NATIONAL TRANSPORTATION COMMUNICATIONS FOR ITS PROTOCOL

CASE STUDY REPORT

NTCIP 9006 v01.06

City of Lakewood, Colorado Lakewood Advanced Traffic Management System

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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) was drawn from interviews with individuals who were directly involved in the NTCIP implementation and from project-related documents such as specifications, test plans, and procurement documents. An attempt was made to interview at least three individuals who 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 the implementation of devices using the NTCIP. It does not attempt to explain the details of the NTCIP. Additional information on the NTCIP, including specific NTCIP standards, is available on the NTCIP Website (www.ntcip.org).[2]

2. THE CASE STUDY

In 1996, the City of Lakewood initiated a project to enhance its traffic signal system. This project included two distinct parts, the replacement of the central traffic control system, and the upgrade and purchase of additional traffic signal controllers. The NTCIP was specified as the communications protocol of choice for both. The central system (termed Lakewood Advanced Traffic Management System or Lakewood ATMS) was also required to be extensible in order to add future capabilities for controlling field devices such as NTCIP Dynamic Message Signs and non-NTCIP closed circuit television cameras.

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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 are commonly referred to as Road Weather Information Systems (RWIS).

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.

The project schedule is summarized in Table 1. A test system of nine controllers had been installed along side of the existing legacy equipment for evaluation and acceptance of the system upgrade approach. A separate project was initiated to replace an additional thirteen controllers, which were expected to come online shortly after the interview was conducted, in June 2002. The Agency plans to replace the existing central control system and its associated legacy controllers between 2002 and 2004.

The Agency operates more than 180 traffic signals within the city. This project sought to provide a test-bed of nine intersections from which a comprehensive system upgrade will be launched. The existing traffic signals within the city are comprised of a central system with multi-drop communications and stand-alone signals using time-based operation. The Agency intended to replace the aging centrally controlled system that was originally installed in 1982. Existing NEMA TS 1 traffic signal controllers will be replaced with NEMA TS 2 signal controllers capable of Type 1 and Type 2 actuated configurations from a single controller unit. The existing communications media consists of several half-duplex 1200-baud leased lines connecting traffic signal controllers to the central system. Over time, the existing communications system will be replaced with 9600-baud fiber optic cables that were made available to the Agency by a local telecommunications company in-lieu of right-of-way access and permitting fees. The existing and new devices are described in Table A-1.[3]

This case study focuses on two NTCIP-compliant components of that project. The Vendor and System Integrator for this study were Econolite and TransCore, respectively. MK Centennial was the design Consultant retained to assist the Agency in developing technical specifications for the system.

The objectives of the Agency in implementing this project were:

- To implement a modernized traffic control system that provides increased functionality and flexibility, and allows for easier maintenance and support;
- To utilize a system that was scalable and modular in design, using commercial-off-the-shelf software as much as feasible;
- To utilize NTCIP communication standards in an effort to ensure compatibility with the National ITS Architecture.

The System Integrator's goal was to adapt its system to support the NTCIP, with the ability to use controllers from a variety of manufacturers.

This project is one of the first NTCIP deployments to use equipment from more than one vendor. It was also one of the first to integrate a third party central system with field traffic controllers using the NTCIP.

Table 1: Project Timeline

AGENCY	***INTEGRATOR / VENDOR***	***NTCIP Standards Status***	***Date***
Began writing Specifications & RFP			10 / 96
		NTCIP Standards approved (NTCIP 1201 (formally known as TS 3.4), NTCIP 1202 (formally known as TS 3.5))	11 / 96
		NTCIP Standards published (NTCIP 1101 (formally known as TS 3.2), NTCIP 2001 (formally known as TS 3.3), NTCIP 1201	1 / 97

3 See Annex A of this report.

AGENCY	*INTEGRATOR / VENDOR*	*NTCIP Standards Status*	*Date*
		(formally known as TS 3.4), NTCIP 1202 (formally known as TS 3.5))	
		NTCIP Pre-ballot Draft issued for NTCIP 1203 (formally known as TS 3.6)	4 / 97
		Modifications to NTCIP 1101 (formally known as TS 3.2), NTCIP 2001 (formally known as TS 3.3) and NTCIP 1201 (formally known as TS 3.4) published as Recommended Technical Revisions	5 / 97
		NTCIP Standards approved (NTCIP 1101 (formally known as TS 3.2), NTCIP 2001 (formally known as TS 3.3))	5 / 97
RFP published			8 / 97
Proposals due			10 / 97
Interviews with Qualified Systems Integrators	Interviews with Qualified Systems Integrators		12 / 97
		Additional amendments recommended and incorporated with previous Technical Revisions (i.e., OER, time differential, dynObj Table)	11 / 98
Notice to Proceed	Notice to Proceed		6 / 98
Original project end date referenced in the Notice to Proceed	Original Project End date		12/99
1st Project Extension issued with a projected end date of 9/00	1st Project Extension		3/00
2nd Project Extension issued with a projected end date of 2/02	2nd Project Extension		12/00
3rd Project Extension issued with a projected end date of 6/01	3rd Project Extension		3/01
4th Project Extension issued with a projected end date of 03/02	4th Project Extension		7/15
NTCIP Operational in Field Test	NTCIP Operational in Field Test		2 / 01
System Accepted	System Accepted		3 / 02

3. PROJECT PROCUREMENT

3-1 PRE-QUALIFICATION

No pre-qualification was required for the Lakewood ATMS.

3-2 ADVERTISEMENT / REQUEST FOR PROPOSAL (RFP)

The Lakewood ATMS RFP was published in August 1997. Proposal responses were due in October 1997. The bid and award procedure for the implementation of the Lakewood ATMS consisted of a two-stage submittal process. In the first stage, contractors submitted a functional proposal without a cost estimate. These proposals were essentially a technical response to the Lakewood ATMS RFP[4] and a statement of qualifications. Six proposals were received for the Lakewood ATMS[5]. Those proposals scoring the highest in the first stage evaluation were allowed to proceed to stage two of the procurement process.

The second stage of the procurement process consisted of a Request for Clarifications to the original submittal, hourly rates, base contract, and options. Interviews were set up after the second stage proposals were complete. Elements within the proposal were again given percentages based upon the value to the Agency. Final award was made to the group with the highest percentage.

3-3 SELECTION & AWARD

The Agency selected the System Integrator from the group of proposals based upon an evaluation of proposal responses obtained through the two-stage procurement process. Selection criteria for Phase 1 consisted of previous system experience, approach and innovation to system specifications, references, quality of proposal, and key staff experience and availability. The selection criteria for Stage 2 consisted of presentation, response to clarifications, estimated labor hours and labor rates, base contract, and options. A scope of services and a price was negotiated with the winning System Integrator.

