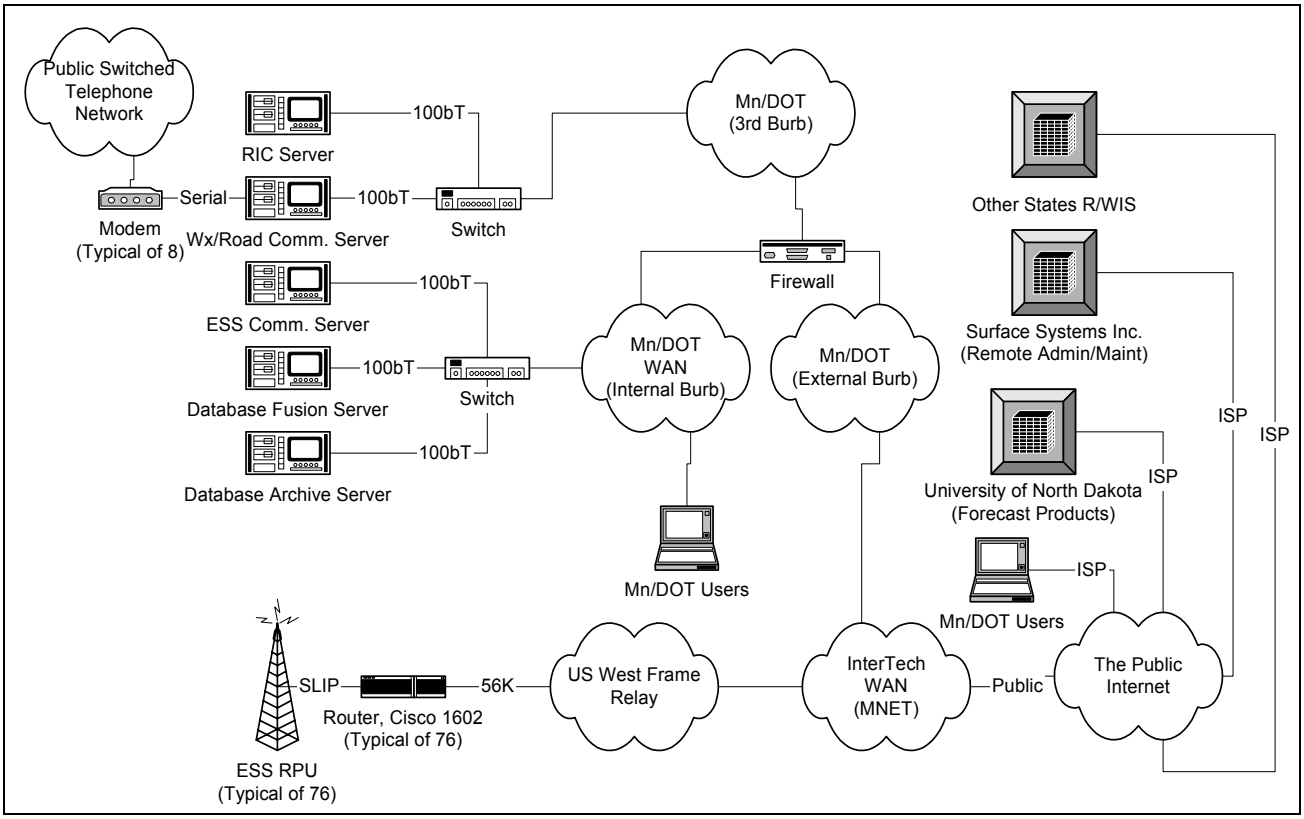


Figure 2: Physical Representation of the Statewide R/WIS system



Important milestones and dates for this project and the applicable NTCIP standards are shown in Table 1.

Table 1: Project Milestones & Dates

AGENCY	*VENDOR*	*NTCIP Standards Status*	*Date*
Report on Road Information Systems Fact Finding Study, by Dean Larson and Edward Fleege. This report was the report of a fact finding tour of Sweden, Finland, and England in February of 1989.	Not applicable	Not applicable	3/89
RWIS Task Force Report to New Technology Research Committee	Not applicable	Not applicable	3/93
Evaluation of Road Weather Information Systems in Minnesota by Braun Intertec Corporation.	Not applicable	Not applicable	9/94
ENTERPRISE Group host a national RWIS workshop for public and private sector entities. This information was used by Mn/DOT in preparing its Request for Private	Not applicable	Not applicable	12/95

