5 Developing Concept of Operations and Requirements

Project scoping begins after the approval of the Initial Project Proposal (IPP). 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)

The Systems Engineering Process contains steps that match the intent and purpose of the project scoping, this includes: Concept of Operations, Requirements, and High-Level Design. This chapter focuses on Concept of Operations and Requirements, while chapter 6 focuses on High-Level Design and Communications Alternatives.

5.1 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) 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.

One key role of the ConOps is to shape and bound the expectations of the system's capabilities for project stakeholders (users). System expectations may be bound by a description of the top-level functions that the system must perform: this might be in the form of a mission statement (agency's perspective), and a description of the deficiency that must be ameliorated (user's perspective, needs). A User Needs Workshop, planned early in the development effort, can help to gather needs (and associated requirements/ design inputs) from project stakeholders.

The ConOps should also be developed with participation from the various stakeholders and users of the ITS System. Information belonging in a Concept of Operations document includes:

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

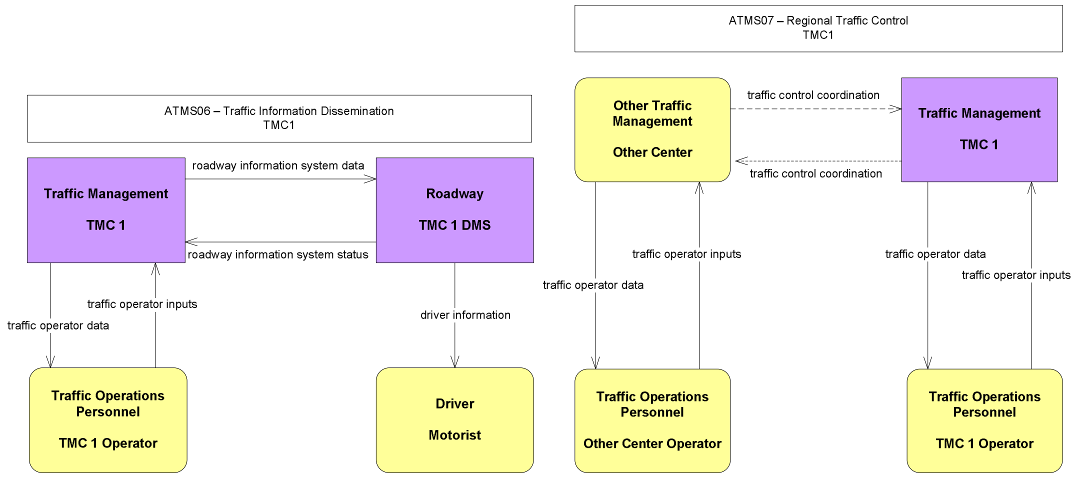
An example Concept of Operations is shown in Appendix C.

5.2 Identification of Users, User Needs, and Roles and Responsibilities

5.2.1 Identification of Users

The ConOps includes a description of who the system's users are, that is, those who are impacted/benefits by/from the system. This may include the operations department (operates the system), maintenance department (maintains the system), and public safety agencies (makes requests). The regional ITS architecture provides an excellent source of information on potential system users. Starting from the customized market package examples shown in the previous chapter the following users and user classes are identified:

Figure 5-1. Example Regional ITS Architecture Customized Market Package Used in ConOps



Users include:

Table 5-1. Example ConOps Users and User Classes

User	User Class
TMC Operator 1	Traffic Operations Personnel
Other Center Operators	Traffic Operations Personnel
Motorists	Driver

5.2.2 ConOps - Regional ITS Architecture Traceability

It is important to formally document how system users were identified and there relation to the regional ITS architecture. The table below shows traceable elements between the ConOps and regional ITS architecture.

Table 5-2. ConOps to Regional ITS Architecture Traceability

ConOps	Regional ITS Architecture	Example Traceability
Service Provider and End-User Needs	Market Package Instance	ATMS06 – Traffic Information Dissemination TMC 1 ATMS07 – Regional Traffic Control TMC 1
User Classes	Architecture Entities	Traffic Operations Personnel Driver
Users	ITS Element	TMC 1 Operator Other Center Operator Motorist
User Roles and Responsibilities	User Roles and Responsibilities	Subset of Regional Responsibilties that Apply to Project

5.2.3 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.** Defines how well the the system is expected to performs. These measures help to quantify the organization/user expectations of the systems. Ideally, performance measures will trace directly to stated needs. For example, quantifying end-user needs will determine a measure of value of the system to the end-user vis-à-vis cost.
- **Gap Analysis.** A description of what operational or end-user need is lacking, or if an existing system, what system features are missing.

