New York State ITS Standards Specification Development Guide

EXECUTIVE SUMMARY

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Prepared for

NYSDOT Statewide ITS Program

Technical Support and Strategic Plan Development

Task 2.A.4

New York State Department of Transportation

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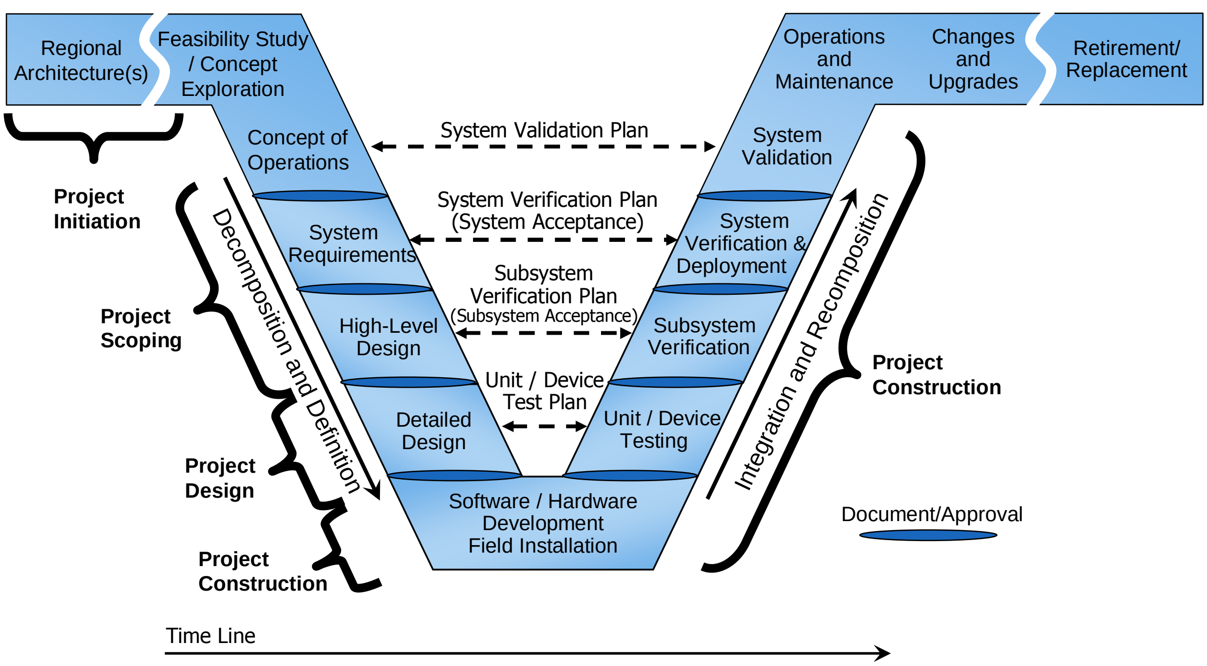
1 Introduction

The transportation project development process progresses through various stages including project initiation, project scoping, review of alternative designs, and the development of plans, specifications, and estimates (PS&E). Specifications are then used in procurement, construction, and inspection. Through this process transportation users needs result in infrastructure improvements and the realization of safety and mobility benefits. This paper provides guidance and samples to facilitate development of design documents, procurement specifications, and test procedures for ITS systems. A systems engineering methodology is discussed and followed throughout because of its strength as a project management and quality control tool.

The systems engineering process (SEP) is a structured approach to technical management, system design, product realization, and technical evaluation. The SEP propagates through a series of steps which lead to a system solution. The figure below shows a representation of the systems engineering process called the VEE diagram. The project development phases (project initiation through project construction) are shown along side of the VEE. Scoping, design and specification development progress down the left side of the VEE, while construction, testing and validation proceed up the right side.