AGENCY	VENDOR	NTCIP Standards Status	Date
Partnership.			
MnDOT let a Request for Private Partnership for a statewide RIW project. Two proposals were received. Negotiations were not successful with either group.	Not applicable	Not applicable	7/96
Not applicable	Not applicable	User Comment Draft of TS 3.7 (NTCIP 1204) was approved and distributed.	8/96
MnDOT working through AURORA[3] joined the NTCIP Working Group in developing the NTCIP ESS standard.	Not applicable	Not applicable	11/96
Not applicable	Not applicable	Modifications to TS 3.2 and TS 3.3 first published as Technical Revision (SNMP now mandatory and STMP optional)	5/97
Not applicable	Not applicable	Recommended Standard for TS 3.7 (ESS)	8/97
		Approved Standard for TS 3.7	11/97
The Regional Weather Information Center (RWIC) evaluated 79 potential Environmental Sensor Stations sites throughout the state in Minnesota.	Not applicable	Not applicable	11-12/97
Publication date of RFP for a statewide RWIS project.	Not applicable	Not applicable	4/98
Opening date of the RFP. Four (4) proposals were received.	Not applicable	Not applicable	5/98
Interviews were held with three (3) of the companies that had submitted proposals. July 14, 1998: Surface Systems, Inc. (SSI) was selected as the successful proposer. Negotiations began with writing an Agreement with SSI.	Not applicable	Not applicable	7/98
Not applicable	Not applicable	Additional amendments for OER, time differential, and dynObj Table recommended and incorporated with previous Technical Revisions	8/98
Not applicable	Not applicable	Recommended Amendment to TS 3.7 was approved	9/98
Not applicable	Not applicable	Amendments formally Approved by SDOs through balloting process	10-11/99
An Agreement was signed with SSI.	Not applicable	Not applicable	12/98
Not applicable	Began software development	Not applicable	02/99
Not applicable	First ESS Commissioned (SNMP/UDP/IP/[PPP/Ethernet]	Not applicable	08/99
March 31, 2000: Original work completion date of the agreement.	Not applicable	Not applicable	3/00
The work completion date was	Not applicable	Not applicable	7/01

[3] AURORA = Consortium of Agencies and Countries to promote RWIS equipment.

AGENCY	VENDOR	NTCIP Standards Status	Date
extended to this date.			
Not applicable	Server optional ClassB (SNMP/NULL/PMPP/RS232) stack delivered	Not applicable	08/01
The last deliverable was received and contract is completed.	Not applicable	Not applicable	10/01

The advertisement of the project was published about eight months after the ESS-standard (NTCIP 1204, formerly TS 3.7) reached Recommended[4] status.

3. PROJECT PROCUREMENT

In order to understand the procurement process chosen for this project, the activities leading up to the issuance of the Request for Proposals (RFP) need to be presented. As outlined in the table, the Agency had already conducted a fact-finding tour to other agencies and countries to determine their experiences with RWIS/ESS equipment. Additionally, the Agency went through an unsuccessful attempt to implement a public-private partnership to provide ESS data.

Since the Agency was participating in the NTCIP ESS standards development from an early point in the process, it had confidence and in-house experience to prepare an RFP that required NTCIP as the communications suite of protocols of choice. The agency also had support from a consultant who was also an active member of the NTCIP ESS WG.

The process used to procure the ESS is described below, while the process used to develop the specifications is described in Section 4.

3-1 ADVERTISEMENT / REQUEST FOR PROPOSAL

The decision to require the NTCIP as the primary communications protocol was made, because the AGENCY was looking for an open standards approach that could be easily added onto in the future. Due to their active participation in the other standards development efforts and their Fact Finding Study, the AGENCY had a very good understanding of the potential benefits of open standards. The AGENCY started to participate in the NTCIP ESS effort to ensure that an open standard was developed that addressed its needs.

NTCIP was selected for the project for the following reasons:

- The fact-finding tour of other agencies and countries revealed that one of the major problems was the inability to exchange data among agencies and states.

- The Agency wanted to purchase and install a ‘state-of-the-art’ RWIS system.

- Interoperability among new and existing system was difficult to achieve. The AGENCY understood that it had to develop ‘protocol translators’ to its legacy RWIS systems (AWOS, ASOS, CR 10, and other existing non-NTCIP RWIS systems from a variety of vendors), but the use of NTCIP now and in the future is believed to ensure that further ‘protocol translator’ developments to integrate RWIS products from companies other than the Vendor will not be necessary.

