A Recommended Information Report of the Joint Committee on the NTCIP

NTCIP 9012 version v01

National Transportation Communications for ITS Protocol

Testing Guide for NTCIP Center-to-Field Communications

published in December 2008

This Adobe® PDF copy of an NTCIP information report is available at no-cost for a limited time through support from the U.S. DOT / Research and Innovative Technology Administration, whose assistance is gratefully acknowledged.

Published by

American Association of State Highway and Transportation Officials (AASHTO)
444 North Capitol Street, N.W., Suite 249
Washington, D.C. 20001

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1099 14th Street, N.W., Suite 300 West
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file version 9012 v01.27r-2008c

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CONTENTS AT A GLANCE

ACKNOWLEDGEMENTS

NTCIP 9012 v01 was prepared by the NTCIP Testing and Conformity Assessment Working Group (TCA WG), which is a subdivision of the Joint Committee on the NTCIP. The Joint Committee is organized under a Memorandum of Understanding among the American Association of State Highway and Transportation Officials (AASHTO), the Institute of Transportation Engineers (ITE), and the National Electrical Manufacturers Association (NEMA). The Joint Committee on the NTCIP consists of six representatives from each of the standards organizations, and provides guidance for NTCIP development.

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In addition to the many volunteer efforts, recognition is also given to those organizations that supported the efforts of the working groups by providing comments and funding for NTCIP 9012 v01, including:

- Consensus Systems Technologies
- Florida DOT
- Intelligent Devices, Inc.
- NET
- PB Farradyne, Inc.
- Quixote Corporation
- Siemens ITS
- SimpleSoft, Inc.
- Southwest Research Institute
- Texas DOT
- Texas Transportation Institute
- TransCore
- Trevilon Corporation
- U.S. Department of Transportation, Research and Innovative Technology Administration, ITS Joint Program Office
- URS Corporation
- Utah DOT
- Virginia DOT
- Washington State DOT

FOREWORD

NTCIP 9012 v01, an NTCIP standards publication, provides general guidance for testing ITS devices to both the NTCIP standards and agency specifications. NTCIP 9012 v01 is not an NTCIP standard and does not contain any normative text. The NTCIP TCA WG expects NTCIP 9012 v01 to be used by transportation agencies to assist them in developing their own testing program when purchasing and deploying NTCIP “compliant” devices and systems.

NOTE—The term “compliant” was used in the preceding paragraph. NTCIP 9012 v01 discusses the issues of *conformance* to NTCIP standards and *compliance* with agency specifications (including project-specific requirements), and clarifies the differences.

The following keywords apply to this document: NTCIP, testing.

For more information about NTCIP standards publications, visit the NTCIP Web site at: www.ntcip.org.

User Comment Instructions

The term “User Comment” includes any type of written inquiry, comment, question, or proposed revision, from an individual person or organization, about any part of this standards publication’s content. A “Request for Interpretation” of this standard publication is also classified as a User Comment. User Comments are solicited at any time. In preparation of this NTCIP standards publication, input of users and other interested parties was sought and evaluated.

All User Comments will be referred to the committee responsible for developing and/or maintaining this standards publication. The committee chairperson, or their designee, may contact the submitter for clarification of the User Comment. When the committee chairperson or designee reports the committee’s consensus opinion related to the User Comment, that opinion will be forwarded to the submitter. The committee chairperson may report that action on the User Comment may be deferred to a future committee meeting and/or a future revision of the standards publication. Previous User Comments and their disposition may be available for reference and information at www.ntcip.org.

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Standard Publication number and version:
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Section, Paragraph, or Clause:
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History

In September 1996, an agreement was executed among AASHTO, ITE, and NEMA to jointly develop, approve, and maintain the NTCIP standards. In December 2001, the Joint Committee on the NTCIP formed the TCA WG to investigate issues surrounding conformance testing and develop testing and conformity assessment documentation. The TCA WG held its first meeting in October 2002. The TCA WG began development of NTCIP 9012 v01 in October 2003.

The TCA WG also produced NTCIP 8007 v01, which promotes a consistent look and feel for testing documentation throughout the various NTCIP standards. Consistent test documentation enables the next published versions of NTCIP 1200-series standards, produced by various NTCIP working groups and based on NTCIP 8007 v01, to be used by anyone wishing to test an implementation of an NTCIP standard.

NTCIP 8007 v01 contains valuable insights into the development of test cases and test procedures for verifying NTCIP conformance. NTCIP 8007 v01 can assist both agencies and manufacturers in developing their NTCIP test procedures, where the standards are silent, or by augmenting test procedures where ITS device requirements have been extended beyond the basic NTCIP functionality.

In January 2006, NTCIP 9012 v01.24d was accepted as a Recommended Information Report by the Joint Committee on the NTCIP. In 2008, versions v01.25 to v01.27 included content editing for publication in December 2008. Version v01.27r-2008c was a second authoring to PDF.

Compatibility of Versions

To distinguish NTCIP 9012 v01 (as published) from previous drafts, NTCIP 9012 v01 also includes NTCIP 9012 v01.27 on each page header. All NTCIP Standards Publications have a major and minor version number for configuration management. The version number syntax is "v00.00a," with the major version number before the period, and the minor version number and edition letter (if any) after the period.

NTCIP 9012 v01 is designated, and should be cited as, NTCIP 9012 v01. Anyone using NTCIP 9012 v01 should seek information about the version number that is of interest to them in any given circumstance.

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Section 1
INTRODUCTION

1.1 OVERVIEW

NTCIP is a series of communication standards intended to promote deployment of interoperable Intelligent Transportation Systems (ITS). NTCIP 9012 v01 is intended to be used by agencies as a reference to assist in the incorporation of NTCIP testing into a testing program to be used when procuring ITS devices for which there is an NTCIP standard. NTCIP 9012 v01 focuses on center-to-field (C2F) communications.

The NTCIP standards have been well received by the ITS industry, and many agencies specify NTCIP standards for new deployments. In the past, an agency would procure the proprietary communications protocol already used in agency-operated ITS devices. Today, agencies may choose to specify an ITS device communications interface based on NTCIP. NTCIP-based agency specifications mitigate the risk of procuring proprietary manufacturer solutions.

NTCIP testing is emerging as a new activity. NTCIP testing ensures that:

a) ITS devices delivered incorporate the mandatory requirements of the NTCIP standards (referred to as **standards conformance**); and

b) an agency's project requirements and specifications are fulfilled (referred to as **agency specification compliance**).

NOTE—Annex A contains complete listings for references, definitions, and acronyms.

1.2 INTENDED AUDIENCE

NTCIP 9012 v01 has been developed to inform a knowledgeable reader about NTCIP testing. A knowledgeable reader is one familiar with NTCIP standards plus the transportation management system hardware standards such as NEMA TS 2 and NEMA TS 4. If you are unfamiliar with the NTCIP communication standards and the NEMA hardware standards, it is recommended you have access to the following standards as representative examples: NTCIP 1202 or NTCIP 1203, and NEMA TS 2 or NEMA TS 4. Annex A contains a glossary of references, terms, and acronyms that a reader may also want to have available.

The intended audience for NTCIP 9012 v01 consists of public agencies; independent testers—both laboratories and consultants; ITS device manufacturers; and specification and test documentation developers.

NTCIP 9012 v01 provides a roadmap to help an agency become an active participant in the testing process and those processes leading up to testing (requirements definition and specification development).

NTCIP 9012 v01 provides guidance on:

a) NTCIP testing concepts and processes;
b) where NTCIP testing fits within a broader testing program that includes hardware testing;
c) test documentation necessary to ensure that an NTCIP testing program is complete;
d) a phased approach to test execution;
e) testing tools; and
f) manufacturer pre-qualification.

Collectively, these are the testing themes discussed in NTCIP 9012 v01.

A testing roadmap is presented in Figure 1. The testing roadmap explains concisely how the testing themes covered in NTCIP 9012 v01 may be structured into a testing program. It also serves as an NTCIP 9012 v01 roadmap.

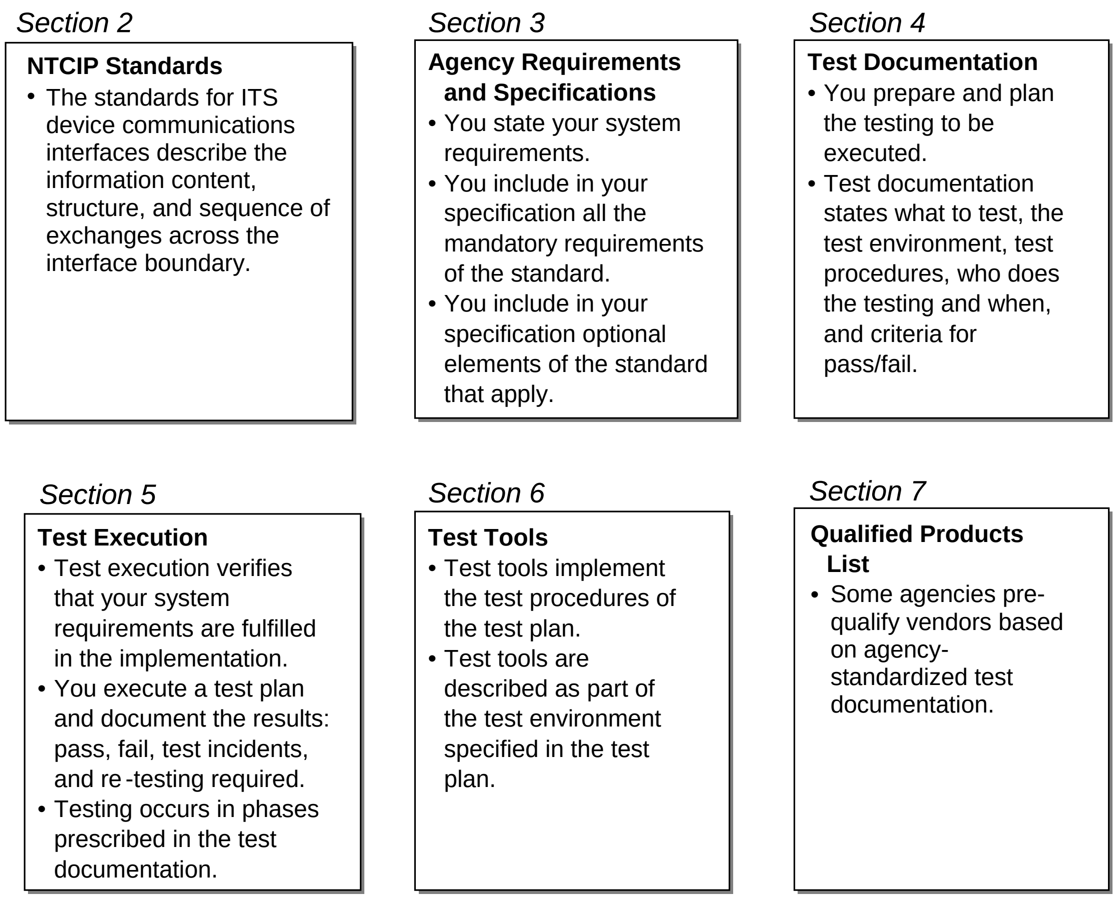

Figure 1 Testing Roadmap

Section 2
NTCIP AND ITS STANDARDS BACKGROUND

A comprehensive ITS device testing program verifies implementation of hardware, environmental, and communications interface requirements. Section 2 provides a brief overview of ITS device standards to assist agencies to understand the role of NTCIP testing in the context of a broader testing program for deploying a traffic management system.

2.1 PURPOSE OF ITS DEVICE STANDARDS

ITS device standards, including the NTCIP series of communications standards, are intended to promote:

a) **Compatibility** among system components (and ITS devices), so that different system components can share a common communications infrastructure;
b) **Interoperability** between system components, so that system components from different manufacturers can work together to provide the necessary functionality; and
c) **Interchangeability** of system components, so that system components can be changed out (switched) with similar components from different manufacturers.

Any component that does not conform to the requirements of the NTCIP standards (and comply with NTCIP-based agency specifications) inhibits or precludes some of these goals from being realized.

2.2 NTCIP ITS DEVICE COMMUNICATIONS INTERFACE STANDARDS

NTCIP standards are organized into a framework of levels modeled after the Open Systems Interconnect (OSI) model. The NTCIP 9001 v03 (known as “the Guide”) contains a more complete discussion of NTCIP standards and their development and usage.

For ITS devices, the NTCIP information level standards (designated as part of the NTCIP 1200-series) define the data (called objects), structure of data (contained in a Management Information Base, or MIB), and sequence of data exchanges (dialogs) that manage ITS device operation, monitor status, and collect necessary data for analysis. Information level standards specify the data elements (parameters) that are used to manage ITS device functionality or to provide specific measurements (e.g., traffic volumes, temperature, voltages) and ITS device status. NTCIP working groups standardized the data content and dialogs necessary to manage the operation and monitoring of conditions and status of various ITS devices, including: Actuated Signal Controllers (ASC), Dynamic Message Signs (DMS), Environmental Sensor Stations (ESS), CCTV Cameras, and Ramp Meters. For a complete list of NTCIP standards, see the NTCIP document library at www.ntcip.org.