Figure 1-1. Integrating the Systems Engineering into the Project Development Process



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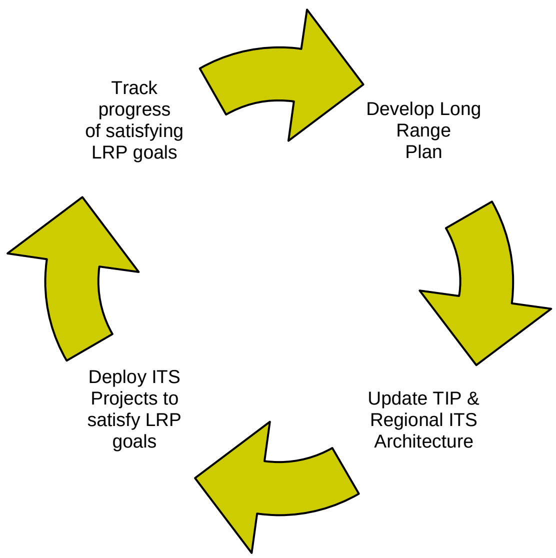
2 The Role of Regional ITS Architecture in Project Planning

The goal of transportation planning is to make informed decisions pertaining to the efficient investment of public funds for regional transportation systems and services. Regional ITS architecture focuses on the *integration* of systems to gain the maximum benefit of each system's information and capabilities across the transportation network. This includes the interfaces, data exchanges, operational concepts and agreements necessary to implement the strategies and transportation services. With these details, ITS projects can be more clearly defined, funded, and implemented to satisfy regional transportation goals.

A regional ITS architecture provides a short-term and long-term, multi-modal vision of how ITS and ITS projects can be deployed in the region. Thus, the regional ITS architecture supports transportation planning on two levels: first, the Long Range Transportation Plan (LRP), and second, the Transportation Improvement Program (TIP)

The relationship between the regional ITS architecture and the development of the LRP and TIP is an iterative one illustrated in the figure below.

Figure 2-1. Regional Transportation Planning Process



As an example let's see more specifically how a regional ITS architecture supports transportation planning. One of the goals defined in the Long Range Transportation Plan (LRP) of many transportation planning organizations is to improve regional mobility and accessibility.

In the regional ITS architecture, several transportation services are likely identified that contribute to meeting these regional objectives. They include ATMS06 – Traffic Information Dissemination, and ATMS07 – Regional Traffic Control. These are shown below and illustrate the system interfaces for each transportation service.

Figure 2-2. Example Customized Market Package ATMS06 – Traffic Information Dissemination

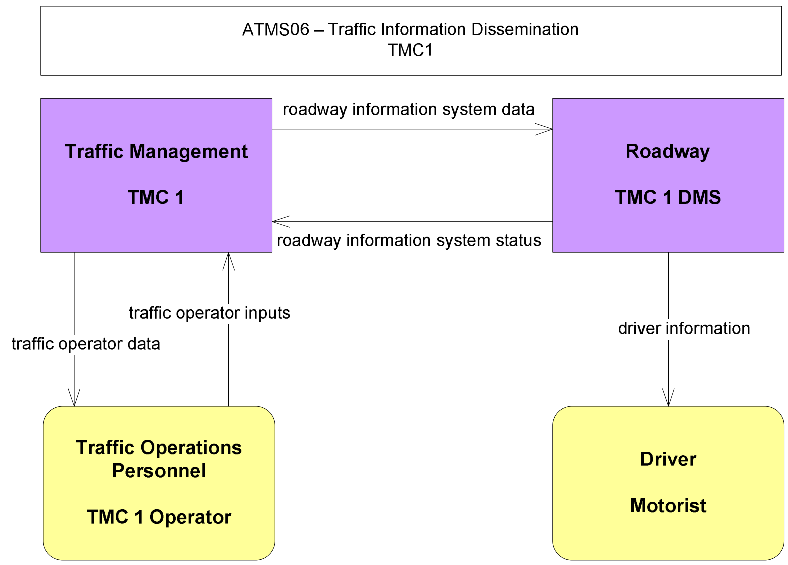
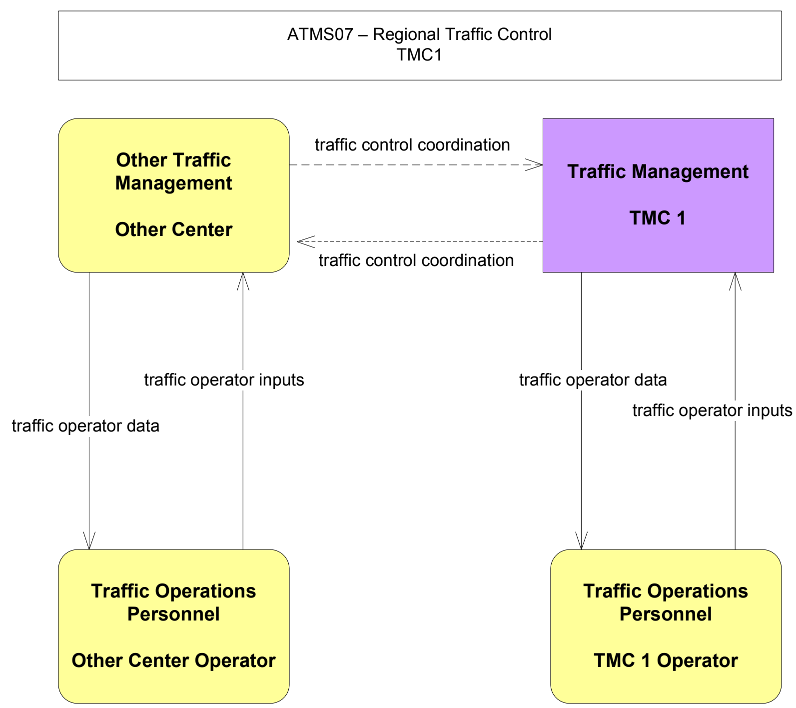