[4] See Annex C for explanations of the standards development process and the various status states.

The advertisement for this project was issued in August 1998; twelve (12) months after TS 3.7 (now known as NTCIP 1204) became a User Comment Draft and one (1) month before it became a Recommended Standard. The Agency was very well aware of the status of the standard and the vendors that could potentially bid on an NTCIP ESS standards implementation. The NTCIP-relevant portions of the Request for Proposal (RFP) are included in Annex B: ESS Specifications.

3-2 SELECTION & AWARD

Four ESS vendors submitted responses to these RFP. The agency started negotiations with three of these vendors, and quickly selected the Vendor based on the following criteria (Note that the Vendor was not the lowest bidder):

1. **Appropriateness of Proposed System** **15%**
   - Consistency with the intent and requirements of the MnDOT RWIS program
2. **Feasibility of Proposed System** **30%**
   - Clear Plan for providing hardware to each variety of sensor site
   - Detailed, realistic time schedule
   - Detailed, realistic cost schedule
3. **Technical Capabilities** **25%**
   - Personnel qualified for the type of services provided
   - Sufficient available tools and technical resources to perform the proposed services
4. **Satisfaction of Functional Requirements** **25%**
   - Ability to satisfy each functional requirement
   - Innovativeness of approach
   - Openness of standards
5. **Reports from Past Users** **5%**
   - Satisfaction of past and current users
   - Responsiveness of proposer in addressing problems
   - Performance on time and within budget

4. SPECIFICATIONS

The Attachment 1, Section 1.09 of the specifications included the following requirement:

> "To meet the challenge of both state-of-the-art systems and adaptability for additional functions, Mn/DOT has chosen to use the National Transportation Communication for ITS Protocol (NTCIP), Object Definitions for Environmental Sensor Stations (ESS), Joint NTCIP Committee Standard TS 3.ESS-199X, published by the American Association of Highway and Transportation Officials (AASHTO), the Institute of Transportation Engineers (ITE), and the National Electrical Manufacturers Association (NEMA). The version available at the time of the preparation of the RFP is dated November 24, 1997, Version 9X.01.11. This document can be downloaded from NTCIP's web site: http://www.ntcip.org.
>
> Coordinated use of appropriate communications and other standards are a part of the Minnesota R/WIS system so that it can be expanded without developing special or new crossover systems. Mn/DOT sees this as an important key to the success of the system over the next 10 years."

Section 4.2 of the procurement specifications further refined this statement. Section 4.2 required compliance with the NTCIP standards listed in Table 2, and required that the Vendor propose all optional Conformance Groups and specific optional object definitions supported to achieve the required functional requirements. Additionally, the RFP stated that vendor-specific object definitions are only to be used if necessary and if approved by the Engineer. MnDOT's Project Engineer was a representative to the NTCIP ESS Working Group, who understood the limitations of the standards. The NTCIP-relevant portions of the RFP are included in Annex B.

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

Standard	*Description*
NTCIP 2301 (formerly NEMA 3.2 – 1996) and Amendment 1	Simple Transportation Management Framework (STMF) Conformance Level 2[5].
NTCIP 2001[6] (formerly NEMA 3.3 1996) and Amendment 1	Class B Profile
NTCIP 1201 (formerly NEMA 3.4 1996)	Global Object Definitions
NTCIP 1204 (formerly TS 3.7)	NTCIP Object Definitions for Environmental Sensor Stations (ESS) Joint NTCIP Committee Standard TS 3.ESS 199X (dated November 24, 1997, Version 9X.01.11 or as approved)
NTCIP 2104 (Dial-up Communication Protocol)	While NEMA TS 3.3 – 1996 was specified, the intent was to provide for dial-up communications. Thus, the specification included a statement to provide for dial-up communications but *"completely transparent, …, to the central computer."* *Note that the requirement for dial-up communications was replaced by a requirement to utilize Frame Relay communications to the ESS devices leading to the replacement of the lower layer profiles (from Null and PMPP232 to TCP/UDP/IP and Ethernet).*

4-1 PROJECT-RELATED NTCIP STANDARDS STATUS

After the project advertisement (or RFP) was issued in July 1998, the following changes were made to the NTCIP standards:

- **November 1998:** TS 3.2 – Simple Transportation Management Framework (now known as NTCIP 1101). 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* (now known as NTCIP 1101) – *Amendment 1*.