NTCIP base standards represent the lower level communications standards and protocols, and define how data are encoded and transmitted over a variety of media types (e.g., fiber, twisted pair, wireless) and protocols (TCP/IP, UDP/IP, point-to-multi-point, or point-to-point protocols). These lower level standards are neutral as to ITS device type and data content. Agencies should consider the unique aspects of their existing and planned ITS communications infrastructure during system acquisition to ensure that agency specifications define the requirements that satisfy agency needs.

Figure 2 is a graphical representation of the NTCIP framework, and summarizes the relationship between information level and base (lower level) standards.

NOTE—Figure 2 is adapted from NTCIP 9001 v03. Refer to NTCIP 9001 v03 for a complete description of the NTCIP standards framework.

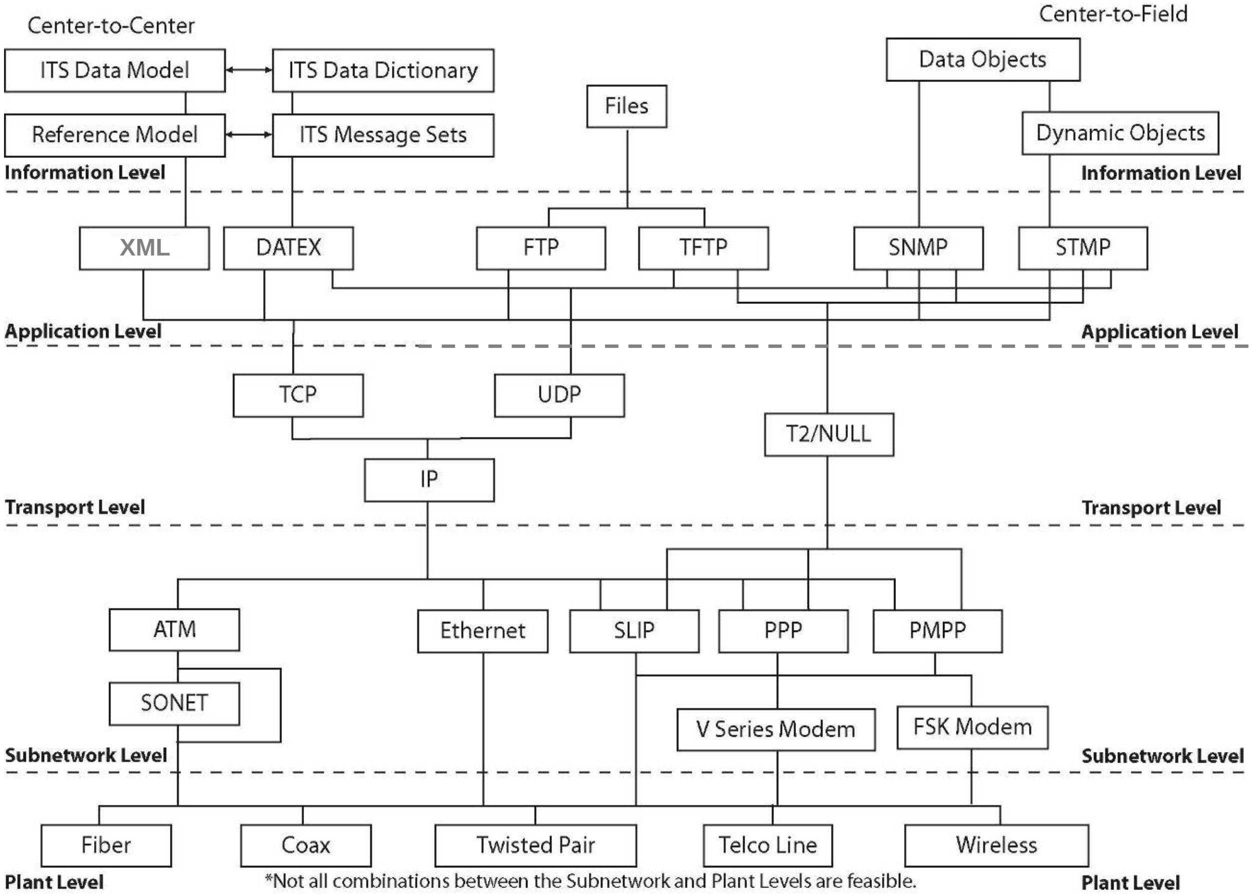

Figure 2 NTCIP Framework

2.3 HARDWARE AND ENVIRONMENTAL STANDARDS

Standardization of traffic signal controllers and cabinets dates back to the late 1970s, beginning with NEMA TS 1. Since then a number of hardware and environmental standards for ITS devices have been developed, including:

a) **NEMA TS 2—**Developed as a design guide for traffic signal devices and provides operational features not covered by NEMA TS 1-1989. NEMA TS 2 supports equipment interchangeability between manufacturers and includes minimum functional requirements for effective intersection control, equipment requirements including environmental standards, and testing procedures.
b) **NEMA TS 4—**Developed as a design and implementation guide for traffic messaging devices, such as dynamic message signs. NEMA TS 4 provides hardware requirements including environmental standards and testing procedures.
c) **Advanced Transportation Controller (ATC)—**The ATC suite of standards provides an open architecture hardware and software platform for a wide variety of ITS applications. The ATC suite of standards includes hardware requirements for the traffic controller and the cabinet (enclosure).

These standards aid agencies in specification of ITS devices by standardizing functional, hardware (electrical and mechanical requirements), performance, and environmental requirements, as well as identifying requirements for testing. For example, an agency procuring traffic signal controllers may reference the appropriate NEMA standard (e.g., NEMA TS 2-2003), which includes a description of functionality, environmental requirements, and testing procedures. Likewise, for DMS, the agency might invoke portions of NEMA TS 4-2005.

NOTE—While NTCIP 9012 v01 references the basic designator for the above standards, the procuring agency should reference the particular version or approval year of the referenced standard, as indicated in the preceding example.

2.4 STANDARDS CONFORMANCE VERSUS AGENCY SPECIFICATION COMPLIANCE

Since completion of the initial versions of the NTCIP standards in 1996, agencies have become interested in testing ITS devices for conformance to standards and compliance with agency specifications.

- **Standards Conformance**—When an item fulfills all of the mandatory requirements as defined by a standard
- **Specification Compliance**—When an item fulfills all the requirements of an agency specification

NTCIP testing focuses on verification of the NTCIP requirements. This includes verification of the mandatory requirements in the standard (referred to as **standards conformance**), and verification of the requirements in your agency specification (referred to as **agency specification compliance**). NTCIP testing may also be extended to encompass verification of the ITS device functions that result from NTCIP communications.

Whether standards conformance or specification compliance, an NTCIP testing program should be designed to show that the ITS device communications interface implementation fulfills requirements and uses appropriate objects to manage ITS device functions. Where dialogs are specified (i.e., a specific sequences of message interactions), testing should be planned to ensure that the ITS device accepts and responds with the correct data and that the ITS device performs the required function.

2.4.1 Standards Conformance

Conformance is a condition that exists when an item fulfills all of the mandatory requirements defined by a standard. Conformance testing is designed to verify that the ITS device fulfills the mandatory requirements of the applicable standard(s). Hence, before starting testing, one should first ensure that a set of well-defined requirements exists and can be verified—requirements are the basis for testing and verification. Conformance testing addresses all parts of the standards that are mandatory for the ITS device, whether that part of the standard is required as part of the agency specification or not. For example, an ITS device that conforms to all parts of NTCIP 1201:2005 implements dynamic objects independent of whether they are used by the project.

As a minimum, the conformance test for NTCIP should cover the following items:

a) Verification of the ability to GET and/or SET each object defined in the required standards and in the correct order.

b) Verification that range limits for the specific objects are satisfied. This is especially important if non-contiguous ranges are specified.

c) Verification that the values SET in the ITS device are reflected in the proper internal location, i.e., that a SET of the cycle length for plan 5 actually sets the cycle length for plan 5, not plan 50. This is typically done by verifying the variables through the ITS device's local display or observing the resultant behavior of the ITS device.

d) Verification that the values retrieved from the ITS device are pulled from the proper location within the controller; again, this is typically done by verifying the values through the front panel display, or by verifying that the behavior of the ITS device matches the values retrieved. For example, observing that the temperature reported by a DMS matches the ambient temperature within the measured area. Some NTCIP standards do not include tolerances on all such measurements.

e) Verification that all objects identified in the standard(s) have the desired operational effect. To do so, the operation of the ITS device is observed or inputs are simulated to measure proper operation (volumes, voltages, temperature).

f) Verification that the ITS device supports the proper dialogs by ensuring that all interactions with the ITS device follow the dialogs identified in the standard. For some ITS devices, there are no dialogs identified—except for the basic database create/verify operations, which should be tested for the ITS device. If the ITS device does not operate properly when exchanges follow the prescribed dialogs, the ITS device is considered non-conformant.

NOTE—Where standards are silent, different manufacturers may have “assumed” that different dialogs are required to manage the operation; such specific requirements should be documented by the manufacturer and provided to the central system supplier with the caveat that different manufacturers’ ITS devices may require different dialogs.

2.4.2 Agency Specification Compliance

Compliance is a condition that exists when an item meets all requirements of an agency specification. Compliance testing is designed to verify that the ITS device fulfills the requirements of an agency’s specification. Creating a specification is necessary to ensure that all optional elements in the standard are required for your deployment. Specifications also allow for the explicit removal of optional elements that do not apply. Therefore, while a manufacturer may state that an ITS device is “NTCIP conformant,” meeting conformance with the mandatory requirements of a standard may not be sufficient to fulfill your agency’s project requirements, or to comply with your agency specification.

Section 3
AGENCY REQUIREMENTS AND SPECIFICATIONS

From an agency perspective, the primary purpose of testing is to verify that the requirements stated in the agency specification are delivered by the manufacturer. Testing verifies that the requirements (hardware, software, and ITS device communications interface) identified in the agency specification are fulfilled. Definition of an agency's system requirements and specification development are major steps preceding testing and are the focus of Section 3.

3.1 TESTING IN THE CONTEXT OF SYSTEMS ENGINEERING

The Systems Engineering Process (SEP) Model shown in Figure 3 identifies the various stages in the acquisition of an ITS device or system.

> ***Why Test?***
> To verify that requirements are fulfilled
> To reduce the risk of misinterpretation between agency and manufacturers

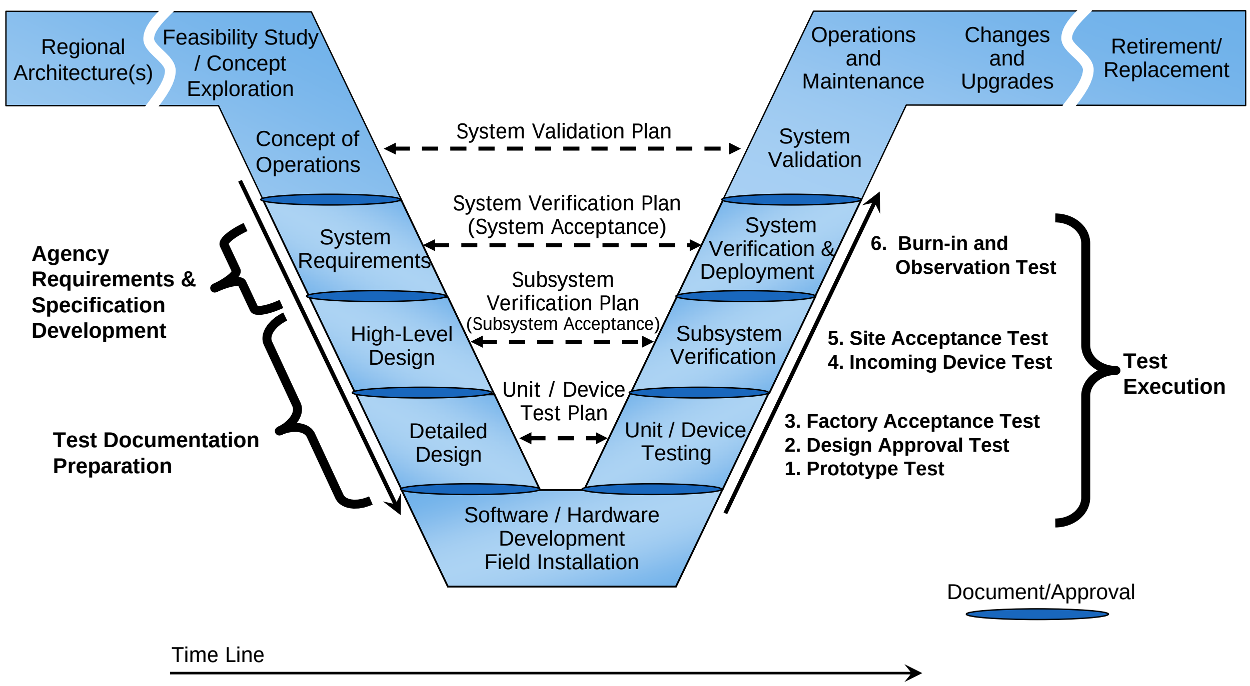

Figure 3 Systems Engineering Process

The major process steps comprising SEP, starting from requirements through testing, include:

a) **Define Agency System Requirements—**Requirements definition is one of the key SEP activities. A set of system requirements defines the functions a system performs, how well a system should perform, and under what conditions this performance takes place. System requirements are the result of the definition of need, the operational concept, and the system analysis. System requirements are a description of what the system's customers expect it to do for them. See IEEE 1233-1998.

b) **Develop Agency Specifications—**Based on agency system requirements, agency specifications are developed to guide system design phases. Agency specifications may be based on a tailoring of the

ITS hardware and environment standards (e.g., NEMA TS 4) and the NTCIP communications standards (e.g., NTCIP 1203:1997). Standards-based agency specifications are not a system design, but rather specify design requirements. The topic of design is outside the scope of the NTCIP 9012 v01, but during design an agency may prepare requirements-based test documentation.

c) **Prepare Test Documentation—**Test documentation is based on agency specifications and is traceable to requirements. Therefore, once an agency specification is developed, the agency should develop test documentation, which specifies what and how to verify that an ITS device fulfills agency specifications and associated requirements. Test documentation specifies the extent of testing that is required for the ITS device. For example, a custom-designed ITS device with new hardware and software is likely to require significantly more testing, and more stringent testing, than an un-modified ITS device with extensive field deployments.