5.2.4 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. As the operational scenarios are elaborated, the user roles and responsibilities should be updated to remain in sync with the information described in the operational scenarios.

5.2.5 ConOps User Needs Example

The table below documents the User Needs for the ConOps.

Table 5-3. Example ConOps User Needs

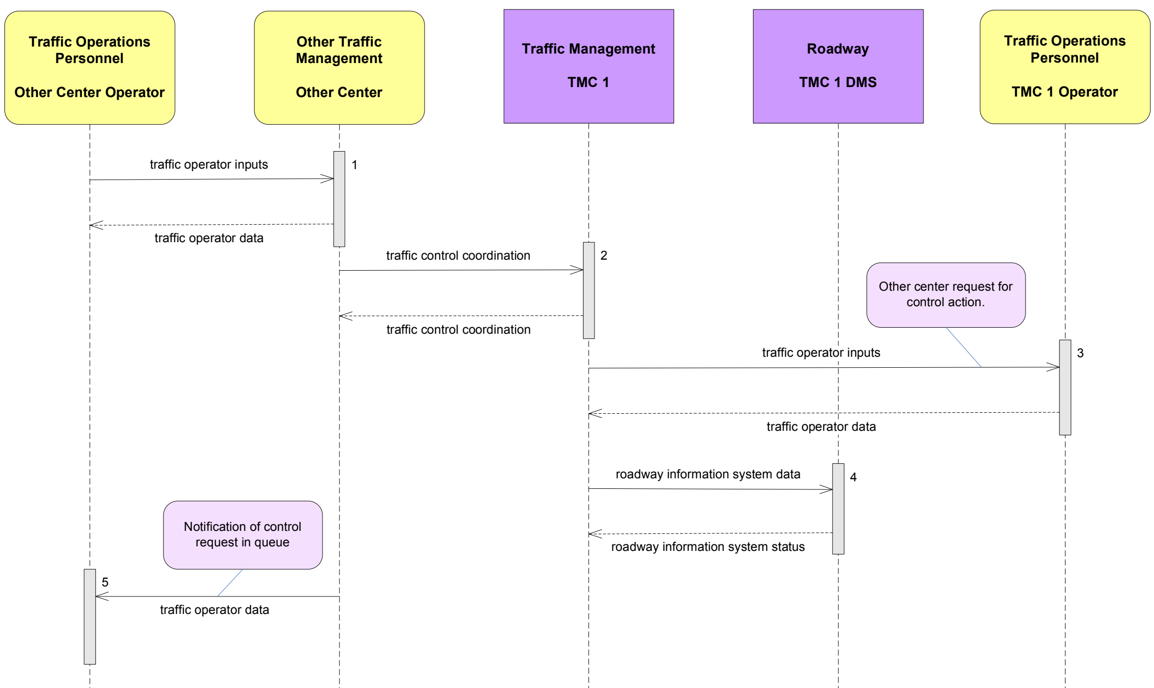
User Need ID	User	User Class	Description	Need	Expected Benefit	Performance Measure
UN001	Motorist	Driver	Traveling public.	Need to plan timely routes. Need to be notified of problems on roadways in order to avoid them.	Improved Travel Time. Improved safety in terms of reduction of incidents.	Travel Time. Number of incidents reported.
UN002	TMC 1 Operator	Traffic Operations Personnel	TMC 1 operators control TMC 1 ITS devices and monitor status of roadways.	Needs to provide warning and alerts to Motorists.	More timely provision of information, warnings and alerts to Motorists so they may change travel plans.	Timeliness of Warnings and Alerts. Wider geographic scope of coverage of alerts and warnings.
UN003	TMC 1 Operator	Traffic Operations Personnel	Other TMC operators control TMC ITS devices and monitor status of roadways in other regions.	Needs to provide warning and alerts to other TMCs.	More timely provision of information, warnings and alerts so other TMCs can provide information in adjacent regions.	Timeliness of Warnings and Alerts. Wider geographic scope of coverage of alerts and warnings.

5.2.6 Operational Scenarios

Operational scenarios define sequence of activities to be performed to satisfy user needs, 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 figures and tables below illustrate two operational scenarios related to 1) Sharing of DMS information and control between two centers, and 2) DMS Device Control. The operational scenario shown below (OS001) is based on Regional ITS Architecture Customized Market Package ATMS07 – Regional Traffic Control TMC 1. This operational scenario satisfies the need UN003.