- **November 1998:** TS 3.4 – Global object definitions (now known as NTCIP 1201). 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*.

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5 Only Conformance Level 1 (SNMP) was ultimately implemented. The original version of STMF required support of STMP and optional support of SNMP for Conformance Level 1, but the Amendment 1 of this standard reversed this. The Agency only wanted the support of SNMP for this implementation.

6 NTCIP 2001 will be replaced by NTCIP 1102, NTCIP 1103, and NTCIP 8004.

- **September 1998:** TS 3.7 – ESS specific object definitions (now known as NTCIP 1204). Editorial changes, some SYNTAX field and DESCRIPTION field modifications 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 1998 had no significant impact on the project.

4-2 SPECIFICATIONS DEVELOPMENT

The Agency developed the specifications for this project, including hardware-specific, software-specific and NTCIP-specific language. Some of the features that the agency mandated were not standardized in the NTCIP standards. The agency understood that such features outside the NTCIP standards would require vendor-specific data element definitions. To account for this fact, the Agency specifically requested the Vendor to propose the optional conformance groups and optional object definitions to be implemented. Vendor-specific object definitions to address these non-standardized functions had to be approved by the Project Engineer. The Vendor discussed the new functions required by the Agency, in consultation with the NTCIP WG to help determine how to handle this problem, and developed new data elements placed under the vendor's global OID node. These data elements will be added in a new version to the NTCIP ESS Standard.

The Agency developed the necessary specifications for this project. Some features that the Agency required were not standardized within NTCIP, but addressable as proprietary features. A few examples of the proprietary features are cited in Section 5-1. 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 findings of this project were fed back into the NTCIP ESS WG, and most of these features are now being integrated into Version 2 of NTCIP 1204.

Due to the large number of implementation sites and various access and coordination challenges, thirteen (13) different amendments and three (3) change orders to the original specifications were issued over the course of the project. However, none of these were due to NTCIP-related issues. One of the main issues was related to the switch for all the new ESS sites from dial-up telephone lines to the State-owned statewide Frame Relay backbone. This required the Agency to switch to Cisco equipment in order to ensure seamless integration and maintenance. This switch lead to the replacement of the specified TS 3.3 (Class B Profile) standard in favor of the TCP/UDP/IP and Frame Relay (≈ Ethernet) standards, which are both established and well-proven information technology (IT) standards[7].

5. NTCIP FUNCTIONS AND FEATURES

This section discusses the NTCIP functions and features implemented. Besides the mandatory[8] NTCIP Conformance Groups, other optional conformance groups, optional object definitions, and any necessary Vendor-specific object definitions were presented to and approved by the MnDOT Project Engineer. The entire list of implemented Conformance Groups is provided in ANNEX A.

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[7] Both TCP/UDP/IP and Ethernet have been approved as NTCIP Profile Standards in 2002. These NTCIP Standards (NTCIP 2201 and 2104 respectively) do not redefine but merely reference the IT Base Standards.

[8] Mandatory, as defined within the relevant NTCIP Standards for this project.

5-1 OBJECTS & CONFORMANCE GROUPS

All of the new ESS devices integrated into the new system are NTCIP-compliant[9] for the functions and corresponding NTCIP object definitions and communications protocols used within this project. Some existing ESS devices were replaced because their upgrade would have led to higher integration costs than just replacing them. The ESS control software implemented all of the Mandatory Conformance Groups defined in TS 3.4-1996 (now known as NTCIP 1201), and Recommended Standard TS 3.7-1998 (now known as NTCIP 1204), as well as many of the Optional Conformance Groups. See Table A1 of Annex A for a complete list of the supported Conformance Groups. The RFP required all of the standardized object ranges[10] to be supported, but allowed the Vendor to propose exceptions to the standardized value ranges, if approved by the Project Engineer.

The Agency and the Vendor identified the following issues related to the standardized object definitions of the TS3.4-1996 (now known as NTCIP 1201) and TS 3.7-1998 (now known as NTCIP 1204).

- The existing object definition setup does not allow collection of data from multiple readings and addition of a timestamp for each reading[11].

- The defined 'essVisibilitySituation' object definition is MANDATORY within its Conformance Group, but does not really provide any intrinsic value. The also defined 'essVisibility' object definition, which is not defined as MANDATORY in that Conformance Group, provides more useful information to fulfill the Agency's data requirements.