   Test documentation is a key element of a testing program. Test documentation includes test plans, test cases, and test procedures. Test documentation may be developed by the manufacturer, the agency, a test laboratory, a consultant, or perhaps it is based on test documentation used by another agency as part of their qualified products program. Testing is conducted by a combination of manufacturer, agency, and possibly an independent laboratory to verify that an ITS device complies with the agency's specification.

d) **Execute Tests Based on Test Documentation—**All testing is conducted based on test documentation. NTCIP 9012 v01 references IEEE 829-1998 and NTCIP 8007 v01 to describe the content of test documentation. Test plans are executed and the results documented in test reports (test logs, test incident reports, and test plan summary reports). Testing progresses through a series of test phases, from prototype test through burn-in and observation test.

3.2 REQUIREMENTS

IEEE 1233-1998 states that a requirement is a condition or capability needed by a user to solve a problem or achieve an objective. Requirements are the basis of agency specifications and testing, and play a cross-cutting role in governing the expectations of a system across the entire system life cycle. Requirements traceability, a key tool in verification, traces a requirement to a place where it is fulfilled in the agency specification, design, implementation, and operation.

Requirements-based verification at each SEP phase provides a method of system quality improvement by helping to:

Types of Requirements

- Hardware
- Software
- Communications
- Functional
- Environmental
- Performance

a) Find and eliminate defects early on;
b) Find requirements gaps and inconsistencies (i.e., conflicting requirements);
c) Find requirements redundancies; and
d) Uncover poorly-structured relationships among system elements.

3.2.1 ITS Device Communications Interface Requirements

ITS device communications interface requirements specify constraints on format, timing, or other factors due to system interaction. Figure 4 illustrates the ITS device communications interface concept.

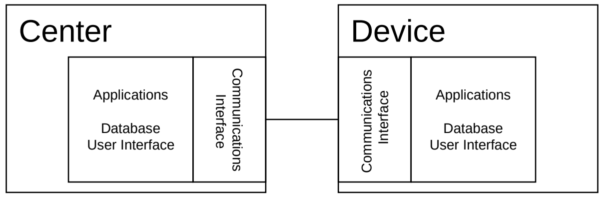

Figure 4 ITS Device Communications Interface Concept

NTCIP standards may include functional requirements. Based on the functional requirements, the definition of data formats and sequence of exchanges across the communications interface are specified. Typically, agencies specify performance requirements (timing and other factors) in a manner appropriate for each deployment. Functional and performance requirements are discussed in Section 3.2.1.1 and Section 3.2.1.2, respectively.

3.2.1.1 Functional Requirements

Functional requirements codify the visible functions and observable behavior of the ITS device. A standard's dialogs and object definitions are developed to fulfill the stated functional requirements. Where standards do not specify functional requirements, an agency is strongly encouraged to develop them and then document traceability to elements in the standards.

NTCIP standards specify ITS device communications interfaces only. However, agencies should ensure that NTCIP-conformant ITS devices perform required functions. Hence, while an ITS device may conform to one or more NTCIP standards, if it accepts and reports data elements (objects) and implements dialogs correctly, the agency should verify that the ITS device performs the intended function, and is, therefore, more likely to do so when installed in an agency's unique installation.

As long as the function being verified matches a functional requirement defined in the NTCIP standard, functional testing may be included as part of the testing of the communications interface. However, it is recommended to test the ITS device functionality separately from communications interface testing (i.e., data formats, and sequence of exchanges). Separating test items for functionality from those for a communications interface helps to isolate any deficiencies in how an ITS device handles the communication of data, versus deficiencies in performing some action resulting from proper communications.

This also reinforces the goal of interoperability, as once a communications interface is deemed to fulfill agency specification requirements, another ITS device that also fulfills the interface requirements may be exchanged.

Extended functionality refers to requirements for ITS device functions that fall outside the scope of standards. Agencies should approach extended functionality in the same manner as the basic NTCIP support. Extended functionality should be defined by one or more well-formed requirements that is testable. A testable requirement is identified by: a) a proper test case; and b) a test procedure that provides verification.

Custom dialogs or message sequences should properly trace to NTCIP standard objects. The agency specification should identify the relationships between the NTCIP objects used to manage the extended functionality and the standard NTCIP objects (including both block and dynamic).

3.2.1.2 Performance Requirements

Performance requirements constrain functional requirements (timing, speed, memory usage, etc.) and (from the NTCIP standards perspective) are agency- and deployment-specific. In the past, ITS device communications performance requirements simply stated necessary support for bit rates and communications equipment (e.g., modems). The advent of NTCIP has increased the communications processing load on the ITS device to the point that communication performance requirements are inextricably linked to device specification.

Specifying performance requirements ensures that a deployment can support the number of ITS devices intended. For example, given a timing constraint (e.g., once per second communications), then the round-trip response time (performance requirement) to a particular ITS device for any NTCIP command determines the total number of units that can be connected to a given communications channel on the network. For ITS devices such as actuated signal controllers, the amount of time allocated for processing the data streams determines how many ITS devices can be connected to a specific channel and the rate of interrogation. If the central system waits up to 1 second for a response, then clearly each ITS device is allocated a full second of time to initiate and complete the response. However, if the ITS device is required to respond within 40 milliseconds, then it may be possible to connect up to 4 ITS devices to a slow speed communications channel (e.g., 1200 bps). Testing of the performance requirements verifies that the ITS device fulfills the performance requirements contained in the agency specification and/or in NTCIP standards (e.g., NTCIP 1103 v01).

As a rule, NTCIP standards do not include performance requirements. One exception to the rule is NTCIP 1103 v01, which includes response times for SNMP message processing. These should be verified as part of the conformance testing unless the specific procurement requires a different response requirement (e.g., on a slow speed PMPP communications infrastructure, the nominal 100 milliseconds may be too long to support more than a few ITS devices on a single communications channel).

3.2.2 Hardware and Environmental Requirements

A number of ITS standards include hardware and environmental requirements, namely, NEMA TS 1, NEMA TS 2, NEMA TS 4, and AASHTO/ITE/NEMA ATC. These are widely referenced by agency specifications for ITS devices. Hardware requirements are further subdivided into electrical and physical-mechanical requirements.

Electrical requirements include specification of electrical connections, data communications, electronic components and interfaces, and power requirements and limits.

Physical–mechanical requirements include specification of the physical dimensions of the ITS device plus location and size of openings for connections, materials, and construction.

Environmental requirements are the bounding environmental constraints over which proper operation of an ITS device is specified. Usually, a set of functional and performance criteria are included with the environmental requirements. These provide a means of testing that an ITS device has sustained a given set of operations over the environmental conditions specified. Environmental requirements specify conditions for: pressure, temperature, vibration, acoustics, shock, radiation, and electromagnetic fields.

3.3 AGENCY SPECIFICATIONS

An agency specification defines, in a complete, precise, verifiable manner, the requirements, design, behavior, or other characteristics of a system or component, and, often, the procedures for determining whether these provisions have been satisfied [Dorfman, *Software Engineering*, 2000]. An agency specification references the relevant and required portions of the applicable ITS standards that apply to that ITS device and the media that are used (or planned for use) for the communications infrastructure.

Agency specifications are based on requirements that define ITS device functions, data formats, storage, performance, and interface capabilities. During the system life cycle, roles and responsibilities may change through phases of system development, testing, implementation, operations, and maintenance. Roles and responsibilities during each phase should be explicitly identified.

The relationship between roles and responsibilities and ITS device specifications is shown in Figure 5.

3.3.1 What should be in an Agency Specification

A successful system deployment is dependent on the availability of quality specifications. Although the development of agency specifications is outside the scope of NTCIP 9012 v01, the agency cannot develop a good testing program without clearly defining the ITS device (or system) requirements in a clear, concise, and testable manner. The agency specification should include the following items:

a) Standards to be used for the ITS device—both NTCIP and device-specific standards.

   1) A PICS (Profile Implementation Conformance Statement) for each tailored standard should be included;
   2) This list should be specific as to version, date of issue, etc., as the standards may change over time; and
   3) Value ranges for all of the objects to clearly identify such parameters as the size of event logs, the number of messages to be supported, and the number of special functions managed.

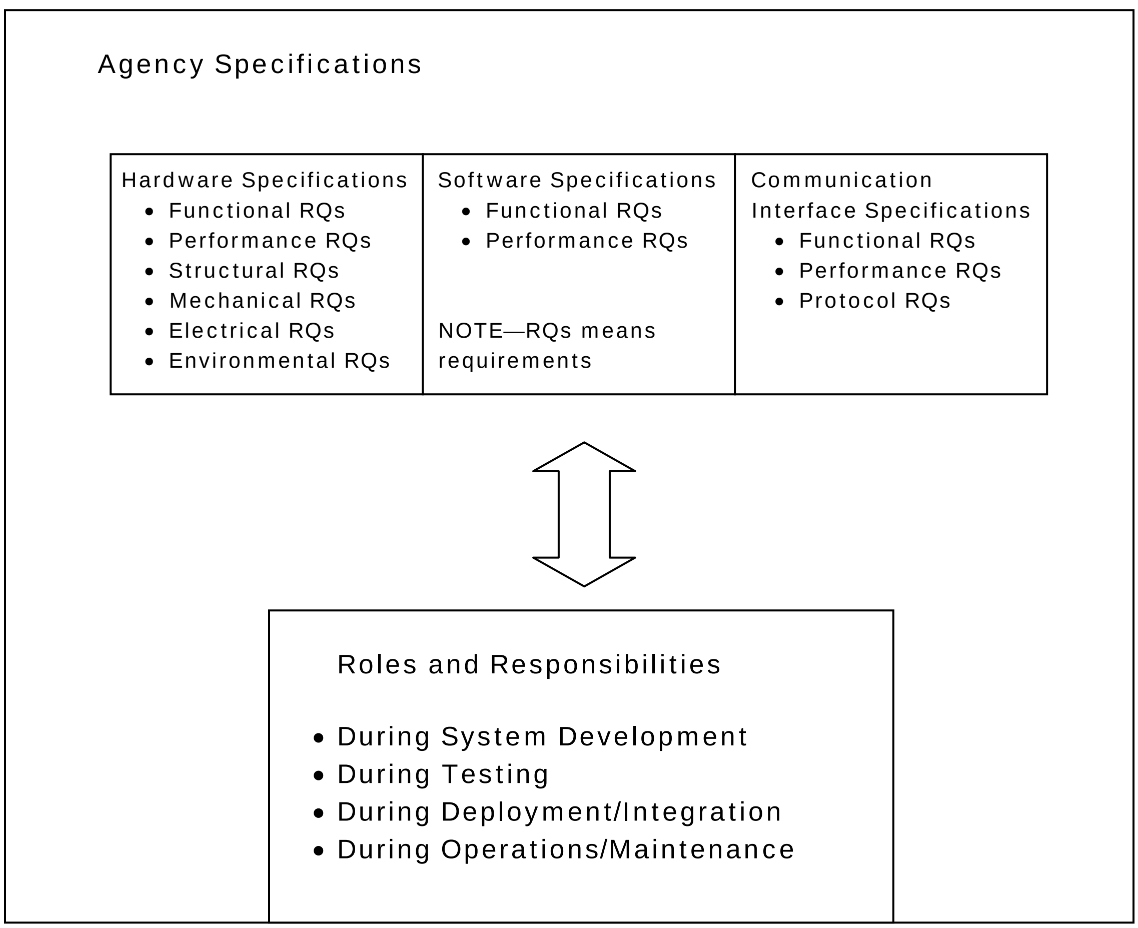

Figure 5 Relationship Between Agency Specifications and Roles & Responsibilities

b) Specification of any optional elements of the reference standards to be included; many standards include both mandatory and optional elements. It is the responsibility of the agency to identify the optional elements to be supported and the value ranges for those optional data elements (objects) where appropriate.

c) Functional requirements that are not covered by standards. Although NTCIP standards include a description of the data objects (in ASN.1 format), the agency should clearly articulate any specific ITS device functionality required or expected, understanding that different manufacturers may interpret the standard differently.

d) Performance requirements for the ITS device that are not covered by the standards. The agency determines what performance requirements to include based on their communications infrastructure, the demands of their central system, and their concept of operations for the ATMS applications. Examples of considerations: the number of units to a channel; the time lag allowed when setting all devices; the poll rate for monitoring status.

e) Environmental requirements for the ITS device that are not covered by NTCIP standards. These requirements are generally part of the NEMA TS 2 or TS 4 documents or generic agency specifications such as the CalTrans TEES at www.dot.ca.gov/hq/esc/ttsb/electrical/index.htm .