The Vendor for traffic signal controller procurements was a partner on the System Integrator team.[6]

4. SPECIFICATIONS

The Agency learned about the NTCIP through meetings and training seminars sponsored by FHWA. The decision was made early to specify NTCIP as a means of providing future compatibility with the National ITS Architecture. At that time (1996), the relevant NTCIP standards were still in a draft form.

The plans and specifications, the functional specification, and the RFP for the controller upgrade were developed by the Agency with outside assistance from a design Consultant hired for the purpose of developing technical specifications for the system. They were written to specify each NTCIP data element to be supported. The specifications went on to describe the optional conformance groups that were required and the supported range value requirements for the data elements. For the traffic signal control equipment, the System Integrator and Vendor were required to provide a conformance statement, cite any reasons for non-conformance, and to provide any alternative solutions. The Vendor identified

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4 See Annex B.

5 Parsons Brinckerhoff; WL Contractors+Econolite; WL Contractors+Peek; Eagle+Siemens; Kaman Sciences+Kimley Horn; and TransCore

6 The TransCore team also included Eagle and PEEK as additional hardware providers for future deliveries.

vendor-specific standard NTCIP object ranges[7] as part of the RFP response, and object definitions to be used in addition to the standard mandatory Conformance Groups and mandatory objects

The Lakewood ATMS (central system) hardware specifications were developed in conjunction with the rest of the system specifications that included software and NTCIP. The hardware specifications required a PC-based server platform from which the central traffic control software would function.

According to the specifications, the Vendor and System Integrator were required to warranty the signal control system and the field controllers for a period of 24 months following acceptance of the deployed system. The specifications set forth detailed NTCIP requirements for the Vendor and System Integrator to meet. The stringent NTCIP requirements, coupled with the desire for a short delivery time, led to problems in finding traffic signal controllers that complied with the specifications. Further complicating the matter was the low quantity of field devices to be purchased under this project without any assurances for future deliveries. Regardless, both the Vendor and the System Integrator were committed to work with the Agency to provide a working implementation of the NTCIP. This commitment included overcoming problems and inconsistencies within the standards, and modifying the implementation if the standards were changed during the course of the project.

4-1 PROJECT-RELATED NTCIP STANDARDS STATUS

The NTCIP standards relevant to this project are shown in the table below.

Table 2: NTCIP-Related Standards and Specifications for the "Lakewood ATMS" Implementation

Standard	*Description*
Very early Draft NTCIP Standard	*May 5, 1995 NTCIP – Working Draft marked "For Committee Reference Only"*[8]
NTCIP 1101 (formally known as NEMA TS 3.2) 1996 and Amendment 1	Simple Transportation Management Framework (STMF) Conformance Level 2.
NTCIP 2001 (formally known as NEMA TS 3.3) 1996 and Amendment 1	NTCIP Class B Profile
NTCIP 1201 (formally known as NEMA TS 3.4) 1996 and Amendment 1	NTCIP Global Object Definitions
NTCIP 1202 (formally known as NEMA TS 3.5) 1996	NTCIP Actuated Signal Controller Object Definitions
Pre-ballot Draft NTCIP 1203 (formally known as NEMA TS 3.6)	NTCIP Objects for Dynamic Message Signs

The Lakewood ATMS project implementation followed on the heels of the implementation of the Phoenix ATMS project,[9] another project that involved both the System Integrator and Vendor. The NTCIP

7 See Annex A, Table A-3 of this report.

8 This "very early draft NTCIP Standard" is show in italics to emphasize the influence this draft had on the NTCIP development within this project, even though it was not the basis for the implementation of this system.

development requirements for both the Phoenix ATMS and the Lakewood ATMS projects largely paralleled each other, since the same Vendor and System Integrator were involved in both projects. In the early stages of these projects, the Vendor and the System Integrator kept abreast of the NTCIP-related working group (WG) activities and had a very good understanding of the protocol and implications of the WG activities. Both the System Integrator and the Vendor began their NTCIP development activities using the May 5, 1995 NTCIP Working Draft marked "For Committee Reference Only" during the specification development. This very early version of the NTCIP standard was still organized in one document and it included only object definitions for traffic signal control[10]. The Vendor began work on their NTCIP implementation using draft standards[11] and subsequent Technical Revisions.[12]

There were several significant changes in the NTCIP that impacted this project. NTCIP 2001 (formally known as TS 3.3) was approved as a NEMA standard in May 1996. This version of NTCIP 2001 required the use of STMP[13]; the use of SNMP[14] was optional. In May 1997, modifications to NTCIP 1101 (formally known as TS 3.2), and to NTCIP 2001 were published as Recommended Technical Revisions, which reversed the requirements for SNMP and STMP. The number of "errata and revisions" to the standards documents made it difficult to "[decide] where to draw the line and move from design to product [implementation]."

5. NTCIP FUNCTIONS AND FEATURES

This section discusses the NTCIP functions and features implemented. NTCIP conformance groups and optional data element (object) definitions are listed in Annex A. Additionally, a number of proprietary data elements to address special functions and the once-per-second communications requirement were created by the Vendor and implemented within the ATMS and the signal controllers.

5-1 DATA ELEMENT AND CONFORMANCE GROUPS

All of the controllers integrated into the system for this project are "NTCIP-compliant." This implementation conforms to "Conformance Level 2" as defined in Amendment 1 of NTCIP 1101 (formally known as TS 3.2-1996[15]). SNMP could not be used exclusively because of bandwidth limitations and because it would not support once-per-second communications.

The specifications defined the data elements and conformance groups to be implemented, but no traffic signal controllers fully supported the specification requirements without substantial investment in new software development. Through a process of negotiation, the Agency, System Integrator, and Vendor agreed upon a set of data element definitions to be implemented.

9 See NTCIP 9004 v1.05, City of Phoenix, Arizona Phoenix Advanced Transportation Management System Case Study for additional details.

10 This version also included concepts of the X.25-format (a network layer protocol) instead of the Internet Protocol (IP), which was specified in later versions of the NTCIP standards. However, no network protocol was used in this implementation.

11 TS 3.1, NTCIP 1101 (formally known as TS 3.2), NTCIP 2001 (formally known as TS 3.3) (4-17-96); NTCIP 1201 (formally known as TS 3.4), NTCIP 1202 (formally known as TS 3.5) (7-13-96).

12 The Amendments to NTCIP 1101 (formally known as TS 3.2), NTCIP 2001 (formally known as TS 3.3), NTCIP 1201 (formally known as TS 3.4) and NTCIP 1202 (formally known as TS 3.5) were approved in 1998.

13 Simple Transportation Management Framework (STMF) describes the organization of the information within devices and the methods of retrieving or modifying any information within the device. STMF also explains how to generate and utilize computer readable information organization descriptions.