Figure 5-2. Operational Scenario OS001: Provide Regional Traffic Control TMC 1



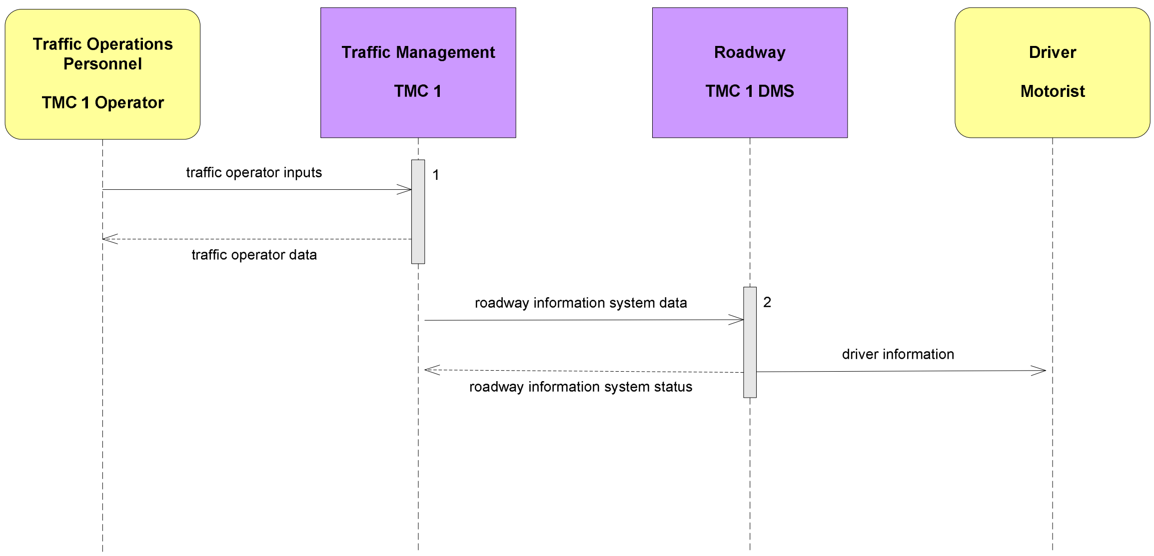
Operational Scenario (OS001) Sequence of Events

1. This operational scenario begins when an operator from an external TMC provides to the external TMC a request to communicate with TMC 1 for information and/or control about TMC 1 DMS.
2. The TMC 1 provides status monitoring information and/or control of dynamic message signs on freeways to other traffic management centers.
3. The TMC 1 provides information about status information sharing and control requests to the TMC 1 Operator. The TMC 1 Operator may reject a control request.

4. The TMC 1requests status updates and/or controls the TMC 1 DMS. The TMC 1 provides status information and control acknowledgement/rejection to the Other TMC.
5. The external TMC Operator is notified of shared monitoring information and/or control request acknowledgement/rejection.

The operational scenario shown below (OS002) is based on Regional ITS Architecture Customized Market Package ATMS06 – Traffic Information Dissemination TMC 1. This operational scenario satisfies the needs UN001 and UN002.

Figure 5-3. Operational Scenario OS002: Provide Traffic Information Dissemination TMC 1



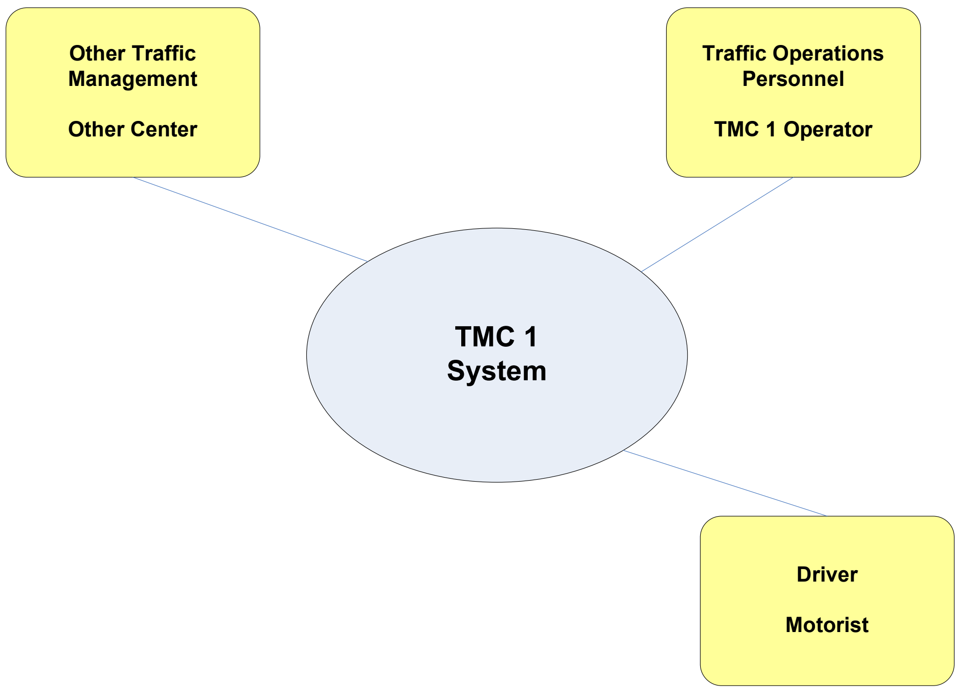
Operational Scenario (OS002) Sequence of Events