Standards are “tailored” for inclusion in an agency specification. Tailoring is based on an agency’s requirements. Including all mandatory requirements of a standard in an agency’s specification ensures the possibility of conformance with the standard.

NTCIP standards contain a PRL (Profile Requirements List), which is a list of all mandatory and optional standards requirements. A PICS is a PRL that has been tailored to your project requirements. The PRL presents an entry point for tailoring of the standard to include in your project just the portions that apply. Table 1 is an example of a PRL.

Table 1 Example Profile Requirements List (PRL)

User Need Section Number	User Need	FR Section Number	Functional Requirement	Conformance	Support / Project Requirement	Additional Project Requirements
2.3.2	DMS Characteristics			M	Yes	
2.3.2.1	DMS Type			M	Yes	
2.3.2.1.1 (BOS)	BOS			O.1 (1)	Yes / No	
2.3.2.1.2 (CMS)	CMS			O.1 (1)	Yes / No	
2.3.2.1.3 (VMS)	VMS			O.1 (1)	Yes / No	
2.3.2.2	DMS Technology			M	Yes	*Note that certain combinations of the following technologies might not be supported by any device.*
2.3.2.2.1 (Fiber)	Fiber			O	Yes / No	
2.3.2.2.2 (LED)	LED			O	Yes / No	
2.3.2.2.3 (Flip/Shutter)	Flip/Shutter			O	Yes / No	
2.3.2.2.4 (Lamp)	Lamp			O	Yes / No	
2.3.2.2.5 (Drum)	Drum			O	Yes / No	

3.3.2 Tailoring an NTCIP Standard to Project Requirements—From PRL to PICS

Procuring ITS devices using NTCIP standards requires agencies to fully understand and state the agency’s requirements for NTCIP implementation including performance, value ranges, and options. For NTCIP standards, implementers and testers may have multiple interpretations of the standards. This can lead to non-interoperability of the ITS devices. An agency’s specifications can clarify these issues. Ultimately, interoperability is a function of your agency’s specifications and is intended to meet your agency’s needs.

Furthermore, early NTCIP standards did not fully articulate the functional and performance requirements of an ITS device. This is an important issue: only if the ITS device's operational and performance requirements are clearly defined and tested through the communications interface can one be assured that the ITS devices are truly interoperable for the functions and features tested.

When developing an agency specification, the standard is tailored to an agency's needs and requirements. A standard's PRL assists in agency specification development. The format of the PRL allows an agency to distinguish between optional and mandatory standards elements. Optional elements in the standard can be either removed from the specification or selected to be mandatory for a specific implementation. When tailoring a PRL, making sure that the PICS includes all mandatory requirements of the standard (that is, those that are beyond the agency's requirements) ensures the possibility of conformance with the standard.

To obtain interoperable ITS devices from an agency specification, the agency should examine applicable standards and resolve the following items:

a) Which optional conformance groups for the ITS device should be supported;
b) Which optional objects for the ITS device should be supported;
c) Specify minimum support values for certain capabilities (i.e., the minimum number of plans in a traffic signal controller, the minimum number of phases, size of event logs, number of fonts supported, etc.); and
d) Interpret objects to have a consistent implementation for the ITS device (i.e., *patternTableType* from NTCIP 1202:1996).

Over time, NTCIP standards have enhanced their approach to facilitate the tailoring necessary to develop an agency specification based on SEP. Some standards, such as NTCIP 1203:1997, include a complete requirements traceability that allows identification of an intended function from the user needs and traces through to the specific NTCIP data element(s) and dialogs that should be supported by the ITS device. Others, such as NTCIP 1202:1996, refer to other standards (e.g., NEMA TS 2-2003) to describe the functionality required. NTCIP 1204 v02 includes test procedures (in NTCIP 8007 v01 format) to evaluate for conformance with the standard.

Section 4
TEST DOCUMENTATION

4.1 OVERVIEW

Figure 6 shows the relationship of key documents and relationships necessary to achieve complete and successful NTCIP testing.

Section 4 reviews Figure 6, and explains each part, as well as key relationships between system documentation items. The concept in Figure 6, showing references from agency specification to standard, and agency test documentation to agency specification, translates well to hardware and environmental testing.

4.1.1 ITS Device Standard

a) **Standard Conformance Statement—**Governs how conformance with the standard is fulfilled. The PRL supports conformance with the standard.

b) **Standard Requirements—**Are the standard’s functional requirements that the dialogs and object definitions fulfill. Generally, only subsets of the standard’s requirements are mandatory, the remainder being optional, or optional under certain conditions.

c) **Dialogs and Object Definitions—**Are the solution elements of the standard and fulfill the standard’s requirements.

d) **PRL—**Lists the mandatory, optional, and conditionally optional requirements.

e) **RTM (Requirements Traceability Matrix)—**Traces a requirement to the standards dialogs and object definitions.

4.1.2 Agency Specification

a) **Reference to Standards—**References the governing ITS standard for the agency’s specification.

b) **Reference to Standards Conformance Statement—**Addresses how the agency specification fulfills the standard’s conformance statement.

c) **Agency Specification Compliance Statement—**Governs how compliance with the agency specification is fulfilled. The PICS may support compliance with the agency specification.

d) **Agency Specification Requirements—**Are project- and agency-specific requirements, the results of tailoring of the standards, mandatory for the project. The PICS may support traceability to mandatory standards requirements and serve to support standards conformance.

e) **Dialog and Object Definitions—**Are project-specific solution elements and fulfill agency requirements.

f) **PICS (Profile Implementation Conformance Statement)—**Is a tailored list of standards requirements that applies to the agency specification. The PICS reflects both a standard’s optional and mandatory requirements and when completed, reflects only those requirements included in the agency specification.

g) **RTM—**Traces an agency specification requirement to a standard’s dialogs and object definitions.

4.1.3 Agency Test Documentation

a) **Reference to Agency Specification—**Refers to the agency's specification(s) for the test documentation.

b) **Reference to Agency Specification Compliance Statement—**Addresses how the test documentation fulfills the specification compliance.

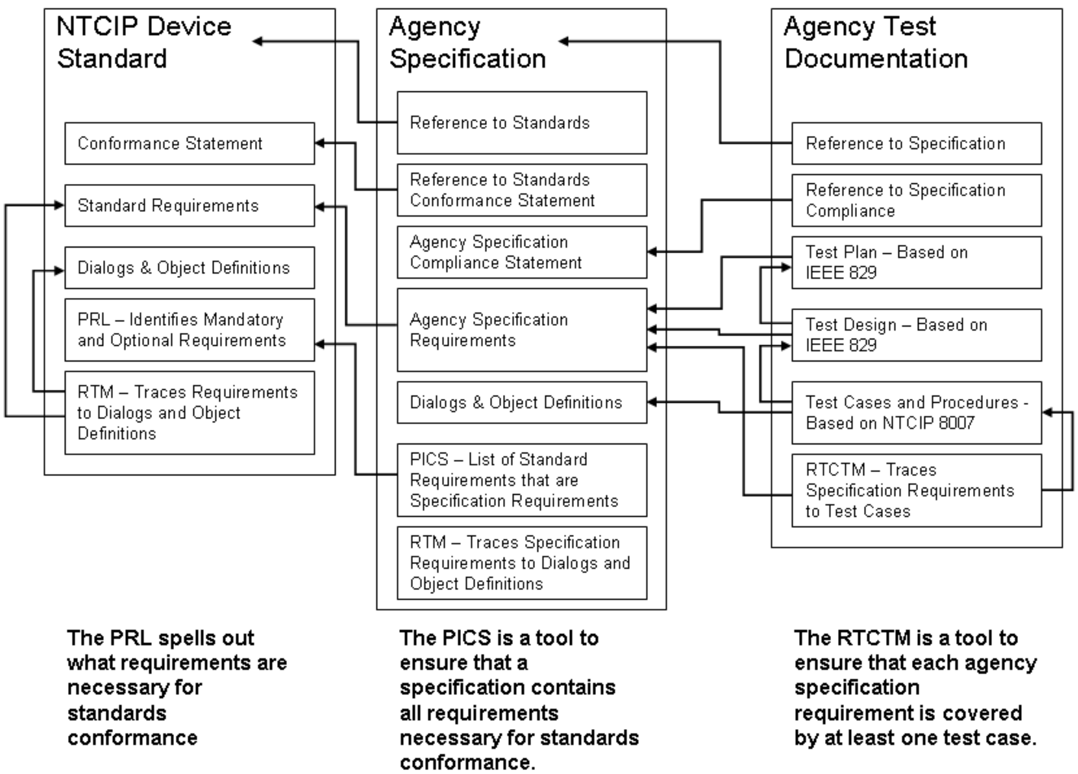

Figure 6 NTCIP Test Documentation

c) **Test Plan—**Describes the scope, approach, resources, and schedule of testing activities.

d) **Test Design—**References the test cases applicable to a particular test plan associated with the test design. The test design also references the features (requirements) to be tested.

e) **Test Cases and Procedures—**Describe the inputs, outputs, expected results, and procedures used to verify one or more requirements.

f) **RTCTM (The Requirements to Test Case Traceability Matrix)—**Traces an agency specification requirement to test cases. The RTCTM can be used to ensure that at least one test case covers each requirement.

Developing agency test documentation can take a significant amount of time and require coordination of many parties. It is recommended that test plan development begin after system interface requirements have been completed and approved. Test design development can begin after agency specification requirements have been approved and signed-off while test case development can begin after the agency's specifications have been approved and signed-off. Test procedure development can begin after the design has been approved. Test plan execution occurs throughout implementation, according to the suggested testing phases described in the SEP summarized in Figure 3. Test reports document test plan execution.

4.1.4 Test Documentation Standards

In the context of NTCIP 9012 v01, two standards cover the test documentation needs for ITS device testing—IEEE 829-1998 and NTCIP 8007 v01.

a) **IEEE 829-1998—**Standardizes test documentation content. IEEE 829 includes content descriptions for test plans, test design specifications, test case specifications, test procedure specifications, and test reports.

b) **NTCIP 8007 v01—**Is an IEEE 829-1998-based standard that focuses on system interfaces for C2F communications. NTCIP 8007 v01 does not include provisions for IEEE 829-1998 test plans and test designs; however, NTCIP 8007 v01 combines test case and test procedure aspects, which IEEE 829-1998 maintains as separate.

4.2 IEEE 829-1998 TEST PLAN

With any standard or specification, discussion eventually turns to the question "how do we know if an implementation or application conforms with the standard and complies with my specification?" A test plan defines how one answers this question.

As defined in IEEE 829-1998, a test plan describes the scope, approach, resources, and schedule of testing activities. It identifies the items to be tested, the features to be tested, the testing tasks to be performed, the personnel responsible for each task, and the risks associated with the test plan.

The details of a test plan should be fully developed before an ITS device is delivered. IEEE 829-1998 provides a template for the content of a test plan, and includes:

a) test Plan Identifier
b) introduction
c) test Items
d) features to be tested
e) features not to be tested
f) approach
g) item pass/fail criteria
h) suspension criteria and resumption
i) test deliverables
j) testing tasks
k) environmental needs
l) responsibilities
m) schedule
n) risk and contingencies
o) approvals

The following subsections group and discuss the 15 items that are part of an IEEE 829-1998 Test Plan.

4.2.1 Test Plan Identifier and Introduction

4.2.1.1 Test Plan Identifier

Each test plan requires a unique identifier, as several test plans may be needed to address a comprehensive testing program for ITS devices.

4.2.1.2 Introduction

The introduction section should describe how a particular test plan fits within the broader testing program, and reference all relevant documents, for example the communications interface requirements, agency specification requirements, and design.