14 Simple Network Management Protocol - A communications protocol developed by the IETF (define), used for configuration and monitoring of network devices.

15 Conformance Level 1 requires support of SNMP, while Conformance Level 2 additionally requires the support of STMP.

The list of standard data elements implemented for this project is included in Table A-2;[16] Table A-3 shows the data element value ranges supported. This data element definition set included most of the data elements defined within the mandatory and optional conformance groups of NTCIP 1201 (formally known as TS 3.4-1996) and NTCIP 1202 (formally known as TS 3.5-1996). All optional data elements of the conformance groups were implemented. Proprietary data elements were implemented in order to address several functional requirements that were not provided by the standard object definitions. These proprietary data elements addressed some optional conformance group functionality differently than that defined in the NTCIP standards.

The proprietary data elements also provided additional functions to the mandatory and optional conformance groups as extensions to the standard tables. The Vendor added so-called “block objects” for database management.[17] [18] Both the System Integrator and the Vendor recognized the utility of block objects and this concept is subsequently being incorporated into NTCIP 1202 v2. The System Integrator required status data elements such as a “transition/offset seeking” object and the remote database download request feature.

The data elements to control these features were developed by the Vendor. The unique object identifiers (OIDs) for these data elements controlling the non-standardized features are located at the Vendor’s NEMA node address. The Agency has the right to re-use the Vendor-provided MIB for future contracts within the City.[19] These non-standard features will be used in future applications for the Agency, as well as for future implementations by the System Integrator and by the Vendor.[20]

5-2 INTERCHANGEABILITY & INTEROPERABILITY

The project specifications were developed in such a manner as to require interoperability, i.e., the ability to support other NTCIP devices on the same communications channel. At this point, however, there is no way to tell whether interoperability has indeed been achieved. With only one traffic signal controller manufacturer having supplied equipment for this project and no other NTCIP device on the project, interoperability can neither be confirmed nor denied at this time. Further testing will have to be conducted in order to ensure that interoperability has been achieved.

The System Integrator and the Vendor have assured the Agency that the standardized data elements implemented on this project are in accordance with the published standards. However, there is no way to tell whether these features are interchangeable because there is only one traffic signal controller manufacturer involved in this project and there are no widely accepted test plans for signals.

16 See Annex A.

17 Database management is one of the most important features within a field device. Within a signal controller, manipulating several data elements as a group is critical since the contents are interrelated. Within the NTCIP, there is a standardized mechanism to achieve this, but the implementation provided an additional proprietary mechanism using “block objects”. This is a mechanism where data elements are defined using the MIB OBJECT TYPE Macro, but where the value of an data element contains a proprietary “message”. These “message” setups are such that each byte, or bit within a byte, or several bytes have a particular meaning. This setup is very similar to the messages used in traditional traffic signal communications protocols.

18 The “block objects” are specific to each vendor, and each vendor’s controller uses a different set of “block objects.” This means that the central system software must be modified (adding a software device driver) every time a new controller is being added to the system.

19 Locating object OIDs under the vendor’s node is appropriate and feasible. However, if an agency requires the development of ‘special’ data elements and/or entire MIBs, it may be more feasible to place them under an agency node to ensure that the control of the object remains with the agency. If data elements are under the vendor’s node, the Agency might need an agreement with the Vendor to maintain the objects until both sides agree to dismiss them.

20 The Vendor and System Integrator used the same software for another implementation.

In addition, the Agency has chosen to use features that are not defined in the standard. The standard allows for such extensions and the Vendor and System Integrator provided these features using proprietary data elements. However, the use of non-standard features prevents full interchangeability. The devices may still be interchangeable with the standard features, but not with the proprietary extensions.

5-3 THE LEARNING CURVE

When the project began, various NTCIP standards were still in draft form. The Agency and their Consultant worked together to become familiar with the draft and the later approved standards. The Agency acknowledges, "we were by no means experts." None of the Agency staff had a background or experience in information technology. Knowledge and information that they gained came through attendance at Institute of Transportation Engineers (ITE) seminars, through a review of the NTCIP Guide (NTCIP 9001), and by studying the standards documents themselves. In fact, key staff from both the Agency and Consultant attended weekly self-taught, in-house learning sessions of 2-3 hours each during the development of the project specifications.

The Vendor continues to be an active participant in the development of all versions of the NTCIP documents. Therefore, they were very knowledgeable about the data elements, their meaning and interpretation. The Vendor's continued participation on these NTCIP Working Groups was valuable in another respect. Implementation and interpretation issues that arose during this project were discussed during the course of the standards development. These discussions contributed to the development of the amendments.[21]

The System Integrator has significant experience developing device drivers to communicate with various proprietary protocols. Its staff were very aware of the emerging NTCIP suite of protocols, and had reviewed and commented on various standards. During the development of the central system, the System Integrator used Internet pages and several books to learn about ASN.1, HDLC[22] and SNMP in addition to the NTCIP Guide (NTCIP 9001) and the NTCIP standards publications.

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 DMS) on the same communications wire/channel.

6. TESTING COMPLIANCE

While the RFP defined the specifics of NTCIP compliance,[23] there were no commercial-off-the-shelf products currently available to meet the project

[21] Errors and inconstancies identified by the Vendor during software development were recorded and presented to the appropriate NTCIP WGs. The Vendors recommendations were incorporated in Amendment 1 of NTCIP 1101 (formally known as TS 3.2-1996) and of NTCIP 1201 (formally known as TS 3.4-1996). The Vendor and the System Integrator made the appropriate modifications to ensure a successful implementation.

[22] HDLC – High-level Data Link Control = Data Link Layer protocol

[23] See Annex B.

requirements. Ultimately, the Agency, Vendor, and System Integrator were able to reach a negotiated settlement in defining a set of data elements that would later become the "de-facto" compliance statement.[24]

The Agency was satisfied with the testing process. The System Integrator and the Vendor developed the software code independently, and began integration testing after testing of the individual components was completed. The Vendor and the System Integrator developed the testing procedures collaboratively. The process was essentially an informal exchange of information between the Vendor and System Integrator wherein the System Integrator and the Vendor discussed and worked out problems as they were discovered. In most cases, problems resulted from interpretation of the standards rather than from bad frame constructs. Textbooks and the NTCIP Exerciser were used to resolve frame construction issues. This process worked well and contributed to the development of an integrated system/product.[25]

Overall, the testing process took much longer than expected. Originally, only one week had been scheduled for testing the NTCIP. In reality, the time required was upward of three months. The additional time was the result of testing, software modifications to fix the problems found on both sides, and subsequent retesting.

It should also be noted that the NTCIP communications testing was largely centered on verifying that data objects were properly formatted, set, and retrieved with SNMP, STMP, and the block objects. The System Integrator developed a test suite, along with some macros for the NTCIP Exerciser, to support the protocol testing. Data was verified with the controller local user interface as well.