- The Vendor needed to define three (3) additional Vendor-specific object definitions to address particular functional requirements otherwise not covered by any NTCIP Standard. These functions include:

  - Video Imaging (snapshot) – provide a still video image from the ESS site. This is a common function provided in many existing installations.

  - Solar Radiation Averaging – provide the ability to average solar radiation over a short period of time (e.g., 10 minutes). The NTCIP 1204 standard includes an object definition that allows averaging over a 24-hour period, which was not seen as sufficient.

  - Sub-Surface Soil Dielectric Measuring – provide the ability to measure the frost depth or fearing front in the soil.

- The setup of the specific conformance groups did not permit specification of the needed functionality because their setup is too broad. Rather specific object definitions would need to be specified to procure the required functionalities.

To address these issues, the Vendor added a private MIB to accommodate a small number of proprietary object definitions. 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 contracts[12].

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9 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.

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

11 Author's Note: The 'Report Conformance Group' as defined in NTCIP 1201 allows to record multiple readings and associate a timestamp to each recording.

12 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

5-2 INTERCHANGEABILITY & INTEROPERABILITY

Both the Agency and Vendor feel that both the relevant standard and the implemented system meet 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 and the Vendor were very well acquainted with the NTCIP due to their involvement with the ESS standard development effort. Both were involved in the development of the NTCIP ESS Standard from its beginning, and both are still involved in the design of the protocol. Prior to the NTCIP ESS development, the Vendor was already a leading firm in developing and implementing Road Weather Information Systems (RWIS)[13].

While the Vendor was accustomed to working with protocols used in other ESS applications, implementing the NTCIP was new to them. The Vendor researched the NTCIP in order to fully understand it and the complications that it presented. Since the Vendor was involved in the ESS Standards development from the beginning, they had no problems with their implementation.

6. TESTING COMPLIANCE

The project did not include the development of any specific NTCIP-standards compliance testing. Testing was performed to ensure that the functional requirements were indeed implemented and implemented correctly. The Vendor selected a Commercial-Off-The-Shelf (COTS) SNMP Browser and developed a server application (ESS Agent Tester) for use in checking NTCIP data packets during acceptance testing. This software was given to the Agency as a maintenance tool.

Additionally, the same product (with different communications protocols) was comprehensively tested for NTCIP compliance in other implementations (WsDOT [see NTCIP 9009, another NTCIP Case Study] and VDOT).

The NTCIP Exerciser could not be used for this project because it did not (and still does not) cover the selected communications protocols (TCP/UDP/IP).

Later the federally-funded Battelle Testing effort performed testing of the implemented ESS standard. This effort selected fifty-two (52) different object definitions that were determined to be 'core functions' for ESS implementations, and determined that the standards were usable. While the Battelle Testing effort does not test implementations for compliance, the simple fact that the Battelle effort analyzed the implemented communications protocols, monitored and analyzed the 'core function object definitions, can be seen as an indication that the implementation is compliant with the NTCIP standards.

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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).

[13] Note that predominant term in the industry is still RWIS. The NTCIP community chose the term 'ESS (Environmental Sensor Systems)' to broaden the field of applicability to cover non-Road systems such as airports, transit facilities, etc., since the ESS industry not only supplies to Road-bound agencies.

7. USING THE NTCIP

The project was executed as expected. Neither the Agency nor the Vendor expected any problems due to their intimate knowledge of the NTCIP standards and their participation in the development. The objectives of allowing other vendors to bid on future expansion projects and seamless integration of legacy systems were achieved.

7-1 FROM THE AGENCY'S PERSPECTIVE

The Agency described their experience as 'pleasant.' During the project, they experienced no problems that could be attributed to the use of NTCIP that would have not been experienced using other proprietary protocols. The need to develop new object definitions to address the Agency-specific functional requirements (such as the video snap shot ability) was considered a minor problem.

The philosophy of interoperability and interchangeability 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 ESS implementation. The risk that the Agency considered relative to the use of the NTCIP was that much of the NTCIP was in draft form or, in the case of Frame Relay communications, not yet available.

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

At the onset of their NTCIP implementation, the Vendor was a little concerned about the use of a new protocol, but it proved that these concerns were unfounded.