4.2.2 Test Items and Item Pass/Fail Criteria

4.2.2.1 Test Item(s)

This is a description of the item, defined by requirements, to be tested. This may include software, communications interface, or hardware and environmental requirements.

The ITS device communications interface test item tests compliance with a specification and/or standards conformance. The standards conformance aspect may simply be an identification of which specification requirements are also mandatory by the standard, so that testing of a requirement that fulfills the requirements of the standard and the specification need only be done once.

A second (and separate) device communications interface test item may be the ITS device functions (observable behavior) that accompany any particular dialog or sequence of data exchanges.

Other test items (for which there should be associated requirements) may include ITS device hardware and environmental testing.

4.2.2.2 Item Pass/Fail Criteria

Item Pass/Fail criteria are used to determine whether each test item has passed or failed a test case or procedure.

4.2.3 Features to be Tested and Features not to be Tested

4.2.3.1 Features to be Tested

The features to be tested are the agency specification requirements associated with their respective test procedure or test case.

4.2.3.2 Features not to be Tested

A test plan should also identify features not to be tested (for example, those standard requirements that are optional or those PICS elements not required in the agency specification). Another example is the case where certain testing would unduly stress the limits of a prototype thus preventing further testing of a scarce resource—the prototype.

4.2.4 Approach, Risks, and Contingencies

4.2.4.1 Approach

The test plan developed by the agency should address the types of testing that are to be conducted to verify that delivered ITS devices comply with agency specification requirements. Testing phases may include:

a) prototype test and inspection
b) design approval test and inspection
c) factory acceptance test
d) incoming ITS device test
e) site acceptance test
f) burn-in and observation test

The approach should identify the test procedures and test cases that are scheduled during each test phase. See Section 5.2.

4.2.4.2 Risks and Contingencies

This section of the test plan identifies the significant risks that may result from testing and associated contingency plans. This includes prospective risks to schedule, related funding impacts, and a process to address the situation if it occurs.

4.2.5 Suspension Criteria and Resumption

This section of the test plan covers test start-up, re-start, and regression testing.

Even if an ITS device has a proven track record, software enhancements or changes to support additional functionality can seriously corrupt the overall performance and conformance of the ITS device. ANY software changes made by the manufacturer may be considered sufficient reason to repeat the full battery of associated NTCIP testing and performance measurements.

A test plan applies to a specific combination of hardware, firmware, MIB, and version of standard. A change in any of these components has the potential to invalidate any previous conformance testing and should trigger a regression test of all completed conformance testing.

When the hardware platform is changed, the working firmware may frequently be modified to work on the new hardware platform even if the firmware retains the same version designation. Depending on the new hardware platform some subtle problems can arise, i.e., byte ordering for messages, calculation of the frame check sequence, or simply the correction of perceived errors.

Even if the hardware platform is maintained, a change in the firmware triggers regression testing for a variety of reasons. Depending on the manufacturer's code management practices, problems that had been resolved can be introduced back into the firmware because a developer was working with an older version of the firmware.

A change in the MIB or the version of the standard used for the ITS device always triggers a regression test. The MIB describes all data that is accessible from the external interface; a change in the MIB has many possible ramifications. The standard describes how the ITS device interface is to function. A change to the standard implies that some functionality has changed either via addition, deletion, or method of operation. An example of this change is NTCIP 1201. The original NTCIP 1201:1996 defined a specific methodology for creating dynamic objects. After NTCIP 1201:1996 was released, an error was discovered in the methodology and an amendment was released in 1998. The amended NTCIP 1201:1996 methodology for creating dynamic objects is incompatible with the original NTCIP 1201:1996 methodology. Therefore, an ITS device that conforms to the original NTCIP 1201:1996 fails conformance testing against the amended NTCIP 1201:1996 standard.

4.2.6 Test Tasks, Test Deliverables, and Schedule

4.2.6.1 Test Tasks

This section of the test plan lists all the tasks necessary to prepare and conduct the testing. This section may include a table of test tasks, listing the following: task identifier, task name, predecessor tasks, responsibility, and special skills required.

4.2.6.2 Test Deliverables

The test deliverables is a list of all the test documentation, the development and writing of which is necessary for the test, including reports on the performance of the ITS device during the tests.

4.2.6.3 Schedule

The schedule is a list of milestones, and when all resources and people are needed. The test tasks included in the approach section of the test plan may serve as a starting point, with start and stop dates and times added.

4.2.7 Environmental Needs

This section of the test plan describes the configuration, necessary hardware, software, testing tools, supplies, lab facilities, centers, and reference documentation for testing. It is often useful to include a diagram showing the set up for testing: locations and positioning of equipment, people, tables, chairs, and projection systems (so that everyone participating in the testing can see what is happening). Also include a list of equipment, equipment description, and equipment purpose to accompany the diagram.

This section of the test plan should also address the management of hardware and firmware configurations. The growing role of software in most ITS devices, and the speed with which the software can be changed, increases the need for careful management of the hardware and firmware configuration that has been subjected to testing. Not only should the configuration be managed but the subject of regression testing takes on a new significance. Current testing programs of ITS devices have frequently found that new firmware for an ITS device, designed to fix some problems, may unintentionally either (a) introduce new problems that were not present before, or (b) bring back problems that had been corrected. The issues with testing and overall ITS device compliance can only be corrected with the definition and execution of effective testing and careful configuration management to ensure that what is delivered is what is tested.

Validating the test environment ensures that errors and anomalies are detected and corrected before testing begins. The test environment includes:

a) all instrumentation to measure and monitor the performance of the ITS device;
b) all environmental test equipment such as temperature and humidity chambers;
c) all input simulation devices where required such as loop simulators or sample data streams; and
d) power line management including transient generators, variacs, and power interrupters.

The test procedure should include a section where the test environment is validated by simulating or stimulating each error that could result from errors inherent in the test environment.

The test procedures should be based on the resources and facilities readily available to them. Environmental test procedures that are currently included in standards, such as NEMA TS 2-2003 and the CalTrans TEES outline elements of the testing process. These testing processes may guide the development of appropriate test plans to demonstrate compliance of the ITS device with the agency specifications. The test plan should completely describe the test installation, all connections, all instrumentation, and exactly what and how the units are to be monitored.

4.2.8 Responsibilities and Approvals

4.2.8.1 Responsibilities

The responsibilities section of the test plan identifies the groups and/or individuals responsible for managing, designing, preparing, executing, witnessing, checking, controlling the environment in the laboratory, getting equipment and supplies, setting up equipment and software, report writing, and approving (who signs the approval sheet) [Kaner, C., *Testing Computer Software*, 1999, p. 248]. Who conducts testing is addressed in Section 5.3.

4.2.8.2 Approvals

Some agencies require that an officer of the corporation approve test results. It is recommended that the agency or a trusted independent agent witness and approve all testing.

4.3 IEEE 829-1998 TEST DESIGN

A test design is generally associated with one test plan. The test design identifies which test cases are used to verify which agency specification requirements. This allows the re-use of test cases and test procedures.

A test design refines the test approach and identifies the requirements to be addressed by the test plan and its associated tests. It also identifies: agency specification requirements, test cases, and test procedures used to accomplish testing, and specifies the pass/fail criteria for each test item. See IEEE 829-1998.

4.4 NTCIP 8007 V01 TEST CASES AND TEST PROCEDURES

4.4.1 Test Case and Procedures Overview

Given the sophistication of today's systems and components, it is impossible to test all possible combinations and permutations of how a system or component might react. In general, the principle is to define at least one test procedure for each agency specification requirement and then exercise those features in the context of how they should react in a normal system operation environment.

Another way to think about this is to consider whether every ITS device procured is tested completely or whether a representative sample is sufficient. For example, is it necessary to test every parameter to see if it can be set to every possible value? Not necessarily. A sample set of values probably suffices for a representative set of parameters. One has to consider the risk involved. If one parameter of some type accepts the minimum, maximum, and several values in between and rejects several invalid values, chances are that all parameters react the same way.

Likewise, ITS device testing should include some measure of negative testing, i.e., the device under test (DUT) should be subjected to normally occurring anomalies such as power failures, disruption of communications channels, overloaded communications channels (worst-case traffic), and such input anomalies as intermittent connections. In most cases, the DUT is expected to recover without intervention and return to normal operation without creating unsafe conditions prior to, during, or after the disruption.

Test procedures and test cases should cover the agency specification requirements to be tested and be fully developed before an ITS device is delivered. While a certain amount of randomness can be added to any well-defined procedure or test case, the specific approach should be spelled out. NTCIP 8007 v01 provides examples of how test procedures and test cases should be defined. As test procedures and test cases are added to NTCIP standards, the need to develop separate, independent test procedures to evaluate NTCIP conformance diminishes.

The test procedure should include a listing of all commands that are to be sent to the unit and all expected responses, as well as timing tolerances for all actions. The test procedure should also include inspections and design reviews for those portions of the agency specification requirements that are not verified by operational testing. These typically include design requirements for electronic components (voltage and thermal margins) and materials as well as construction techniques. A requirements matrix, which puts in table form each agency specification requirement—with additional tables for the requirements for the standards conformance—should be developed. Then, for each requirement, the table should identify a test case or type of measurement or inspection that is to be made to verify compliance with the agency specification requirement.

The test procedure should be written with some flexibility so that a suspected anomaly can be verified (re-tested) as the test progresses. It is also important to note that **any** anomaly—no matter how slight—should be documented. If the anomaly is "improper operation," then the cause and cure should be determined and documented. For example, if an anomaly appears once in 10 testing attempts, the total number of occurrences, when 100 units are installed, is likely to be much higher. Often, moving ahead with testing (after the anomaly *seems* to disappear) is suggested, while awaiting more detailed findings regarding the anomaly observed. While this approach typically has value because testing proceeds, and it is possible to evaluate whether the DUT is likely to meet all other agency specification requirements, there is a risk that the correction introduced to fix the anomaly may necessitate complete re-testing. This is a judgment call with risks and benefits for all parties involved with the testing. It is important to determine the root cause and cure for any anomaly, or intermittent problems may surface during subsequent testing or after installation of the ITS device in the field.

4.4.2 Boundary and Error Condition Tests

Testing should include verification that invalid data communications does not cause the ITS device to operate in an abnormal manner. Invalid data communications can include any of the following:

a) A noisy communications link
b) A chattering modem
c) Improperly formatted data
d) Properly formatted data that does not meet the ITS device's consistency checks
e) Interrupted and restored communications

In addition to continuing to operate when invalid data is impinging on the ITS device's communication port, the ITS device should co-exist with others on the same channel and not be adversely impacted. During ITS device testing in some deployments, the following extreme test outcomes have been observed:

a) ITS device clock drift while interpreting NTCIP messages destined for a different ITS device;
b) ITS device "crashes" while attempting to read data from a noisy communications line; and
c) Inability of the ITS device to manage its field functions while processing NTCIP messages

This section of the test plan ensures that the ITS device (or system) performs the required functions when exposed to the proper data elements (parameters) in the proper sequence (dialogs) and does not perform improperly when subjected to bad data or the wrong sequence of data elements and messages. This aspect of testing should be tempered with reasonable risk assessment as not all possible conditions can be tested. These conditions should include those situations that are likely to exist under extreme situations.

4.4.3 Test Case and Procedures Documentation

A format for developing test procedures is included in NTCIP 8007 v01. The test procedure should reference the agency specification requirements, and those requirements contained in the NTCIP standard. The agency specification should include the operational, maintenance, and performance requirements to be tested, define the dialogs that satisfy the agency specification requirements, and trace to the appropriate objects (from the NTCIP standards).

The test procedure should identify a test case for each of the agency specification requirements or in some cases, each NTCIP data object. Using this as background, the test procedure should exercise each of the data parameters (objects) and require specific observations based on the agency specification requirements. Many test cases are complex and require very complex testing set-up to verify a single requirement (e.g., Daylight Savings Time transition).

NTCIP 8007 v01 organizes test cases and includes the following elements:

a) **Test Case Identifier—**A unique test case identifier.

b) **Test Case Title—**A unique title for the test case. This title is to be used in the trace matrix.

c) **Description—**Describes the test and purpose of the test case.

d) **Test Items—**These identify the agency specification requirements being tested. Mapping of requirements to test cases is documented in the RTCTM.

e) **Input Specification—**A description of data values and tolerances for each data concept requirement. If the information is kept in a file, then this may be the file name. The input specification also includes a way to indicate whether data values are valid. This is the criteria for pass/fail.

f) **Output Specification—**A description of data values and tolerances for each data concept requirement. If the information may be logged to a file for subsequent verification and analysis of format and data value ranges, then this may be the file name. The output specification also includes a way to indicate whether data values are valid. This is the criteria for pass/fail.

g) **Environmental Needs (Optional)—**In cases where the environmental needs are different (or require additional resources from what is described in the test plan or test design specification), then this section should be included.

h) **Special Procedural Requirements (Optional)—**In cases where special procedures for start-up, set-up, wrap-up, etc. differ, then this section should be included, as applicable.

i) **Dependencies—**This lists the dependencies for this test case. It allows an ordering of test case execution to be developed.

j) **Procedure Steps—**This lists steps and step number.

k) **Test Log—**A record of relevant details about the execution of a test. Test log information should note procedure step.