Figure 2-3. Example Regional ITS Architecture Customized Market Package ATMS07 – Regional Traffic Control



Approved projects identified in the TIP and regional ITS architecture move from project initiation into the project scoping phase.

3 Developing Concept of Operations and Requirements

Project scoping begins after project initiation and approval. The purpose of the project scoping includes:

- Understanding the problems and needs (SEP Concept of Operations)
- Establishing project objectives and the design criteria (SEP Requirements)
- Identifying feasible alternatives (SEP High-Level Design)

3.1 Documenting User Needs and Developing a Concept of Operations

According to the International Council on Systems Engineering (INCOSE) *Systems Engineering Body of Knowledge*, systems engineering focuses on defining user needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem.

The Concept of Operations (ConOps, for short) clearly defines the user needs and operational context for the functions that the ITS system will support. A regional ITS architecture provides a solid foundation for ConOps development -- the experience and interaction of relevant stakeholders, and the documentation of these interactions, provides valuable input to the ConOps.

INCOSE's definition of a system supports why this system architecture-ConOps linkage creates value. A system is "a construct or collection of different elements that together produce results not obtainable by the elements alone. The elements, or parts, can include people, hardware, software, facilities, policies, and documents; that is, all things required to produce systems-level results. *The value added by the system as a whole is primarily created by the relationship among the parts; that is, how they are interconnected.*" The ConOps provides a project and operational context for the system elements, while a system architecture documents the system element relationships.

The ConOps should be developed with participation from all stakeholders that benefit or are impacted by the system, and includes:

1. Identification of Users
2. System Overview
3. User Needs Assessment
4. User Roles and Responsibilities
5. Operational Scenarios.

3.1.1 Identification of Users

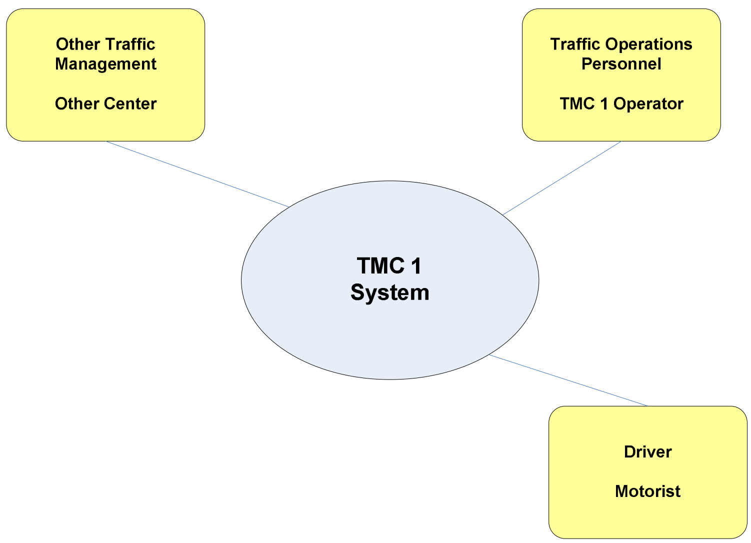
The ConOps includes a description of who the system's users are, and who is impacted/benefits by/from the system. This may includes the operations department (operates the system), maintenance department (maintains the system), and public safety agencies (makes requests). Starting from the customized market package examples shown in the previous section (figures 2-3 and 2-3) the following users and user classes are identified:

Users include: *TMC Operator 1*, *Other Center Operator*s, and *Motorist*s.