The Vendor indicated that the NTCIP implementation experience was positive and they were 'glad to have done it.' However, the possible myriad of communications protocols may be a cost factor in future projects. In previous installations, they could implement almost any protocol, as long as the implementation worked. This was due to the fact that Request for Proposals (RFPs) have historically been generally silent about this issue, leaving the selection to the Vendor.

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.
- Familiarize yourself with the NTCIP Guide, the data dictionaries, and the communications protocols. An ESS implementation consists of more than NTCIP 1204 and NTCIP 1201 standards.
- Realize that legacy systems do not have to be replaced, but can be integrated into a new 'NTCIP compliant' system.

- Identify the communications infrastructure first and then select/identify the corresponding communications protocols.
- Include the provision of an extensive training program into your RFP that addresses hardware, software, and implemented NTCIP standards.

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.[14]
- As for Agencies, familiarize yourself with the NTCIP Guide, the data dictionaries, and communications protocols.
- Be prepared to do 'lots and lots of reading' in terms of SNMP, other communications protocols, and data dictionaries.

8-3 RECOMMENDATIONS FOR IMPROVEMENTS TO THE NTCIP STANDARDS

- **Improving the NTCIP Exerciser.** Consider expanding the Exerciser to:
  - ⇒ Address the communications stack implemented in this project.
  - ⇒ Provide a more 'user-friendly' user interface.
- **Test Procedures.** The Vendor indicated that the provision of standardized test procedures would be a very good idea[15]. The existing Virginia DOT ESS test procedures were mentioned and praised for their comprehensiveness, but it was mentioned that these would need to be maintained.
- **Continued Funding for Standards Maintenance.** Both interviewees indicated that continuous funding is needed to maintain and enhance these standards.
- **Outreach and Education Training (OET) program.** This is a very good program and should be maintained and possibly expanded.
- **Sample Procurement Specifications.** Provision of sample specs would be greatly appreciated.
- **New Standards.** There is a need to develop additional standards to cover wireless communications and non-intrusive ESS sensors. However, the difficulty to keep up with the ever-faster changing communications protocols was recognized.

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[14] Author's Note: An attempt was made to involve all vendors in the standards development effort. The ESS Working Group included five state agencies (plus a consortium of state agencies, AURORA), three vendors, one university, and two ITS/NTCIP consultants.

[15] The NTCIP community is currently in the process of establishing a Testing WG that will provide a framework of testing procedures. Each device-specific WG will then use this framework to develop the device-specific test procedures, since only these WGs have the domain-specific knowledge.

ANNEX A: NTCIP EQUIPMENT DESCRIPTIONS

The communications technologies used for the ESS field devices are described below. It should be understood that the AGENCY specified the associated functionalities for all vendor-implemented capabilities, but it only required the use of the mandatory Conformance Groups via the specifications.

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	Mandatory	A	V
Timebase Event Schedule	TS 3.4	Optional		
Report	TS 3.4	Optional		
STMF	TS 3.4	Optional		
PMPP	TS 3.4	Optional		(V)
ESS Configuration	TS 3.7	Mandatory	A	V
ESS Location	TS 3.7	Mandatory	A	V
Pressure	TS 3.7	Optional		V
Wind Date	TS 3.7	Optional		V
Mobile Wind Data	TS 3.7	Optional		
Basic Temperature Data	TS 3.7	Optional		V
Enhanced Temperature Data	TS 3.7	Optional		V
Basic Precipitation Data	TS 3.7	Optional		V
Standard Precipitation Data	TS 3.7	Optional		V
Enhanced Precipitation Data	TS 3.7	Optional		V
Emerging Precipitation Data	TS 3.7	Optional		
Solar Radiation	TS 3.7	Optional		V
Visibility Data	TS 3.7	Optional		V
Standard Pavement Sensor Data	TS 3.7	Optional		V

CONFORMANCE GROUP	*Reference Standard*	*Conformance Status*	*CAPABILITIES*	
			Requested	*Implemented*
Enhanced Pavement Sensor Data	TS 3.7	Optional		V
Standard Sub-Surface Sensor Data	TS 3.7	Optional		V
Enhanced Sub-Surface Sensor Data	TS 3.7	Optional		V
Emerging Mobile Platform	TS 3.7	Optional		
Pavement Treatment	TS 3.7	Optional		
Air Quality	TS 3.7	Optional		
Staffed Station	TS 3.7	Optional		