4.5 TEST EXECUTION REPORTS

This section briefly summarizes the test reports outlined in IEEE 829-1998 and NTCIP 8007 v01, where additional detail is provided.

a) **Test Log—**The test log is a chronological record of the execution of the test including persons present and roles, procedure results, and any anomalies encountered.

b) **Test Incident Report—**This report documents any event that occurs during testing that required further investigation. It records expected versus actual results, procedure and procedure step, and attempts to repeat the test. It should also record potential impacts on further testing activities.

c) **Test Summary Report—**This report summarizes the test plan executions.

4.6 SAMPLE TEST DOCUMENTATION LINKS

Example test procedures from several agencies are available on the Internet. The referenced test procedures demonstrate the amount of effort that is required to properly test ITS devices incorporating

NTCIP standards. These example test procedures are the result of multiple iterations of testing. The example test procedures include:

a) NTCIP test procedures developed for the "ENTERPRISE" pool fund project and are available at http://www.trevilon.com/library.html.

b) Actuated signal controller test procedures that Texas Transportation Institute developed can be found at http://www.itstestlab.org/ by clicking on testing and then on *In House Testing and Scripts*. The files under the procedure column are in NTCIP 8007 v01 format.

c) Florida Department of Transportation (FDOT) Florida State University (FSU) Traffic Engineering Research Lab (TERL) has been developing NTCIP test procedures to qualify Dynamic Message signs for use in the state. Information on their test procedures and results can be found at: http://potentia.eng.fsu.edu/terl/areas_of_work_ntcip_testing.htm.

d) Additional test procedures are likely to become available as more and more agencies adopt NTCIP for their center to field protocols.

4.7 SUMMARY

A significant level of expertise in the ITS device and agency specification requirements is needed to develop test documentation. Significant resources, in terms of facilities and personnel, are needed to implement a comprehensive testing program, and the use of independent testing laboratories, or reliance on test results from other sources such as other states may be warranted. While this approach can be successful, the agency should examine the test plans, specification requirements, and test results to verify that the results of the testing are applicable to an agency's unique implementation and related testing program. Where there are differences, the agency should evaluate risk associated with accepting previous results against the benefit of establishing a new testing program.

Section 5
TEST EXECUTION

5.1 OVERVIEW

A complete ITS device testing program consists of many phases of testing, taking place in a methodical approach. Overall, the testing program should cover all requirements leading to a complete ITS device design including electrical requirements, mechanical requirements, operational requirements, communications requirements, and design requirements (such as voltage and thermal operating margins for electronic components). Each phase may be described in its own test plan covering a set of test items: one for hardware and environmental requirements (e.g., structural, mechanical, electrical, or environmental), one for software-related requirements (e.g., functional, operational), and one for communications requirements (e.g., communications interfaces).

A Testing Program:

- Should include ALL requirements
- May be separated into test plans, each testing a TYPE of requirement
- Should be performed in phases

An agency's approach to testing for any deployment depends on the maturity of the ITS device, the number of units being acquired and installed, the agency's ability to test, available expertise, and the relative significance of each agency specification requirement, among other factors.

5.2 ITS DEVICE TESTING PHASES

The approach to testing should be tempered with the number of units to be acquired, the degree of tailoring of the ITS standards to accommodate unique agency or project implementations, and the history of the ITS device and standards involved. ITS device testing is generally divided into the following phases:

a) Prototype test and inspection
b) Design approval test and inspection
c) Factory acceptance test
d) Incoming ITS device test
e) Site acceptance test
f) Burn-in and observation test

Figure 7 summarizes the relationship of these ITS device testing phases with the testing phases defined by the SEP. Table 2 summarizes key attributes of these ITS device test phases.

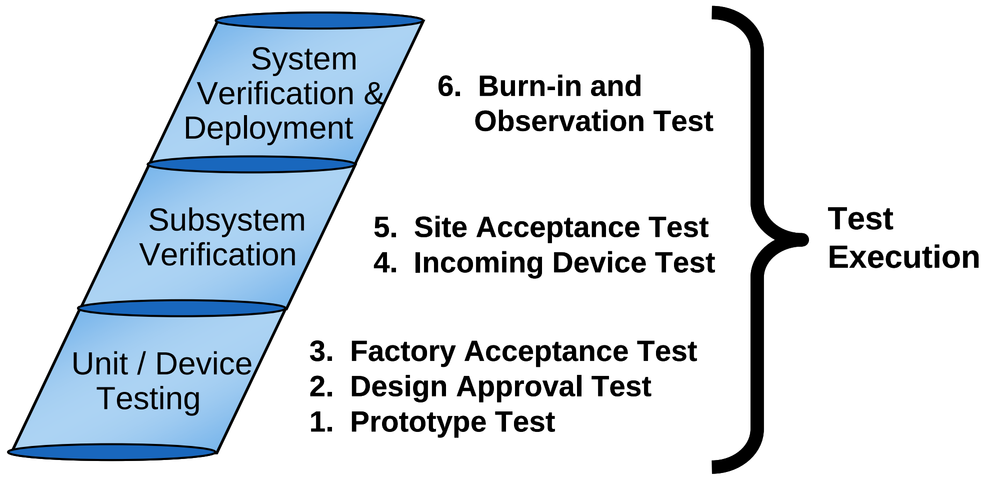

Figure 7 Relationship of Test Execution Phases to the VEE Model

Table 2 ITS Device Testing Phases

Test Phase	Purpose	Number of Units	Test Location
Prototype Test and Inspection	Verify the electrical and mechanical design	One prototype	Test Laboratory
Design Approval Test and Inspection	Verify the final design	Pre-production or a small percentage of the production units	Laboratory
Factory Acceptance Test	Verify production units are identical to the final design and production quality	A percentage of the production unit	Production factory
Incoming ITS device Test	Inspect for damage due to shipping and handling	All delivered units, including spares	Agency
Site Acceptance Test	Full functionality of the entire system	All installed units	Final location for operation
Burn-in and Observation Test	Monitor proper operation of the installed unit	All installed units	Final location for operation

A brief description of each phase follows.

5.2.1 Prototype Test and Inspection

The purpose of the prototype test is to verify the electrical and mechanical design of the ITS device for the environmental conditions of the specifications. If the ITS device is a custom development or custom extension to an existing ITS device designed to meet a unique agency specification requirement with a number of unique physical and electrical requirements, then it may be necessary to identify a prototype testing phase for the ITS device. During the prototype testing phase, the ITS device manufacturer constructs a fully operational version of the ITS device for inspection and testing by the agency. Testing may follow a hardware testing profile, such as NEMA TS 2 or CalTrans TEES, and is performed by the manufacturer, an independent laboratory, or the agency itself. Testing, at a minimum, should include environmental testing (temperature and humidity) and electrical testing (voltage variation, interruptions, and transients), although the testing apparatus and instrumentation required to conduct a rigorous NEMA testing program requires expertise in the electrical and electronic aspects of testing. Prototype testing also verifies the functionality (e.g., actuated operation, ramp control) and performance requirements (e.g., timing accuracy, transmission times, start-up times, communications timing). One aspect of testing that is often postponed until the final production version of the ITS device is shock and vibration testing depending on the completeness of the mechanical design.

NTCIP testing (communications, functionality, and performance) is usually a part of the prototype test. It is important that such a prototype testing program include inspections to verify that the DUT truly complies with **all** of the requirements of the agency specification requirements and those auxiliary standards typically referenced including NEMA, New York State, CalTrans, and Military standards as examples.

Agency specification requirements should define appropriate testing for any custom or semi-custom ITS device that is electrically and mechanically different from ITS devices previously tested. Changes to the electrical design and components may have significant effects on compliance. Testing on a previous version of an ITS device may provide some indication of the performance of the new design. However, a repeat of previous testing may be warranted as even minor changes can have an impact, and any electrical or electronic changes typically warrant a repeat of previous environmental testing.

Agency specifications may also include additional provisions such as more extensive power interruptions and slowly varying AC line voltages that are further defined beyond what is required by a referenced standard. As an example, NEMA TS 2 does not require that a traffic signal controller be subjected to transient voltages at low temperatures. If transient voltages under these conditions have been of concern, an agency may wish to include test items for traffic signal controllers using transient voltages during low temperature operation, if transient voltages under these temperature conditions have been an issue previously.

Even when an ITS device is “standard,” and has been used before or is already on another agency’s qualified products list (QPL), the procuring agency should perform a design review to ensure that the ITS device complies with the agency’s specification requirements. This review should include an examination of the details of the testing and inspection program used to accept the ITS device on the QPL to ensure that the ITS device is, in fact, the same product that was previously tested.

ITS device functional testing should also include the ability to manage failures, detect failures, and report failures where these requirements are identified (in either the agency specification or referenced standards).

For large devices such as dynamic message signs, a sample unit may be constructed consisting of a few panels, sample control electronics, etc. This is generally sufficient to evaluate the performance and operation of the ITS device, as long as it is subjected to worst-case loading and maximum processing loads. Such a sample unit should be large enough to fully stress the power supplies and controller operation or test results may not be representative of the final unit performance. Under these circumstances, the agency should work with the manufacturer to ensure that the sample unit tested is representative of a worst-case deployment of the ITS device.

5.2.2 Design Approval Test

The second phase of ITS device testing occurs when the ITS device is in its final production form. This is generally considered the Design Approval Testing (DAT) and includes a repeat of the prototype testing and inspection along with the shock and vibration testing. DAT verifies that the ITS device in its production form fully complies with all of the standards (conformance) and agency specifications (compliance). At this point, the documentation for the ITS device should also be included in the inspection.

DAT is typically performed on a group of pre-production (or production) units randomly selected from the first production run. It is generally recommended that a minimum of five units be simultaneously tested, although when procuring a small number of large ITS devices (e.g., DMS) this may be impractical. NTCIP testing should be part of the DAT program; it is beyond the scope of NTCIP 9012 v01 to provide guidance in managing DAT beyond NTCIP testing.

It is recommended that shock and vibration testing be performed prior to the performance and environmental testing. This ensures that any latent failures (e.g., partially fractured connections) are more likely to become visible during the more extensive environmental testing.

Several issues are important when reviewing the proposed prototype testing; first, exactly what is monitored and how. It is important that the test environment be thoroughly inspected and tested to see that if errors do occur, they are detected. Further, all monitoring should be continuous, since some failures can be transient in nature and caused by thermal gradients within the ITS device. The instrumentation used to measure the operation of the ITS device or the test environment (temperature, voltage, etc.) should be calibrated—and the calibration should be recent. The calibration should be performed based on the instrumentation manufacturer's guidelines and depends on the type of instrumentation and usage.

Second, it is important to fully define what constitutes proper and improper operation. This should be clearly identified within the test procedure.

A word of caution; many ITS devices can be very complex in nature and there may be occasions when an "anomaly" occurs during which the DUT does not function properly, e.g., it may have reset and recovered, and a repeat of the same test step seemed to clear the failure. Other examples might include pixel failure reports that seem to disappear or measurements that seem to have a transient error when read. Such occurrences are suspect and should cause the test to be classified as "failed," requiring a detailed analysis of the cause and cure for the anomaly. There is a tendency to "pass" a DUT with such a transient failure, but if such an anomaly was experienced in a small sample of ITS devices, additional anomalies may be anticipated in a larger number of ITS devices when deployed. As an example, if the DUT experiences an unexplained anomaly that requires manual intervention (e.g., reset, power cycling) during the test (for no apparent reason), when many units are installed, it may be anticipated that a larger number of deployed ITS devices may exhibit similar anomalies, each necessitating manual intervention.

Both prototype testing and DAT should be witnessed by the agency or an independent, knowledgeable third party. Agency participation has several advantages, including:

a) The agency is the best judge of many issues, such as ease of repair or accessibility;
b) The agency has the opportunity to observe the device under extreme conditions; and
c) Should the ITS device experience an anomaly or failure, the agency gains some experience and understanding of what to expect when ITS device failures occur after installation.

5.2.3 Factory Acceptance Test

This is usually the final test performed prior to delivery of the ITS devices to the agency and may be observed by the agency. The purpose of this testing is to ensure that production units have been constructed in a manner identical to the unit that was subjected to the DAT and that all connections and functions are fully operational. Where the ITS device includes analog functions, these need to be verified to ensure that the operation is within acceptable tolerances.

For larger ITS devices, such as DMS, this typically includes such aspects as detailed inspection of the construction, review of such requirements as the power consumption and the weight of the unit, and verification that all pixels are operational and of uniform intensity. In general, the factory acceptance test (FAT) includes a 100% continuity and function verification to make sure it has been constructed without errors.