Functional testing, i.e. testing the controller functionality, was left to the Agency which installed the controllers and tested specific functionality considered essential to the Agency.

6-1 TESTING TOOLS

Use of the NTCIP Exerciser was required within the specifications and it was indeed used for certain testing procedures. In order to utilize the NTCIP Exerciser effectively, the System Integrator had to create a sophisticated set of macros for use on this and the Phoenix projects. No other testing procedures and tools were defined or described in the RFP.

The Vendor conducted compliance testing using several different tools, including DataScan, a GET NEXT tester, and a suitcase tester. The Vendor designed the GET NEXT tester, which automatically sequences through all data elements, and the suitcase tester,[26] which uses dynamic objects to read signal indications, set parameters, and to read or set other data elements. The suitcase tester was also used to test non-standard NTCIP functionality.

The Vendor used the NTCIP Exerciser and the set of macros created by the System Integrator when questions related to frame constructs arose. The Vendor and the System Integrator compared the frames generated by the NTCIP Exerciser to the ones they developed. The NTCIP Exerciser was also used during development of the testing tools mentioned above.

The Vendor chose to develop their own testing tools because the NTCIP Exerciser did not meet their needs. They needed a more sophisticated testing tool with a better user interface. At that stage, the

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24 This does not necessarily mean that every implementation can, or should, implement all of the propriety data elements used in this implementation. The interview did not reveal whether the system could be operated without using these proprietary data elements.

25 Leaving it up to the Vendor and System Integrator could lead to problems when other devices or device types are being added to the system. The interpretation of the NTCIP has to be unambiguous to guarantee that systems can provide interoperability and interchangeability.

26 A 'suitcase tester' is a testing tool contained in a briefcase or suitcase for portability.

setup and the code (software) needed work. The Vendor found it far easier to form frames manually than to use the NTCIP Exerciser.

It should also be noted that the use of dynamic objects (STMP) was critical to the interaction between the central computer and the field controllers, due to the once per second status monitoring and detector uploading requirements. However, the NTCIP Exerciser does not support dynamic objects, hence the System Integrator developed macros and test software to test and verify proper STMP operation.

At the time of the interview (June 2002), the system had been fully tested and accepted by the Agency.

7. USING THE NTCIP

The Agency, System Integrator, and Vendor representatives were asked to briefly describe their “NTCIP experience.”

7-1 FROM THE AGENCY’S PERSPECTIVE

The Agency described their experience as being “a challenge.” While it was “exciting,” the Agency indicated that such an implementation is “not something that they would likely do again without the support and funding from federal agencies.” The Agency indicated that in hindsight, the use of NTCIP when the project began was probably risky given that their funding commitments were city only, which left them in really no position to do research and development. Overall, the project proved to be very successful in the end and provided many learning opportunities along the way.

The Agency considers the RFPs used for this project satisfactory at the time they were developed, and the process used to develop the specifications was generally effective. However, looking back on the project now, the Agency questions the timing of their project, given the immaturity of the NTCIP standards when the project was initiated. The parties involved in this project struggled to “hit a moving target” with respect to revisions to the standards. From the Agency’s perspective, “I guess there had to be pioneers.”

The Agency was especially concerned with the fact that there were very few field devices and systems that were fully NTCIP conformant. In the case of this project, the Agency was in jeopardy of losing their project funding if at least one manufacturer had not been found to substantially deliver within the scope and duration of their project. Looking back, the Agency optimistically believed that manufacturers would actually be ready to build and deploy NTCIP conformant devices in short order after approval of the standards. This optimism eventually led to a 27-month project extension in order to allow for standard stabilization and software development.

The Agency believes strongly in the creation of good lines of communications between the Standards Development Organizations (SDOs), the Federal Highway Administration (FHWA), and the implementing agency in an effort to develop reasonable expectations of what such early implementation projects will cost in terms of time and money. Further, information gained through these early implementations of the standards should be fed back to the SDOs for improvement to the standards documents themselves.

Overall, the Agency feels that “the project has been quite an experience.” The information that they gathered in 1996 pointed to a new era of traffic control becoming a reality, something that had been envisioned for years. The ITS standards, including NTCIP, were to bring this to fruition. From the Agency perspective, the biggest difficulty for the early implementers was the lack of a clear direction on how to deploy the standards after an initial flurry of meetings. The benefits of the new standards were often touted. No one, however, had taken these standards and actually used them in a deployment. The Agency felt that the NTCIP standards used on this project could have been more complete and the NTCIP Exerciser could have been much more of a mature product. The Agency feels that it has taken a quantum leap by implementing their new system and only time will tell as to whether that leap was worth it.

7-2 From the Vendor's Perspective

The Vendor was committed to the implementation of the NTCIP, although they expected interface issues to arise from the onset of the project. The Vendor's primary concern in implementing the NTCIP was bandwidth availability. The NTCIP Class B protocol (as it was referred to in early stages of this project), designed for use with slower communications links, requires more overhead than most of the proprietary protocols in use today. This made it unlikely it would be possible to maintain the same polling cycle time with the same number of controllers per channel and the same data rate. While the Vendor developed upload/download functionality (block objects) to overcome some of the limitations of the 1200 bps communications rate, dependence on the use of these proprietary objects runs counter to the objective of the NTCIP. The number of controllers on each communication line remained at four for both the proprietary protocol and the NTCIP.[27] However, this fact was known at the onset of the project.

While the level of effort required to implement the NTCIP was much higher than anticipated, the implementation itself went smoother than anticipated.

The Vendor encountered errors and problems with the balloted standards. In particular, there were errors in the NEMA PER[28] encoding, dynamic objects were poorly defined,[29] and the design of the upload/download mechanism for the database[30] was not as efficient and clear as it could have been.[31]

7-3 From the System Integrator's Perspective

The System Integrator saw their concern of trying to implement evolving standards realized. However, due to the commitment to ensure a successful implementation, changes and modifications were implemented.

Other concerns included:

a. The overhead associated with SNMP and usage of standard NTCIP data element definitions prohibiting communications over 1200 bps communications lines (even 9600 bps) proved inconvenient. To work around this, a great deal of work was required (development of specific block objects), and it led to the decrease in the number of controllers per communications channel.

b. The standard data element definition sets (NTCIP 1201 and NTCIP 1202) did not support all the operations of the controllers due to proprietary features. This affected virtually every group of objects within NTCIP 1202 and led to the creation and implementation of proprietary (Vendor)

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27 The project design called for four devices per channel for the leased communication lines operating at 1200 bps. The original design for the 9600 bps fiber communication lines called for 24 devices per channel, but the number of devices per channel was reduced to 16 because of the data transmission and polling requirements.