Note: A = Requested by AGENCY
V = Implemented by Vendor

Table A2: Supported Communications Technologies and Speeds (new ESS sites only)

Technology	*1200 bps*	*2400 bps*	*9600 bps*	*14.4 Kbps*	*19.2 Kbps*	*56 Kbps*	*Comments*
Multi-drop, half duplex							
Multi-drop, full duplex							
Dial-up – Wire-line	V	V	V	V	V	V	Used, but speed to certain sites go down to 300 bps.
Dial-up – Wire-less							
OTHER Frame Relay (TCP/UDP/IP over Ethernet)							Each site has up to 64 kbps with a committed information rate (CIR) of 16 kbps

ANNEX B: ESS SPECIFICATIONS

The following contains only the NTCIP-relevant portions of the "MnDOT Statewide Road Weather Information System Project" - RFP (Section 4.2). Please contact Ed Fleege (MnDOT Consultant) at 218-728-1198.

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4.2 Communications Software Protocol Specification

4.2.1 Introduction

To meet the challenge of "state-of-the-art" systems, adaptability and interchangeability for additional functions, Mn/DOT has chosen to use the National Transportation Communication for ITS Protocol (NTCIP), Object Definitions for Environmental Sensor Stations (ESS). Joint NTCIP Committee Standard TS 3.ESS 199X, published by the American Association of Highway and Transportation Officials (AASHTO), the Institute of Transportation Engineers (ITE), and the National Electrical Manufacturers Association (NEMA). This standard is to be used between the environment sensor station and central computer. The version available at the time of the preparation of the RFP is dated November 24, 1997, Version 9X.01.11. This document can be downloaded from NTCIP's website: www.ntcip.org

4.2.2 General NTCIP Specifications

a.) The Central Computer (CPU) and Environmental Sensor Stations (RPUs) software shall comply with the referenced National Transportation Communications for ITS Protocol (NTCIP) when installed. The software shall comply with the versions of the relevant NTCIP standards that are current at the date of this document, or a later version.

b.) The communications software shall comply with NEMA TS 3.2, *Simple Transportation Management Framework,* and shall meet the requirements for Compliance Level 2 support and the Recommended Technical Revision.

c.) The hardware interface shall be EIA/TIA 232-E. The following exceptions are permitted:
1. Additional hardware may be provided which converts this EIA/TIA 232-E signal to a different hardware interface. A Hayes-compatible dial-out modem is one example. Any additional hardware which does not use Hayes-compatible AT commands must be completely transparent, in both hardware and software terms, to the central computer. (The ESS may receive the signal directly. For example, an on-board Hayes-compatible dial-out modem chip is permitted).
2. A 9-pin RS-232 interface is permitted.

d.) The communications software shall comply with NEMA TS3.3 the Class B profile. Other profiles are permitted. However, the Class B profile as defined above must be implemented at the Central Computer for later integration of Environmental Sensor Stations from other manufacturers. The contractor shall clearly state what, if any, exceptions from the Class B profile will be implemented.

e.) The software shall implement all mandatory objects of all mandatory conformance groups as defined in *Global Object Definitions*, NEMA TS 3.4, and *Environmental Sensor Stations*, NEMA 3.7.

f. The contractor shall state in the proposal which optional conformance groups will be supported, and which specific objects. Manufacturer-specific objects may be used only if no appropriate standard object is available, and must be approved by the project engineer.

g. The software shall be supplied with full documentation, including a 3.5–in. floppy disk(s) and/or CD-ROM, containing ASCII versions of the following MIB files in ASN.I format:

1. The relevant version of each official NEMA Standard MIB Module referenced by the device functionality.

2. If the device does not support the full range of any given object within a NEMA standard MIB Module, a manufacturer specific version of the official NEMA Standard MIB Module with the supported range indicated in ASN.1 format in the SYNTAX field of the OBJECT-TYPE macro. The filename of this file shall be the same as the standard MIB filename with the extension ".man." Additionally, the software shall be supplied with full documentation, including a 3.5–in. floppy disk(s) and/or CD-ROM, containing ASCII versions of any and all manufacturer-specific objects supported by the device in ASN.I format in a manufacturer-specific MIB with accurate and meaningful DESCRIPTION fields and supported ranges indicated in the SYNTAX field of the OBJECT-TYPE macros.

h. The manufacturer shall allow the use of any and all of this documentation by any party authorized by the Minnesota 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.

ANNEX C: 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 two-thirds 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.

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