If the ITS device being offered is "standard," and the ITS device has undergone previous prototype and DAT, then the detailed design review and environmental testing is often waived. This means that the FAT is the only opportunity the agency may have to review the ITS device prior to shipment.

Some agencies (e.g., CalTrans) require that all units undergo a monitored burn-in and environmental cycle over either the full or a limited range of the anticipated ambient temperatures for the installation. This type of burn-in is recommended for electronic ITS devices and is typically on the order of 100 hours.

While the entire DMS cannot be temperature tested, portions of the ITS device such as the controller could be subjected to the environmental cycling. The FAT should include inspection for construction such as conformal coating and water leakage testing.

5.2.4 Incoming ITS Device Test

Once the ITS device is delivered to the agency, it should be inspected for damage due to shipping and handling. Where possible, the ITS device should be powered and run through a test that fully exercises all of the connections, features, and functions.

Some agencies have established testing labs and/or integration test facilities. Where such a facility is available, the incoming ITS device testing can be more rigorous and involves portions of the site acceptance testing. This approach is often taken when the agency plans a large-scale upgrade program. Such an integration testing facility allows the agency to fully configure and test the ITS device under simulated conditions (loops, communications, signal heads) and verify the end-to-end operation.

Where the central system is not available, this becomes a unit test of the ITS device where all of its operations can be verified using a stand-alone simulator or other test unit and all inputs can be simulated.

5.2.5 Site Acceptance Test

Once the ITS device has been installed at its intended location for operation, the full ITS device functionality is again tested and verified. If the system is in place, this means connecting the ITS device to the complete system and verifying all of the operation and feedback of the ITS device. Where the central system or the communications infrastructure may not be available, this testing should be performed with a stand-alone central simulator or similar tester. Once the ITS device has been tested and verified (e.g., CCTV images are within tolerance, pan-tilt-zoom functions work properly, sign messages display properly, all pixels function correctly and that failure detection logic is working properly), the ITS device is accepted subject to a period of observation and operation.

When installing ITS devices, such as CCTV cameras and dynamic message signs before the communications systems are in place, additional guidance should be considered. Once the ITS device is installed at its final location, and the site acceptance test has been completed, it is recommended that the ITS device be energized and monitored. It is generally not recommended that the ITS device be installed and remain un-powered and unused for a prolonged period of time.

5.2.6 Burn-In and Observation Test

Once the ITS device is installed and verified, it is connected to the system and undergoes a period of observation; this is typically a period of 30-60 days during which the ITS device should exhibit fault free operation. During this period of time, the ITS device should be exercised to monitor the functionality of the unit. This may include test messages, operator usage of a camera, operation of the traffic signal, or data collection as examples.

It is important for this phase of the testing that the ITS device be exercised and inspected regularly, that failures are detectable, that the ITS device is continuously monitored, and that failures of the communications infrastructure or the central system are not attributed to the ITS device itself. Where ITS device acquisition is independent of the communications infrastructure and the central system, it is important that acquisition provisions identify the responsibilities of the ITS device manufacturer in a manner that can be measured and ongoing resource allocation purposes.

It is also important that the ITS devices and the system be subjected to full communications loading to ensure that there are no latent processing problems due to the amount of network traffic. Recent experiences with some ITS devices in an Ethernet environment have revealed processing deficiencies that have caused ITS devices to gain/lose time, go into flash, or experience other timing anomalies. Hopefully these types of problems have been anticipated and were included in the DAT.

5.3 WHO SHOULD PERFORM TESTING

With any ITS device testing, the agency should identify the party that conducts the testing, as well as appropriate performance provisions and a clear understanding of the responsibilities of all parties involved with testing. The agency should also include a clear description of the consequences of test failure in terms of procurement, budget constraints, and schedule.

5.3.1 Agency Testing

Agency testing is that component of the testing framework that is carried out by members of the agency's staff. It is expected that the agency, possibly with an outside consultant, possesses the technical knowledge, the tools, and the staff to conduct this phase of testing, independent of manufacturer assistance. Frequently this is the last stage of testing for the project when the agency is making the final determination that the delivered system complies with the agency specifications.

To ensure comprehensive testing of an ITS device, an agency should be involved in the creation of the requirements and test documentation used to verify whether or not the ITS device complies with the agency specification. The agency should also develop an understanding of the referenced standards to accurately evaluate the results of the testing. Agency personnel should also witness testing to provide verification of the proper execution of test plans.

5.3.2 Manufacturer Testing

Manufacturer testing covers those tests that are conducted by the manufacturer. Procurement of a field-proven, off-the-shelf ITS device may not necessitate additional manufacturer testing. If an ITS device is being developed specifically for the agency, or an existing ITS device is being modified for the agency, then additional tests should be required. The agency, or its consultant representative, should witness such additional manufacturer tests.

The issue of hardware/firmware configuration management is particularly important for manufacturer testing. The manufacturer should be able to positively identify both the hardware revision and firmware revision that has been (or is being) tested. The firmware version number should provide the agency with sufficient information that the specific firmware build can be tracked, including all test versions.

Although manufacturer testing is typically required, it is not sufficient by itself. The drawback to manufacturer testing is the lack of the unique installed environment in which the ITS device is expected to function in the field. The environment includes the central system, the communications infrastructure, and the presence of other ITS devices or components that are functioning together with the ITS device (i.e., peripherals or devices that share the same communications channel). If a project specifies that an ITS device should extract information from another ITS device and send that data to the central system, the second ITS device should be available to adequately test the function.

Manufacturers should submit a complete description of their test approach, test environment, and explain and demonstrate how the test configuration measures the parameters and detect errors when they should occur.

5.3.3 Independent Laboratory Testing

Independent laboratory testing is often used to verify that an ITS device meets certain environmental specifications such as vibration, temperature ranges, power conditions, and light output. Such testing is commonly required for traffic controllers and other ITS devices. A testing outline is contained in such documents as the NEMA TS 2-2003 standards for traffic signal controllers and previous versions of the NEMA Standards (e.g., NEMA TS 1-1989), the CalTrans TEES, and NEMA TS 4-2004. However, such standards do not document all of the unique agency or project test procedures, test configuration, and equipment operation to be monitored. Such test procedures are often developed by the manufacturer or the agency and provided to the testing laboratory that monitors the testing and provides the measurement and monitoring equipment.

When an independent laboratory is used for NTCIP testing, the agency should first define the test procedures and test cases the independent laboratory is using. For example, the agency should determine whether the laboratory is testing communication with the ITS device or the function of the ITS device. In either case the agency should work with the laboratory to define the entire test methodology. If the testing laboratory is unfamiliar with the ITS device or the standards, then the agency (or consultant) should provide guidance in the form of a test plan that includes the test configuration and test procedures.

An independent laboratory may not have domain expertise. Even when a detailed agency specification requirements and associated PRL are provided, there is significant opportunity for errors in testing based on lack of domain expertise. Database download, for example, is an area that requires significant domain expertise. For instance, if a download of the *Phase Block Data* as specified in NTCIP 1202 v2 is rejected, domain expertise determines where the test procedure, the test environment, or the ITS device failed. Depending on the data supplied for some of the elements of the data block, a rejected download is the correct action by the controller.

And finally, the independent laboratory does not necessarily have access to the assets necessary to conduct the testing. Testing of some ITS devices requires specific knowledge about how the ITS devices are installed in the field. For traffic controllers, the combination of alarm bits returned in *unitAlarmStatus1* and *shortAlarmStatus* for a police panel flash condition varies on the cabinet type (TS 1, TS 2, or TS 2 operating as a TS 1) and how the agency implements the flash. Given that laboratory personnel have the required domain knowledge to configure ITS devices, the test environment should also mimic field installation conditions to validate ITS device performance.

Several laboratories have established NTCIP testing facilities and are developing broad procedures (following NTCIP 8007 v01) to test for NTCIP conformance. Further, each software change should necessitate a complete re-test for NTCIP conformance as each new version of the NTCIP standards is published.

If an independent laboratory is selected to act as the testing facility, the agency (or a consultant to the agency) should examine the test plan and detailed test procedures to ensure that all of the requirements of the applicable standards and agency specifications are tested in a manner consistent with expected agency operation.

Section 6
NTCIP TESTING TOOLS

NOTE—AASHTO, ITE, and NEMA do not endorse ITS devices, products, manufacturers, test tools, or facilities. Trademarks or manufacturers' names that appear in NTCIP 9012 v01 are not statements of compliance.

6.1 OVERVIEW

Generally, agencies anticipate verification of the field operation of an ITS device, but the communications protocol between the field ITS device and the central system represents a more recent consideration. Testing NTCIP necessitates that an agency understand this communication mechanism and how to verify its correct operation. Collecting data requires a set of passive and active tools, including serial protocol analyzers, network sniffers, and protocol exercisers.

Testing tools consist of specialized software and/or hardware used to examine the interface of NTCIP-based ITS devices. There are two types of testing tools: passive and active. Passive testing tools are used to monitor the operation of a system but do not provide or respond to an ITS device stimulus. Examples of the passive type of tool are Serialtest Async for serial data (reference www.fte.com) and the Ethereal (reference www.ethereal.com) tool for capturing network traffic. These tools provide a method for the tester to "see" what data is being exchanged between the test rig and the DUT by using an independent software package.

The passive tools only function when both ends, the field ITS device and central system, are currently operational. If there is no software to request messages, then the passive ITS devices have no function. Active tools, such as the NTCIP Exerciser, provide a means to send messages to ITS devices and await the response. Some limitations associated with active tools prevent complete testing of the ITS device. For instance none of the existing active tools support the proprietary logical blocks developed to support NTCIP 1202:1996 and support for the logical blocks defined in NTCIP 1202 v02 has not yet been incorporated into the tools. Therefore, special purpose software is developed to perform this additional testing.

Active testing tools allow the tester to send a known stimulus, such as a GET object command, to the DUT, and then monitor how the DUT responds. The NTCIP Exerciser is a prime example of this type of tool. The current generation of active test tools supports testing basic functions, such as GET and SET for specific objects, but does not support more sophisticated testing, such as communication load testing.

6.2 LIST OF TOOLS

Identification of Test Tools for Intelligent Transportation Systems Devices and Subsystems provides a starting point to evaluate various NTCIP testing tools. Since publication of that report, additional tools have become available. Current software tools may provide a variety of testing capabilities, including:

a) tests for conformance to specific standards (e.g., NTCIP 1201:2005, NTCIP 1202 v02, NTCIP 1203:1997);
b) support for SNMP and STMP;
c) scripting features to support automated testing;
d) various protocols including PPP, PMPP, and
e) a wide variety of media, including Ethernet and TIA RS-232-F/422-B/485-A/530-A.

A partial listing of examples of these types of tools follows:

a) **SimpleTester** by SimpleSoft; for additional information, reference the following link: www.snmptest.com/SimpleTesterNTCIP.html

b) **DeviceTester** by Intelligent Devices; for additional information, reference the following link: www.intelligentdevicesinc.com/device_tester.html

c) **Ntester®** by Trevilon; for additional information, reference the following link: www.trevilon.com/products.html

d) **FTS for NTCIP** by Frontline Test Equipment, Inc. and Trevilon; for additional information, reference the following link: www.trevilon.com/products.html

e) The **NTCIP Exerciser** in the public domain, for additional information, reference the following link: www.ntcip.com/library/software/

f) **PacketView Pro** by Klos Technologies, Inc; for additional information, reference the following link: www.klos.com/TrafficView/

There are many other tools available for monitoring network and serial traffic and SNMP packets; the tools listed above have specific support for NTCIP. This list is by no means complete, and no claims of performance or conformance are suggested by inclusion in, or exclusion from, the list.

Section 7
QUALIFIED PRODUCTS LIST

7.1 OVERVIEW

NTCIP 9012 v01 introduces many of the concepts necessary to develop and manage a qualified products list (QPL). A QPL is a list of ITS devices (products) that have been tested to verify compliance with an agency's specifications. A QPL allows an agency to partially re-use agency specifications and test documentation thus simplifying the system acquisition process. This can conserve valuable project resources.

Each agency has its own process to accept an ITS device for inclusion on its QPL. Using SEP, an agency may:

a) determine the operational needs an ITS device satisfies;
b) define requirements, including functional, hardware, and performance requirements;
c) develop test documentation for QPL qualification;
d) execute test plans to verify that the ITS device fulfills the agency's requirements and specifications;
e) provide project site documentation and instructions for completing inspection of the ITS device in the field; and
f) on a periodic basis, recertify the ITS device to ensure that it continues to comply with agency specifications.

7.2 PROCURING FROM THE QPL

Prior to procuring an ITS device from a QPL, an agency should verify that:

a) The requirements used to qualify an ITS device fulfill the project requirements. If the project requires changes to the ITS device, this essentially becomes a "new" device and previous QPL testing may not apply.

b) The qualification testing leading to the QPL is adequate to ensure the ITS devices meet the agency specification requirements. This includes a detailed examination of the test documentation used to verify compliance.

c) The hardware/firmware combinations to which those ITS devices on the QPL were tested are still available.

d) The configuration of the ITS device currently listed on the QPL to ensure that it is truly the same as the ITS device the agency wishes to acquire.