3.1.2 System Overview

The system overview shows the system from the users perspective. This is shown below.

Figure 3-1. Example TMC 1 System Overview.



3.1.3 User Needs Assessment

The user needs assessment should include the following:

- **Vision.** What the outcome of the ITS System will be. For example, will provide travelers with real-time incident and diversion information.
- **Performance Measures.** These measures help to quantify the organization/user expectations of the systems. Ideally, performance measures will trace directly to stated needs, and can be used to determine the value of the system/service to the end-user vis-à-vis cost to deploy.
- **Gap Analysis.** A description of what operational or end-user need is lacking, or if an existing system, what system features are missing.

3.1.4 User Roles and Responsibilities

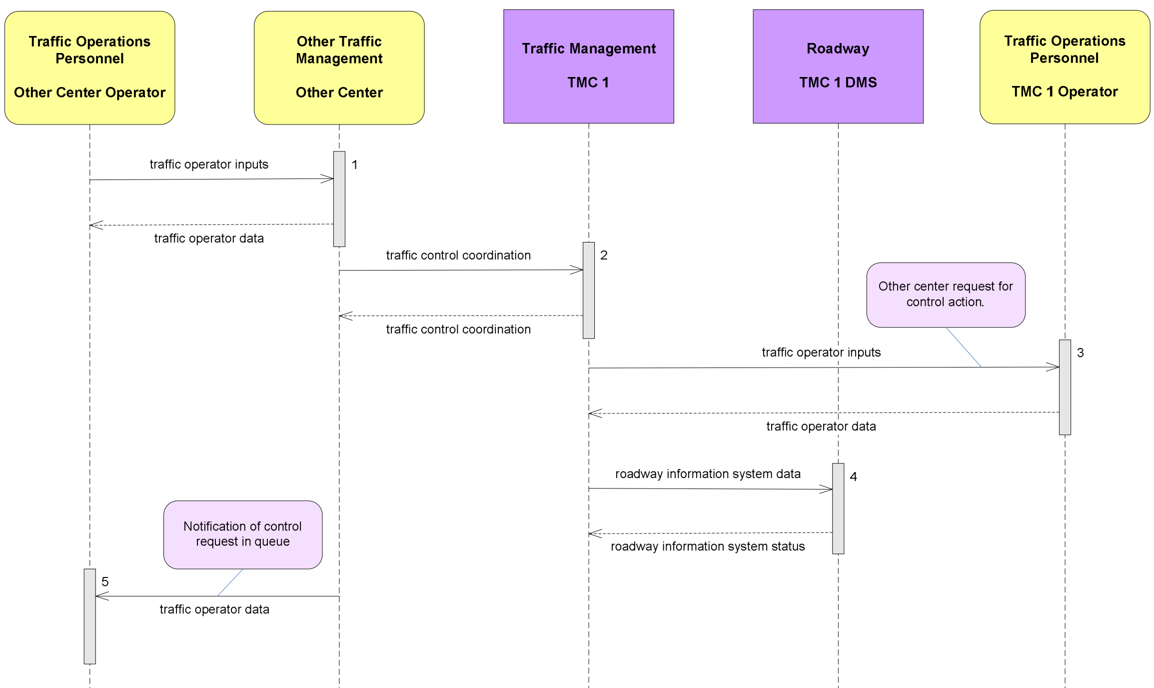
Defining the user roles and responsibilities may begin with those defined in the regional ITS architecture. However, with the more defined scope of a project (rather than region). The roles and responsibilities may be fine-tuned, and more detail added.

3.1.5 Operational Scenarios

Operational scenarios define the sequence of activities to be performed to satisfy user needs, and the information flows between entities. For example, it may include the procedures on how public safety agencies make requests for action, and how maintenance requests are monitored and made. To the extent that the operational scenarios capture all system functions and human- and system-to-system interactions, then validation becomes a straight-forward step, and one can answer the question, "*when are the requirements complete?*"

The figure below illustrates an operational scenario related to DMS information and control between two centers.