28 Packed Encoding Rules (PER) was developed for use on low bandwidth communications links, as specified in NTCIP 1101 (formally known as NEMA TS-3.2). In the later version of NTCIP 1101 (formally known as TS 3.2-1996) - Amendment 1, these encoding rules were renamed Octet Encoding Rules (OER) because, unbeknownst to each other, the International Standards Organization (ISO) also developed a set of encoding rules they also referred to as PER.

29 Author's Note: The dynamic objects were not as "poorly designed" as a comparison between the first version and the version within Amendment 1 might indicate. The DynObj table was split in two, because it was felt that there would only be one owner of a DynObj. Additionally, some objects that might have been queried using SNMP but contain the STMP DynObj values have been deleted.

30 See NTCIP 1201 (formally known as TS 3.4-1996) under Database Management Conformance Group, and NTCIP 1101 (formally known as TS 3.2)-Amendment 1 under Database Management Conformance Group.

31 Author's Note: These issues have been addressed in Amendment 1 of NTCIP 1101 (formally known as TS 3.2) (STMF), NTCIP 2001 (formally known as TS 3.3) (Class B Profile) and NTCIP 1201 (formally known as TS 3.4) (Global Object Definitions).

MIBs, which will require an adjustment (development of separate device drivers) of the software for each controller type.

c. For certain functionality, the Vendor elected to use proprietary objects instead of the standardized optional objects to manage specific functionality. This meant custom code and additional software development was required.

d. The interactions between some of the custom objects (and implied functionality) and the standards, and optional objects, was not well documented or understood. In this case, it took some experimentation and cooperative work between the Vendor and the System Integrator to identify and resolve issues that arose.

e. The dynamic objects and tight channel timing were the most technically difficult issues for the implementation. Channel timing was critical (with 4 controllers on a 1200 bps channel and a once per second polling rate), and with the complexity of STMP, it was difficult for the Vendor to meet the 40-millisecond line turnaround time requirements.

8. LESSONS LEARNED

8-1 FOR AGENCIES

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

- Gain a thorough understanding of the NTCIP.[32]
- Understand the interchangeability and interoperability effects of NTCIP.
- Have realistic and finite goals and objectives, and work towards those goals and objectives.
- Be careful in preparing your specifications and ensure that manufacturers are able to supply products in a timely fashion.
- Monitor the progress of standards development and the stability of the standards.

8-2 RECOMMENDATIONS FOR IMPROVEMENTS TO THE NTCIP STANDARDS

- **Improve the NTCIP Exerciser.**
  - ⇒ Consider modifying the Exerciser to perform communications testing, and to help construct frames and setup frame sequences.[33]
  - ⇒ Improve the user interface and make the Exerciser more user-friendly.
  - ⇒ Add STMP support and timing management/measurement to the NTCIP Exerciser.
- **Include a data element for transition** that monitors the status of when the controller is actually in a transition state.
- **Consider making more of the optional data element and conformance groups mandatory.**

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32 The NTCIP Guide (NTCIP 9001) proved to be a primary resource for the Agency in understanding the NTCIP.

33 Author's Note: the functionality to perform communications testing and to help construct frames is, and was always, included in the NTCIP Exerciser.

- **Develop standards or universally accepted test procedures** to aid in compliance testing and in defining compliance.

8-3 THE NTCIP JOINT COMMITTEE AND FHWA

- **Continue outreach and education** to inform customers of the development progress and completion of the standards.
- **Ensure backwards compatibility** as standards are maintained.
- **Provide procurement specification examples** from case studies of early implementers.
- **Develop realistic testplans** or testing procedures to help compliance testing and conformance.
- **Improve the NTCIP Exerciser** so that it is a useful tool for testing the NTCIP.
- **Continue improving the NTCIP Guide.** Improve general discussions of data exchange with respect to data rate, system status, and upload/download. Specifically, provide improved discussions on latency issues and bandwidth capabilities.[34]

[34] The most recent published version of the NTCIP Guide is available on the NTCIP homepage and generally addresses these issues.

ANNEX A: NTCIP EQUIPMENT DESCRIPTIONS

Table A1: Existing and New Equipment

Equipment information	*Before project non-NTCIP*	*After project Non-NTCIP*	*After Project NTCIP*
Number of Devices	183 total	174	9
Device Types	SIGNAL CONTROLLERS: IDC/Multisonics 820 controllers	SIGNAL CONTROLLERS: IDC/Multisonics 820 controllers CCTV	SIGNAL CONTROLLERS: Econolite ASC/2
Controller Connection	Multi-drop, Multisonics VMS System	Multi-drop, Multisonics VMS System	Multi-drop, Multisonics VMS System, and NTCIP

Table A2: NTCIP Conformance Groups Implemented for Signal Systems

Conformance Group	*Reference Standard*	*Conformance Status*	*CAPABILITIES*	
			Requested	*Implemented*
Configuration	NTCIP 1201	Mandatory	Y	V=Y / SI=Y
Database Management	NTCIP 1201	Optional	N	V=Y
Time Management	NTCIP 1201	Optional	Y / Mandatory Objects	V=P / SI=Y
Timebase Event Schedule	NTCIP 1201	Optional	Y / Mandatory Objects	V=P
Report	NTCIP 1201	Optional	Y / Mandatory Objects	V=N
STMP	NTCIP 1201	Optional	Y / Mandatory Objects	V=Y
PMPP	NTCIP 1201	Optional	Y / Mandatory Objects	V=N
Phase	NTCIP 1202	Mandatory	Y / partial	V=Y / SI=partially
Detector	NTCIP 1202	Mandatory	Y / partial	V=Y / SI=partially
Vehicle Occupancy Report	NTCIP 1202	Optional	Y / partial	V=Y / SI=Y

Conformance Group	Reference Standard	Conformance Status	CAPABILITIES	
			Requested	Implemented
Unit	NTCIP 1202	Optional	Y / partial	V=Y / SI=partially
Special Function	NTCIP 1202	Optional	Y / partial	V=Y / SI=partially
Coordination	NTCIP 1202	Optional	Y / partial	V=P / SI=partially
Time Base	NTCIP 1202	Optional	Y / partial	V=P
Preempt	NTCIP 1202	Optional	Y / partial	V=P
Ring	NTCIP 1202	Optional	Y / partial	V=Y
Channel	NTCIP 1202	Optional	Y / partial	V=Y
Overlap	NTCIP 1202	Optional	Y / partial	V=Y / SI=partially
TS 2 Port 1	NTCIP 1202	Optional	N	V=Y

Note 1: Y=Yes, N=No, V=Vendor, P = Private objects, SI=System Integrator, partial=a mix of mandatory and optional objects of a conformance groups were used, but not all mandatory objects were needed and therefore not supported.
Note 2: Portions of Coordination objects were supported (being able to command coordination were implemented using standard objects)

Table A3: ECONOLITE ASC/2 Series Controller NTCIP Support

In addition to the above description, the Vendor provided the following information *(excerpt without any changes)* regarding the objects and the object ranges that are supported in this implementation. While providing this information deviates from the approach taken in other case studies, the authors felt this information was too important. However, the implementation also implemented a large number of proprietary objects, which are not provided due to intellectual property rights issues.