Most QPL programs test the ITS device for full compliance with the agency specification, including environmental, design, mechanical, operational, and performance requirements, in addition to NTCIP conformance.

Several states have established an NTCIP testing program that reviews an ITS device's implementation of the NTCIP standards. Again, it is important for the procuring agency to review the testing plan and procedures as well as the results to determine if the QPL product is a likely candidate for compliance with the agency specification.

7.3 QPL MANAGEMENT

In an era of rapid change in both hardware and software, several issues can impact the availability of hardware/firmware identical to the configuration on the QPL. These include electronic components going out of production, corrections to the firmware that might impact apparently unrelated areas of the ITS device operation, and addition of new features.

Standards used to generate the QPL are also subject to change as clarifications are included or new capabilities are added. The changes to a standard may not be backward compatible.

And finally, requirements used as the basis for the QPL should be re-evaluated from time to time to adapt to changing demands and technology. Rapid changes in communications media is one example where requirements written as recently as five years ago are significantly out of synchronization with the advance of technology.

The QPL approach to obtaining interchangeable ITS devices is exemplified by the Florida DOT (FDOT) dynamic message sign procurement. The FDOT approach uses an agency-developed MIB, describing agency-required MIB objects and how they function to supplement standard MIB objects. Notice that the agency described the functionality (specific power supplies to be monitored) and the custom NTCIP objects to support that feature. When functionality is clearly described (in a measurable and observable manner), then ITS devices that use the same objects to manage the same well-defined functionality **are interchangeable**.

Annex A
REFERENCES, DEFINITIONS, AND ACRONYMS

A.1 REFERENCES

Normative references contain provisions that, through reference in this text, constitute provisions of NTCIP 9012 v01. Other references in NTCIP 9012 v01 might provide a complete understanding of the entire protocol and the relations between all parts of the protocol. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standard listed.

NOTE—NTCIP 9012 v01 is an information report, and NTCIP 9012 v01 contains no normative references.

A.1.1 Other References

AASHTO / ITE / NEMA	*Advanced Traffic Controller Standard*
AASHTO / ITE / NEMA NTCIP 1202:2005	*Object Definitions for Actuated Traffic Signal Controller (ASC) Units—Version 2* published November 2005
AASHTO / ITE / NEMA NTCIP 1203:1997	*Object Definitions for Dynamic Message Signs (DMS)* published December 1999
AASHTO / ITE / NEMA NTCIP 8007 v01	*Testing and Conformity Assessment Documentation within NTCIP Standards Publications* published May 2008
AASHTO / ITE / NEMA NTCIP 9001 v03	*NTCIP Guide* published October 2002
AASHTO / ITE / NEMA NTCIP 9010 v01	*Information Report, XML in Center-to-Center Communications* published November 23, 2004
NEMA	*Standardization Policies and Procedures of the National Electrical Manufacturers Association* published July 2008
NEMA TS 1-1989	*Traffic Control Systems*
NEMA TS 2-2003	*Traffic Controller Assemblies with NTCIP Requirements, version 2.06*
NEMA TS 4-2005	*Hardware Standards for Dynamic Message Signs (DMS) with NTCIP Requirements*

Dorfman, M. & Thayer R.H.	*Software Engineering* Los Alamitos, CA, IEEE Computer Society Press, 2000.
AASHTO/ITE/NEMA	Battelle, *Identification of Test Tools for Intelligent Transportation Systems Devices and Subsystems*, April 2004
IEEE 610.12-1990	*IEEE Standard Glossary of Software Engineering Terminology*
IEEE 829-1998	*IEEE Standard for Software Test Documentation*
IEEE 1008-1987	*IEEE Standard for Software Unit Testing*
IEEE 1233-1998	*IEEE Guide for Developing System Requirements Specifications*
INCOSE	*Systems Engineering Handbook*, INCOSE-TP-2003-02-031, Version 3.1, August 2007
Kaner, C.	*Testing Computer Software,* 1999, New York, NY: John Wiley & Sons, Inc.
Perkins, D. & McGinnis, E.	*Understanding SNMP MIBS* 1997, Upper Saddle River, New Jersey: Prentice Hall, Inc.

A.1.2 Contact Information

A.1.2.1 NTCIP Standards

For revision information on NTCIP 9012 v01, contact:

NTCIP Coordinator
National Electrical Manufacturers Association
1300 North 17th Street, Suite 1752
Rosslyn, VA 22209-3801
e-mail: ntcip@nema.org

For draft revisions to this NTCIP standard, and recommended revisions of the NTCIP Joint Committee, visit www.ntcip.org.

A.1.2.2 IEEE Standards

IEEE standards may be obtained from:

IEEE (originally Institute for Electrical and Electronics Engineers, Inc.)
445 Hoes Lane
Piscataway, NJ 08854-4141
(732) 981-0060
www.ieee.org/portal/site

A.2 DEFINITIONS

For NTCIP 9012 v01, the following terms are defined:

Term	Definition
Agency Specification	A document that has been prepared by an agency to define requirements for a subject item or process when procured by the agency.
Capability	The ability of a component to support a specific implementation of a feature. For example, a phase on a signal controller is a feature; supporting 8 phases is termed a capability within this paper.
Compatibility	The ability of two or more systems or components to exchange information. NOTE—See IEEE 610.12-1990.
Compliance	A condition that exists when an item meets all of the requirements of an agency specification.
Component	One architectural piece of a system. NOTE—Within NTCIP 9012 v01, the subject system is defined to be central software/hardware with various field ITS devices. Thus, a component most often refers to a given field ITS device but may also reference the central software/hardware itself. Within other contexts (i.e., viewing a specific software application as the system), a component can reference a unit of code. Within NTCIP 9012 v01, the term 'unit' refers to the code level concept.
Concept of Operations	A document that describes the purpose for a system project, including a description of the current and proposed system, as well as key user needs that the new system is required to address.
Configuration Management	A management process for establishing and maintaining consistency of a component's performance, functional, and physical attributes with its requirements, design and operational information throughout its life.
Conformance	A condition that exists when an item meets all of the mandatory requirements as defined by a standard. It can be measured on the standard as a whole, which means that it meets all mandatory (and applicable conditional) requirements of the standard or on a feature level (i.e., it conforms to feature X as defined in section X.X.X), which means that it meets all mandatory (and applicable conditional) requirements of the feature.
Design Requirement	A requirement that specifies or constrains the design of a system or system component. NOTE—See IEEE 610.12-1990.
Dialog	A sequence of information or message exchanges.
Feature	A behavior that may be offered by a component or device.
Functional Requirement	The necessary task, action, or activity [to] be accomplished. NOTE—The initial set of top-level functions are the eight primary system life-cycle functions. Top-level functions are identified by requirements analysis and subdivided by functional analysis. As modified from INCOSE, *Systems Engineering Handbook*. A requirement that specifies a function that a system or system component [is to] be able to perform. NOTE—As modified from IEEE 610.12-1990.
Functional Testing	Testing that ignores the internal mechanism of a system or component and focuses solely on the outputs generated in response to selected inputs and execution conditions. NOTE—See IEEE 610.12-1990.

Term	Definition
Interchangeability	A condition [that] exists when two or more items possess such functional and physical characteristics as to be equivalent in performance and durability, and are capable of being exchanged one for the other without alteration of the items themselves, or adjoining items, except for adjustment, and without selection for fit and performance. NOTE—As modified from National Telecommunications and Information Administration, U.S. Department of Commerce.
Interface	a) A shared boundary across which information is passed. b) A hardware or software component that connects two or more other components for the purpose of passing information from one to the other. NOTE—See IEEE 610.12-1990.
Interoperability	The ability of two or more systems or components to exchange information and use the information that has been exchanged. NOTE—See IEEE 610.12-1990.
Management Information Base (MIB)	MIBs are specifications containing definitions of management information so that networked systems can be remotely monitored, configured, and controlled. NOTE—See Perkins, *Understanding SNMP MIBs*.
NTCIP Object	A representation of a data element that is managed. The definition of a data element or message including its name, object identifier, description and syntax.
NTCIP Testing	In the context of NTCIP 9012 v01, includes standards conformance testing, agency specification compliance testing, and where the standard includes functional requirements, functional testing, of an ITS device communications interface.
Performance Requirement	A requirement that imposes conditions on a functional requirement. NOTE—For example a requirement that specifies the speed, accuracy, or memory usage with which a given function [is to] be performed. As modified from IEEE 610.12-1990. The extent to which a mission or function [is to] be executed, generally measured in terms of quantity, quality, coverage, timeliness, or readiness. NOTE—Performance requirements are initially defined through requirements analyses and trade studies using customer need, objective, and/or requirement statements. Performance requirements are defined for each identified customer (user and supplier) mission and for each primary function (and sub-function). Performance requirements are assigned to lower level system functions through top-down allocation, and are assigned to system elements and the system through synthesis. As modified from INCOSE, *Systems Engineering Handbook*.
Performance Testing	Testing conducted to evaluate the compliance or conformance of a system or component with specified performance requirements. NOTE—See IEEE 610.12-1990.
Profile Implementation Conformance Specification	A Profile Requirements List that is completed to indicate the features that are to be supported in an implementation.
Protocol Requirements List	Provides the traceability between a user need and requirements. Defines conformance requirements thereby allowing users to select the desired user needs for a particular project.
Requirement	A condition or capability needed by a user to solve a problem or achieve an objective. NOTE—See IEEE 1233-1998.

Term	Definition
Traceability	The degree to which a relationship can be established between two or more products of the development process, especially products having a predecessor-successor or master-subordinate relationship to one another; for example, the degree to which the requirements and design of a given software component match. NOTE—See IEEE 610.12-1990.
Standard	A product, process, or procedure with reference to one or more of the following: nomenclature, composition, construction, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which it is designed. NOTE—See NEMA, *Standardization Policies and Procedures of the National Electrical Manufacturers Association.*
Specification	A document that specifies, in a complete, precise, verifiable manner, the requirements, design, behavior, or other characteristics of a system or component, and, often, the procedures for determining whether these provisions have been satisfied. NOTE—See IEEE 610.12-1990.
Test Case	A document that specifies the actual inputs, predicted results, and set of execution conditions on a test. It also identifies constraints on the test procedures resulting from use of that specific test case. NOTE—See IEEE 829-1998.
Test Design	A test design refines the test approach and identifies the features to be covered by the design and its associated tests. It also identifies the test cases and test procedures, if any, required to accomplish the testing and specifies the feature pass/fail criteria. NOTE—See IEEE 829-1998.
Test Documentation	Documentation describing plans for, or results of, the testing of a system or component. Types include test case specification, test incident report, test log, test plan, test procedure, test report. NOTE—See IEEE 829-1998.
Test Plan	A document that prescribes the scope, approach, resources, and schedule of the testing activities. It identifies the items to be tested, the features to be tested, the testing tasks to be performed, the personnel responsible for each task, and the risks associated with the plan. NOTE—See IEEE 829-1998.
Test Procedure	A document that specifies a sequence of actions for the execution of a test. The test procedures test the implementation of the requirement. Test procedures are separated from test design as they are intended to be followed step by step and should not have extraneous detail. NOTE—See IEEE 829-1998.
Test Reports	Test reporting is covered by four document types: a) A test item transmittal report identifies the test items being transmitted for testing in the event that separate development and test groups are involved or in the event that a formal beginning of test execution is desired. b) A test log is used by the test team to record what occurred during test execution. c) A test incident report describes any event that occurs during the test execution which requires further investigation. d) A test summary report summarizes the testing activities associated with one or more test design specifications. NOTE—See IEEE 829-1998.
Unit	A piece of a larger system. NOTE—Within the context of NTCIP 9012 v01, it references a “unit of code” or a software module.

A.3 ACRONYMS

ASC	Actuated Signal Controllers
ATC	Advanced Transportation Controller
ATMS	Advanced Traffic Management Systems
C2F	Center-to-Field
CalTrans	California Department of Transportation
CalTrans TEES	CalTrans Transportation Electrical Equipment Specifications
CCTV	Closed Circuit TeleVision
DAT	Design Approval Test
DMS	Dynamic Message Signs
DUT	Device Under Test
ESS	Environmental Sensor Stations
ITS	Intelligent Transportation Systems
MIB	Management Information Base
OSI	Open Systems Interconnect
PICS	Profile Implementation Conformance Statement
PMPP	Point-to-MultiPoint Protocol
PPP	Point-to-Point Protocol
PRL	Profile Requirements List
QPL	Qualified Products List
RTCTM	Requirements to Test Case Traceability Matrix
RTM	Requirements Traceability Matrix
SEP	Systems Engineering Process
SNMP	Simple Network Management Protocol
STMP	Simple Transportation Management Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
UDP/IP	User Datagram Protocol/Internet Protocol

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