Figure 3-1. Operational Scenario OS001: Provide Regional Traffic Control TMC 1



3.2 Developing Use Cases, Test Cases and Requirements

3.2.1 Use Case and Requirements

The Use Case methodology outlined here identifies portions of the operational scenario for which more functional detail (system role) is being specified. Any portion of an operational scenario that is being implemented by the system is a candidate for a use case. Each interface (or *dialog*) whether system-to-system or human-to-system, can be identified and requirements developed. In the example below, requirements for the *Other Center* ← → *TMC 1* interface (Step 2), a system-to-system interface, are defined.

In moving from ConOps to Use Cases we move from ITS architecture concepts to those of the ITS standards. Note the change of name from *traffic control coordination* (architecture flow) to standards-based name *MSG_DMSControlRequest* (ITS standards message).

A new sequence diagram is developed, providing more detail, to guide the use case and requirements development. This is shown below.

Figure 3-3. Example Use Case Dialog: UC101 - Provide DMS Control

Note: Other Dialogs for Operational Scenario Step 2 include: UC102 – Provide DMS Inventory and UC103 - Provide DMS Status.

Table 3-1. Example Use Case UC101 – Provide DMS Control

UCId	Operational Scenario Id	Step	Actor	UC Description	UC Pre Conditions	UCBasicCourseEvents-Requirements	UC Exception Events	UC Post Conditions	Technical Requirements	TestCase
UC101	OS001	2.1	TMC 1	Provide DMS Control to External Centers	The remote center sends a DMS control request message to the local center that controls a sign that a message is to be posted onto.	1. Receive DMS Control Request. 1.1. The local center shall be capable of accepting and processing valid DMS control requests to display a pre-defined or new text message from one or more authorized remote centers. 1.2. The request shall include the following: - The ID of the receiving center - The ID of the receiving center - The ID of the sending center - The device ID of the DMS - The unique request identifier assigned by the requesting center - The security attribute (user name and password) - The operator and agency name making the request - The message number for the pre-defined message that is to be displayed, or - The specific message to be displayed - The message page flash time - The priority of the message being requested - The start time for the message - The start date for the message - The expiration time for the message - The expiration date for the message - Additional information/comments 2. Validate and Parse Request Message. 3. Send Control Message to DMS. 4. Receive Control Response from DMS. 5. Create Response Message. 6. Send DMS Control Response. 6.1. The local center shall be capable of sending a response to the requesting center. 6.2. The response to a DMS control request shall include the following: - The ID of the receiving center - The ID of the sending center - The unique request identifier - The operator and agency name in the request - The name of the operator at the local center acting on the request - The status of the request (implemented, queued, rejected) - Additional information/comments		The remote center receives the response to a DMS control request.	Dialog Properties: Synchronous;	

3.2.2 Test Case Development

Well written requirements are testable and trace back to ConOps to ensure the specification and system satisfy the user needs of project. The principle is to define at least one test procedure for each requirement and then exercise those features in the context of how they should react in terms of normal system operation.

3.3 User Needs and Requirements Traceability

A key control and validation activity of the system development process is requirements traceability. This tracing occurs in two directions- backwards to the user needs defined in the concept of operations and forward to the specification of dialogs, messages, and data elements.

Two types of traceability should be managed throughout the design and development process: 1) Needs to Requirements traceability, and 2) Requirements to Design traceability.

The Needs-Requirements Traceability Matrix (NRTM) is used to verify that the requirements defined trace to one or more user needs.

The Requirements Traceability Matrix (RTM) verifies that requirements trace to the detailed design. In this way, the traceability table can be used to verify and validate that the detailed design satisfies one or more information exchange requirements.

3.3.1 Setting up a Dialog Worksheet

A Dialog Worksheet provide sufficient information for detailed design, implementation, and test procedure development. It carries forward information and control exchange requirements into the detailed design. A dialog worksheet provide details for:

- Communication Exchanges (Sequence of Inputs and Outputs)
- Encoding
- Transport

Table 3-2. Example Dialog Worksheet for Center-to-Center

Dialog	Sequence Step	Dialog Attributes	Trace to Detailed Design
DL_C2C Provide DMS Control	2.1	**Inputs**: MSG_DMSControlRequest **Outputs**: MSG_DeviceControlSubscription Response **Encoding:** SOAP **Transport**: HTTP	dmsControlRequest deviceControlSubscriptionResponse

The dialog worksheet provides a way to specify dialogs cleanly and the development of test procedures. Diligence in developing and traceability ensures that the requirements and user needs are met.