ECONOLITE
CONTROL PRODUCTS, INC.

Econolite is currently supporting NTCIP Class B communications in the ASC/2 Series controllers. The level of NTCIP support is as defined in the new NEMA TS2 specification recently approved by NEMA. The specification defines NTCIP Level 1 and Level 2 compliance for actuated controllers. A summary of the NEMA Level 1 and Level 2 compliance for actuated controllers, as set forth in the new TS2 standard, is included as an attachment to this document.

The ASC/2 controller can support system operation using the ASC/2 Level 1 NTCIP objects plus the ASC/2 private objects. Econolite NTCIP software for the ASC/2 controller is currently NEMA NTCIP Level 1 compliant (ASC/2 NTCIP software is currently undergoing integration testing for the Phoenix, AZ; Lakewood, CO; and Salt Lake City, UT ATMS projects). The ASC/2 Level 1 NTCIP software also supports the following optional conformance groups: Database Management as defined in TS 3.4, and Volume Occupancy Report, Unit, Special Function, *Ring, Channel, Overlaps and TS2 Port 1 as defined in TS 3.5. Attached is a list of objects currently supported by the ASC/2 NTCIP Level 1 controller software.*

The NTCIP optional Coordinator, Preemption and Timebase conformance groups are not supported with ASC/2 NTCIP Level 1 compliant software. However, all ASC/2 Coordinator, NIC, Time-of-Day, Holiday and Preemption functions are supported using private objects. Although coordination is supported using private objects, three objects from the NTCIP Coordinator conformance group are supported: "coordPatternStatus," "localFreeStatus," and "systemPatternControl." See the ASC/2 Programming Manual and Appendix B.

Econolite can supply copies of the ASC/2 MIBs if required by project specifications.

The ASC/2 NEMA NTCIP Level 1 compliant software supports the Object Requirements as indicated in the table below.

Table 1 – Object Requirements

Object	***Object Requirements***
TS 3.4	
moduleType	*Value 3*
dbCreateTransaction	*All Values*
dbErrorType	*All Values*
globalDaylightSaving	*Values 2 & 3*
The timebase functions are implemented using private objects. The full ASC/2 NIC, Time-of-Day and Holiday programming operation is supported. Please see the ASC/2 Programming Manual and Appendix B. NEMA NTCIP timebase operation will be supported in the future release of ASC/2 NTCIP Level 2 compliant software.	
maxTimeBaseScheduleEntries	*Future Level 2 (1999)*
maxDayPlans	*Future Level 2 (1999)*
maxDayPlanEvents	*Future Level 2 (1999)*
maxEventLogConfigs	*Future Level 2 (1999)*
NEMA NTCIP event log recording will be supported with the future NTCIP Level 2 software. The ASC/2 now logs controller, detector, and MMU. Our NTCIP Level 1 software will be capable of returning these logs using private objects.	
eventConfigMode	*Future Level 2 (1999)*
eventConfigAction	*Future Level 2 (1999)*
maxEventLogSize	*Future Level 2 (1999)*
maxEventClasses	*Future Level 2 (1999)*
maxGroupAddress	*Future Level 2 (1999)*
TS 3.5	
maxPhases	*12*
phaseStartup	*Values 2 thru 6*
phaseOptions	*All Values*
maxPhaseGroups	*2*
maxVehicleDetectors	*64*
vehicleDetectorOptions	*All Values*
maxPedestrianDetectors	*12*
unitAutoPedestrianClear	*All Values*

Object	Object Requirements
unitControlStatus	All Values
unitFlashStatus	All Values
unitControl	All Values
maxAlarmGroups	2
maxSpecialFunctionOutputs	8
The coordination functions are implemented using private objects. The full ASC/2 coordinator is supported. Please see the ASC/2 Programming Manual and Appendix B. NEMA NTCIP coordinator operation will be supported in the future release of ASC/2 NTCIP Level 2 compliant software.	
coordCorrectionMode	Values 2 thru 4
coordMaximumMode	Values 2 thru 4
coordForceMode	Values 2 & 3
maxPatterns	64
patternTableType	2
maxSplits	12 (one per phase)
splitMode	Values 2 thru 7
localFreeStatus	Values 2 thru 6. The ASC/2 coordinator takes other corrective action to handle bad cycle lengths and out-of-range offsets.
The timebase functions are implemented using private objects. The full ASC/2 NIC, Time-of-Day and Holiday programming operation is supported. Please see the ASC/2 Programming Manual and Appendix B. NEMA NTCIP timebase operation will be supported in the future release of ASC/2 NTCIP Level 2 compliant software.	
maxTimebaseASCActions	The ASC/2 supports timebase operation using private objects, which offer 200 NIC steps and 100 time-of-day steps. Appendix B lists all private timebase related objects. Please refer also to the ASC/2 Programming Manual.8
The preemption functions are implemented using private objects. The full ASC/2 preemptor, including priority and bus preemption, is supported. Please see the ASC/2 Programming Manual and Appendix B. NEMA NTCIP preemptor operation will be supported in the future release of ASC/2 NTCIP Level 2 compliant software.	
maxPreempts	6 plus 4 bus.
preemptControl	Private objects.
preemptState	Private objects.
maxRings	2
maxSequences	The ASC/2 uses the Alternate Sequence operation as defined in the NEMA TS2 specification that essentially supports 16 sequence plans. NEMA NTCIP sequence control will be supported in the future release of ASC/2 NTCIP Level 2 compliant software.
maxChannels	16
channelControlType	Values 2 thru 4
channelFlash	Values 0, 2, 4, 6, 8, 10, 12, & 14
channelDim	Values 0 thru 15

Object	*Object Requirements*
maxChannelStatusGroups	*2*
maxOverlaps	*4*
overlapType	*Values 2 & 3*
maxOverlapStatusGroups	*1*
maxPort1Addresses	*18*
port1Status	*Values 2 & 3*

Enhancements

1. *Extended detector alarm capability provides for up to three different detector alarm periods each day for each of 64 detectors. The NTCIP specification requires only one alarm period.*
2. *Extended objects support the complete set of ASC/2 Phase, Detector, and Overlap functions. Please see Appendix B for a listing of all supported objects.*
3. *Because upload and download operations are very slow using 1200 bps data rates, Econolite supports block upload and download of the ASC/2 database using private MIBs.*