4 ITS Communications Framework and Alternatives Analysis

4.1 ITS Standards Communications Packages

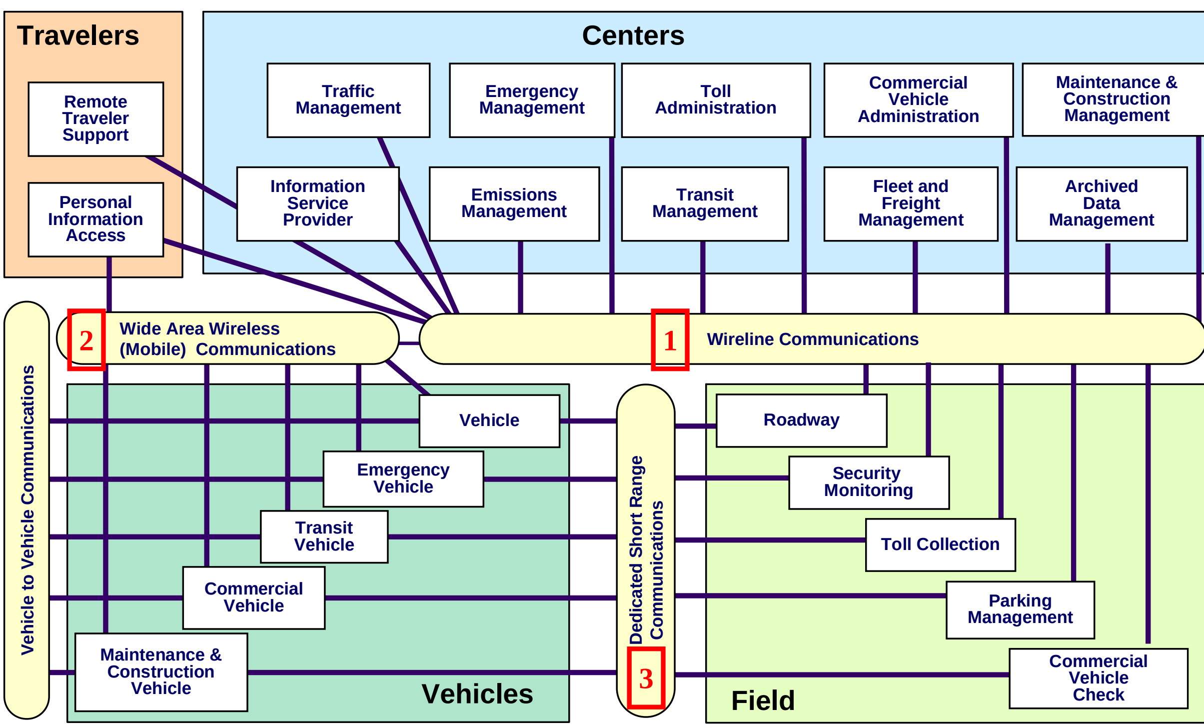
ITS Standards Communications Packages combine specific standards into alternatives for deployment. Communications packages represent re-usable pieces that together define all of the levels of communications required for ITS deployments. This should help project developers get a head start in understanding which standards to apply in developing an ITS communications solution. The communications packages may also be used as a checklist in developing procurement specifications.

The Communications Packages are grouped into 3 areas, with direct relation to the communications methods National ITS Architecture. This is done intentionally to form a bridge between regional ITS architecture and communications standards. The 3 groups are:

- Wireline Center-to-Field and Center-to-Center Communications,
- Wide Area Wireless Communications, and
- WAVE / DSRC

This is illustrated in the figure below.