Table A4: Supported Communications Object Definitions

Conformance Group	*Reference Standard*	*Conformance Status*	*CAPABILITIES*	
			Requested	*Implemented*
RFC 1213-MIB – data elements	NTCIP 2001	Mandatory	Not specified	V=Y / SI=N
atTable data elements				V=N / SI=N
netToMediaTable-data elements				V=N / SI=N
RFC 1317-MIB – data elements	NTCIP 2001	Mandatory		V=Y / SI=N
RFC 1381-MIB –data elements	NTCIP 2001	Mandatory		V=Y / SI=N
Support of Traps?	NTCIP 2001	Optional		V=N / SI=N
STMP	NTCIP 1201	Optional		V=Y / SI=Y
PMPP	NTCIP 1201	Optional		V=N / SI=N

Table A5: Supported Communications Equipment and Communications Speeds

TECHNOLOGY	*1200 bps*	*2400 bps*	*9600 bps*	*14.4 Kbps*	*19.2 Kbps*	*56 Kbps*	*COMMENTS*

TECHNOLOGY	***1200 bps***	***2400 bps***	***9600 bps***	***14.4 Kbps***	***19.2 Kbps***	***56 Kbps***	***COMMENTS***
Multi-drop, half duplex	V						
Multi-drop, full duplex							
Dial-up - Wire-line							
Dial-up - Wire-less							
Single-mode fiber optic, Multi-drop, half duplex			V				

Vendor: only Class B Profile was implemented.

ANNEX B: LAKEWOOD ATMS REQUEST FOR PROPOSALS

Unfortunately, the complete wording of the Lakewood ATMS RFP was not available in electronic format.

Please contact Mr. James Richey of the City of Lakewood Traffic Engineering Division (303-987-7985 or mailto:jimric@lakewood.org) for additional information.

EXCERPT FROM THE CITY OF LAKEWOOD ATMS RFP FOR TRAFFIC SIGNAL CONTROLLER NTCIP REQUIREMENTS, PAGES 61-67

The traffic signal controller software shall comply with the referenced National Transportation Communications for ITS Protocol (NTCIP) Standards prior to June 30, 1997. The controller software shall comply with versions of the relevant NTCIP standards **that** are current at the date of this document, or a later version.

The controller software shall comply with NEMA Standards Publication TS 3.2, *"NTCIP Simple Transportation Management Framework,"* and shall meet the requirements for Conformance Level 2. The controller software shall comply with NEMA Standards Publication TS 3.3, *"NTCIP Class B Profile,"* and shall include both an EIA/TIA 232-E and an FSK modem interface for NTCIP based communications.

The traffic signal controller software shall implement all mandatory Conformance Groups as defined in NEMA Standards Publication TS 3.4, *"NTCIP Global Object Definitions"* and NEMA Standards Publication TS 3.5, *"NTCIP Object Definitions for Actuated Traffic Signal Controller Units."*

The controller software shall also implement all mandatory objects of the following optional Conformance Groups as defined in NEMA TS 3.4:

- Time Management Conformance Group;
- Time Base Event Schedule Conformance Group;
- Report Conformance Group;
- STMP (Simple Transportation Management Protocol) Conformance Group; and,
- Point to Multi-Point Protocol (PMPP) Conformance Group.

Additionally, the traffic signal controller software shall implement all mandatory objects of the following optional Conformance Groups as defined in NEMA TS 3.5:

- Volume Occupancy Report Conformance Group;
- Unit Conformance Group;
- Special Function Conformance Group;
- Coordination Conformance Group;
- Time Base Conformance Group;
- Preempt Conformance Group;
- Ring Conformance Group;
- Channel Conformance Group; and,
- Overlap Conformance Group.

The controller software shall also implement the following optional objects as defined in NEMA TS 3.5:

- phaseControlGroupTable; and
- vehicleDetectorReportedAlarms,

It is the City's desire that the controller software also implement the following optional objects as defined in NEMA TS 3.5:

- phaseRedRevert;
- phaseCarsBeforeReduction;
- phaseDynamicMaxLimit;
- phaseDynarnicMaxStep;
- phaseControlGroupForceOff,
- vehicieDetectorQueueLimit;
- vehicieDetectorFailTime;
- vehicieDetectorReportedAlarms;
- preernptMinimumGreen;
- preemptMinirnumWalk;
- preemptEnterPedClear,
- preemptDwellPed;
- preemptState;
- preemptControlTable;
- maxRingControlGroup;
- ringControlGroupTable;
- ringControlGroupMax2;
- ringControlGroupMaxlnhibit;
- ringControlGroupRedRest; and,
- ringControlGroup0mitRedClear.

All objects required by these specifications shall support all values within its standardized range, unless otherwise approved by the city of Lakewood. The standardized range is defined by a size, range, or enumerated listing indicated in the object's SYNTAX field and/or through descriptive text in the object's DESCRIPTION field of the relevant standard. Table 5.1.6.a - Specific Range Values for Actuated Signal Controllers (Required Parameters) provides the current listing of known variances, from the appropriate standard, required by this project. Table 5.1.6.b - Specific Range Values for Actuated Signal Controllers (Desired Parameters) provides the current listing of known variance, from the appropriate standard, desired in this project.

Table 5.1.6.a - Specific Object Range Values for Actuated Signal Controllers (Required Parameters)

OBJECT	MINIMUM PROJECT REQUIREMENTS (value or range)
Global Objects (TS 3.4)	
maxTimeBaseScheduleEntries	48
MaxDayPlans	48
MaxDayPlanEvents	48
MaxEventLogConfigs	48
Actuated Controller Objects (TS 3.5)	
MaxPhases	20(12 vehicle + 4 peds + 4 overlaps)
PhaseNumber	0-20
PhaseYellowChange	3.0 – 35.5 seconds
phaseOptions	Must support editing of bits 0-11, 13, 14
phaseRing	1-4
maxPhaseGroups	3

Table 5.1.6.a – Specific Object Range Values for Actuated Signal Controllers

(Required Parameters) (cont.)

OBJECT	MINIMUM PROJECT REQUIREMENTS (value of ranges)
phaseStatusGroupNumber	3
phaseControlGroupNumber	1-3
maxVehicleDetectors	64(16 volume/occupancy)
vehicleDetectorNumber	0-64
vehicleDetectorCallPhase	0-20
VehicleDetectorSwitchPhase	0-20
maxVehicleDetectorStatusGroups	8
vehicleDetectorStatusGroupNumber	1-8
activeVolumeOccupancyDetectors	1-16
maxPedestrianDetectors	8
pedestrianDetectorNumber	1-8
pedestrianDetectorCallPhase	0-20
unitRedRevert	2.0-6.0
maxSpecialFunctionOutputs	8
specialFunctionOutputNumber	0-8
maximumPatterns	48
patternNumber	48
patternCycleTime	30-255
patternOffsetTime	0-254
patternSplitNumber	0-16
patternSequenceNumber	0-16
maxSplits	0-16
splitPhaseNumber	1-16
splitPhaseNumber	1-20
coordCycleStatus	0-510
coordSyncStatus	0-510
maxTimeBaseActions	48
timebaseASCActionNumber	0-48
timebaseActionPattern	0-48
timebaseActionPlan	0-48
maxPreempts	6
preemptNumber	0-6
preemptControl	0-2

Table 5.1.6.a – Specific Object Range Values for Actuated Signal Controllers (Required Parameters) (cont.)

OBJECT	MINIMUM PROJECT REQUIREMENTS (value of range)
preemptLink	0-6
preemptDwellGreen	1-255
preemptControlNumber	0-6
maxRings	4
maxSequence	16
sequenceNumber	1-16
sequenceRingNumber	1- 4
maxChannels	20
channelNumber	0-20
channelControlSource	0-20
maxChannelStatusGroups	3
channelStatusGroupNumber	1-3
maximumOverlaps	4
overlapNumber	0-4
overlapTrailYellow	3.0-25.5
MaxOverlapStatusGroups	1
overlapStatusGroupNumber	1

Table 5.1.6.a – Specific Object Range Values for Actuated Signal Controllers (Desired Parameters)

OBJECT	MINIMUM PROJECT REQUIREMENTS (value of range)
phaseRedRevert	2.0 - 6.0
phaseControlGroupForceOff	0 - 254
preemptControlNumber	0 – 6
maxRingControlGroups	1

The controller software shall be supplied with full documentation, including 31/2-inch floppy disk(s) containing ASCII versions of the following MIB files in ASN.1 format:

- The relevant version of each official NEMA Standard MIB Module referenced by the device functionality.
- 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.*"
- Any and all manufacturer-specific objects by the software shall be documented in ASN. I format in a manufacturer specific MIB with accurate and meaningful DESCRIPTON fields and supported ranges indicated in the SYNTAX fields of the OBJECT-TYPE macros.

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

5.1.7 Other Optional Features

Optional traffic signal controller features desired include speed detection and transit priority, as described in this subsection. Optional features shall be treated as a manufacturer specific object (in terms of NTCIP) and the software required to implement these features shall be documented in ANS. I format as described in Section **5.1.6 Traffic Signal Controller Communications.**

5.1.7.1 Speed Detection

As an optional feature, vehicle detectors shall be capable of being assigned to a minimum of 16 speed detectors. Speed shall be detected using both one and two detector configurations. When using a one detector configuration, speed shall be calculated using user **specified** values for average vehicle length and average loop length. When using a two detector configuration, speed shall be calculated using a user specified value for the distance between detectors.

5.1.7.2 Transit Priority

As an optional feature, traffic signal controllers shall allow for addition of a future transit preemption module which shall accommodate a minimum of four transit vehicle preempts (priorities). This module will be in the form of an updated, user installable program chip. These transit priority features are anticipated to provide early green or green extension indications for the vehicle phases concurrent with the priority request. Functional characteristics of a desirable priority operation are described in Appendix D.

5.1.7 Testing and Warranty

5.1.8.1 Testing

Test and acceptance shall be based on this specification and on the latest revision of NEMA Standards Publication TS 1 and TS 2. The acceptance tests for controller assemblies will continence within two working days after the units are delivered to the Lakewood Traffic Signal Maintenance Shops at 1060 Quail Street in Lakewood, Colorado and extend through the final system acceptance tests for the entire system

A computerized record of all testing will be by the city to document all phases of the operation. A time stamp will be used to log the controller into acceptance testing by the city technician performing the testing. Payment of 50 percent of the controller bid price will be authorized at the start of the acceptance testing for each unit delivered in working order.

Prior to delivery, the supplier shall burn in each controller assembly for a period of 48 hours at a temperature of 60°C or for a period of 96 hours at 23°C. A certification shall be included with each controller unit indicating the dates of the burn in period, number of hours, and the burn in temperature.

The SYSTEM CONTRACTOR shall perform NTCIP compliance tests utilizing the Federal Highway Administrations (FHWA) NTCIP Exerciser software. The most recent version of this software will be utilized for the NTCIP compliance test. Results of this test shall be certified. If any of the optional elements described in Section **5.1.7 - Other Optional Traffic Signal Controller Features** are included in the local controller software, the system contractor shall have to add elements to the NTCIP Exerciser software to test the optional features supplied.

The city, or at the city's option, an independent laboratory, may perform additional tests as described in Part 2 of NEMA Standards Publications TS 1 and TS 2.

Should the controller unit fail any of the additional tests described in the previous paragraph, the supplier will be notified in writing of the reason for failure. Notification will be by facsimile (fax) to an operating telephone number provided by the manufacturer. The original notification will be posted First Class U.S. mail, addressed to a location provided by the manufacturer. The supplier will have 30 calendar days from the date of notification to repair or replace the controller assembly at their expense. The city will not pay for shipping and handling. If the failure is related to an inherent hardware or software problem common to all units, the problem must be corrected in all controller assembly units furnished. Failure to meet this 30 calendar day limit will require the vendor to show cause to remain on the approved vendor list. During this time the vendor will be on suspension and not allowed to provide any additional controller units. If the vendor fails to show cause, they will be removed from the Qualified Supplier List.

Noncompliance by the supplier at any point in the process will be cause for nonpayment. Failure of any portion of the test for a third time will result in the removal of the unit or device and the vendor notified of noncompliance.

5.1.8.2 Warranty

All traffic signal controller units shall be guaranteed by the manufacturer against mechanical and electrical defects for a period of 24 months from the date of acceptance. Any defects of design, workmanship, or material shall be fully corrected by the manufacturer without cost to the city. The System Contractor shall pay all shipping charges for equipment returned for repair under warranty.

The equipment shall be warranted to meet all requirements of this specification at the time of installation.

5.1.9 Payment for Traffic Signal Controller Units

Payment for traffic signal controller units will be made per unit delivered and shall include all work necessary to supply fully operational units, including incidentals and programming of existing timing parameters and items necessary for proper operation in new or existing traffic signal controller cabinets.

ANNEX C: TEST PLANS

The System Integrator developed a set of written procedures for testing various aspects of the central system and its functionality. The test plan included a variety of sections on central system hardware configuration and software operations. However, the test plan was silent on specifics regarding NTCIP testing. According to the city, ad hoc NTCIP testing was performed during the integration and acceptance phases of the project.

Please contact Mr. James Richey of the city of Lakewood Traffic Engineering Division (303-987-7985 or mailto:jimric@lakewood.org) for additional information.

ANNEX D: THE NTCIP STANDARDS PROCESS

During the standards development process, all NTCIP standards progress pass through a series of stages. These stages are described below:

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

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