Figure 4-1. Relation of Communications Packages to National ITS Architecture



Example communications packages are contained in the tables below:

Figure 4-2. Wireline Communications Packages

1 - Center-to-Field Communications over IEEE 802 IP Networks
2 - Center-to-Field Communications Point-to-Point or Point-to-MultiPoint
3 – XML Messaging for Center-to-Center Communications

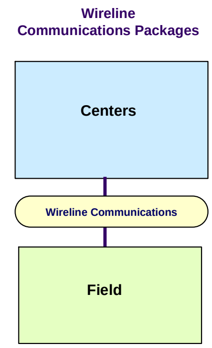
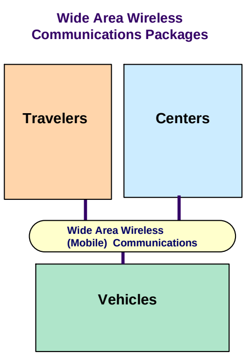


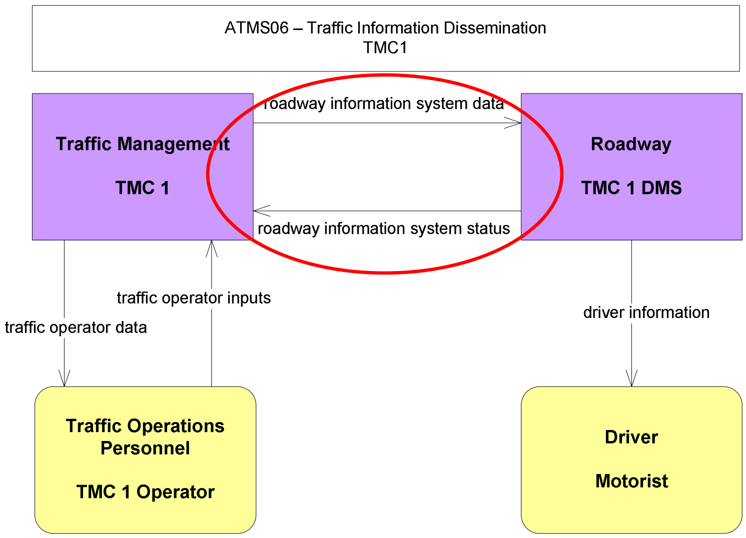
Figure 4-3. Wide Area Wireless Communications Packages

1 - Mobile XML Messaging over Cellular Networks
2 – Mobile XML Messaging over Wi-Max Networks
3 – Mobile XML Messaging over Private IP Networks
4 – Mobile XML Messaging over Private non-IP Networks
5 - Mobile XML Messaging over Wi-Fi Local Area Networks



4.2 Using the ITS Standards Communications Packages to Identify Communications Alternatives

Carrying forward from the example ConOps developed previously, let's identify what part of the ITS communications framework applies to the following portion of the market package below.



Identifying what communication package(s) apply involves the following steps:

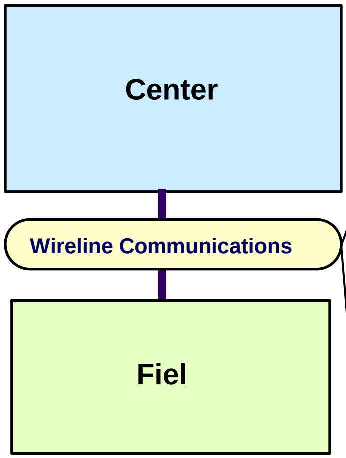
1. Identify what classes of the architecture are being connected. The architecture has 4 classes: travelers, centers, field, and vehicles. In this case, a Traffic Managemenent Center (centers) is being connected to a Roadway (field) ITS element. Connecting centers and field is part of the wireline communications packages. Shown below.
2. Next identify which alternative best applies, or allow all to be possible alternatives. We can select from the following options:

1 - Center-to-Field Communications over IEEE 802 IP Networks
2 - Center-to-Field Communications Point-to-Point or Point-to-MultiPoint
3 – XML Messaging for Center-to-Center Communications

   In this case option 1 will apply – Center-to-field Communication over IEEE 802 IP Networks, though multiple options can be used in conducting an alternatives analysis.

3. Looking up this option in the communications framework yields the following communication stack showing pre-determined communications solutions for all communications layers.

Figure 4-4. Example Using ITS Communications Framework



ITS Standards Framework	Technology/Implementation	Standards
Information Level	NTCIP MIB Objects	NTCIP 1200 Series MIBs
Application Level	SNMP	NTCIP 2301
Transport Level	TCP IP	NTCIP 2202 identifies the use of these IETF Standards
Subnetwork Level	Layer 2 – Data Link IEEE 802 Networks, Token Ring, FDDI, HDLC, Frame Relay, ATM, Fibre Channel Layer 1 - Physical T1, E1, 10BASE-T, 100BASE-TX, ISDN,	NTCIP 2104 defines framework for IEEE 802 Networks.
Plant Level	Fiber, Coax	

5 ITS Standards Specification Catalog and Testing Framework

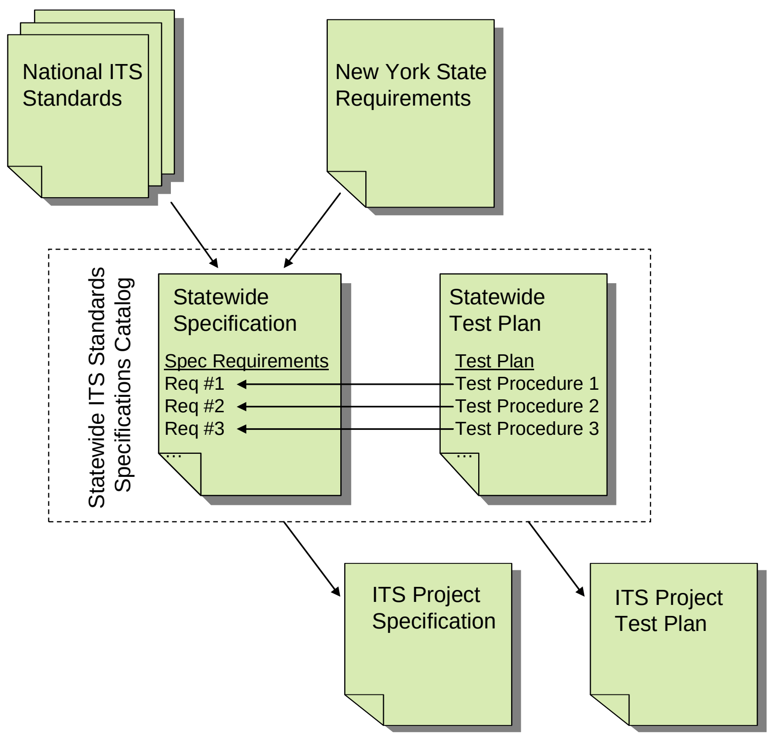
An ITS Standards Specification Catalog and Testing Framework support re-usability of specifications and test plans and should include:

- Standardizing language and content for procurement specifications
- Approach to testing to support interchangeability of devices
- Test plans and procedures and recommended test tools and practices

Given pre-defined specifications, ITS engineers can quickly pull together draft ITS specifications, draft feasibility studies for alternatives for deployment of ITS communications, and systems engineering analysis reports.

The concept of using an ITS Standards Catalog and Testing Framework is shown below.

Figure 5-1. Example ITS Standards Specification Development and Testing Framework



5.1 Procurement Specifications

A successful system deployment is dependent on the availability of high-quality specifications. Moreover, an agency cannot develop a good testing plan without clearly defining what is required of the device (or system) in a clear, concise and testable manner.

5.2 Interchangeability of Devices and Approaches to Certification Testing

One approach for an agency to obtain interchangeable devices from a specification is to examine the communications standards. When the functionality is clearly described (in a measurable and observable manner), then devices that use the same communications (inputs/outputs, encoding, and transport) to manage the same well-defined functionality will be interchangeable.

5.3 Testing Methodology

5.3.1 Develop Test Procedures

The test procedures provide step by step descriptions of the tests to be performed. The Dialog Worksheet presents an excellent starting point for development of detailed procedure. Starting from the Dialog Worksheet allows test plan/procedures to trace to the use case/requirements test cases to ensure verification of the system functionality. The worksheet allows breaking out the test procedures into the following verification steps for each dialog specified:

- Verification of communications exchanges and correct sequencing of inputs and outputs.
- Verification of encoding of inputs and outputs for data communications transport.
- Verification of transport mechanism.

5.3.2 Conduct the Test and Post-Test Analysis

Conduct of the test shall begin when all applicable test plans have been approved and the system is ready for testing. The test team should allow enough time to develop and collect all necessary test data. Data analysis will not be performed on site, except when necessary to verify an anomalous condition. The test team will keep a test log including date and time of all events to all cross-referencing captured raw test data with specific events.

Finally, a post-test workshop should be held to brief all stakeholders of the test findings and recommendations, and to solicit feedback and comments for use in preparation of the final test report for the tested standards.