1. The TMC 1 Operator can control the information displayed to travelers on dynamic message signs or other equipment along the roadway.
2. The TMC 1 controls the equipment on the roadway that displays informationto Motorists.

5.2.7 System Overview

The system overview shows the system from the users perspective. The System Overview below was derived from the Operational Scenarios developed in the section above.

Figure 5-4. Example TMC 1 System Overview.

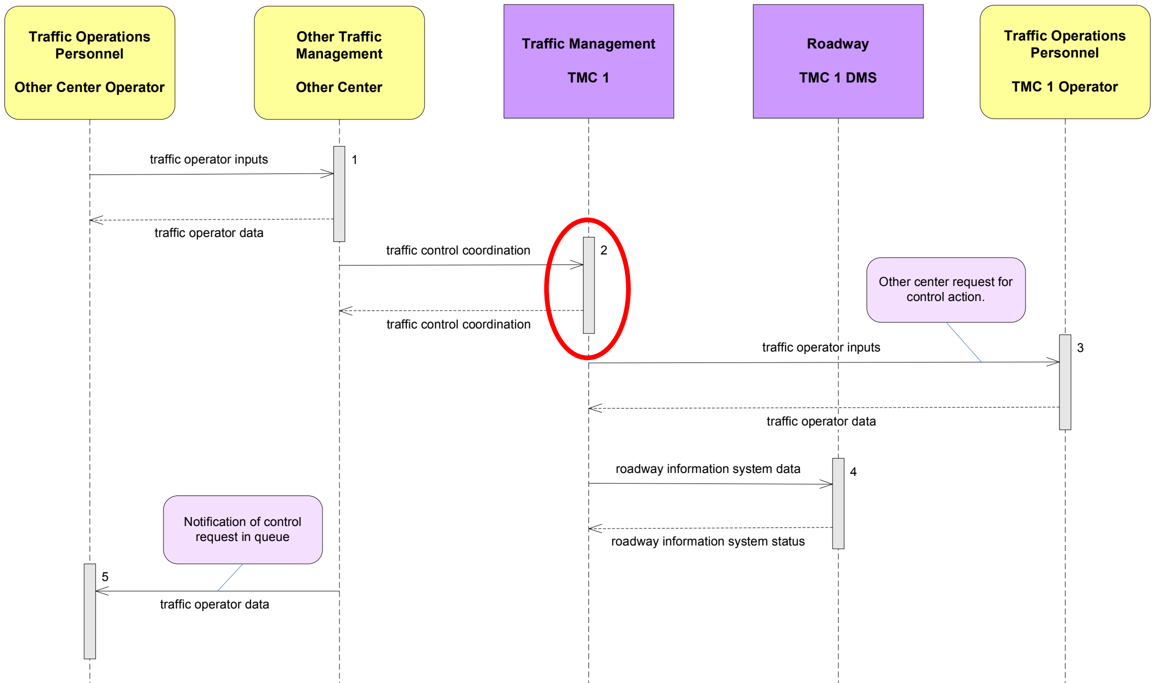


5.3 Developing Use Cases, Test Cases and Requirements

5.4 Use Case and Requirements

This portion of the development process identifies the system requirements that satisfy a particular user need of the ConOps. If this sounds like what an operational scenario does, it is. The difference is that the system requirements specify what the system will do versus the entire sequence of activities including human elements. The Use Case methodology outlined here identifies portions of the operational scenario for which more functional detail (system role) will be specified. Any portion of an operational scenario that is being done by the system is a candidate for a use case, though there are also non-functional and implementation requirements that will be identified. Each interface (a.k.a., dialogs), 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, a system-to-system interface, are defined.

Figure 5-5. Use Case Analysis for Operational Scenario Provide Regional Traffic Control TMC 1 - Step #2



In moving from ConOps to Use Cases we move from ITS architecture concepts to those of the ITS standards.

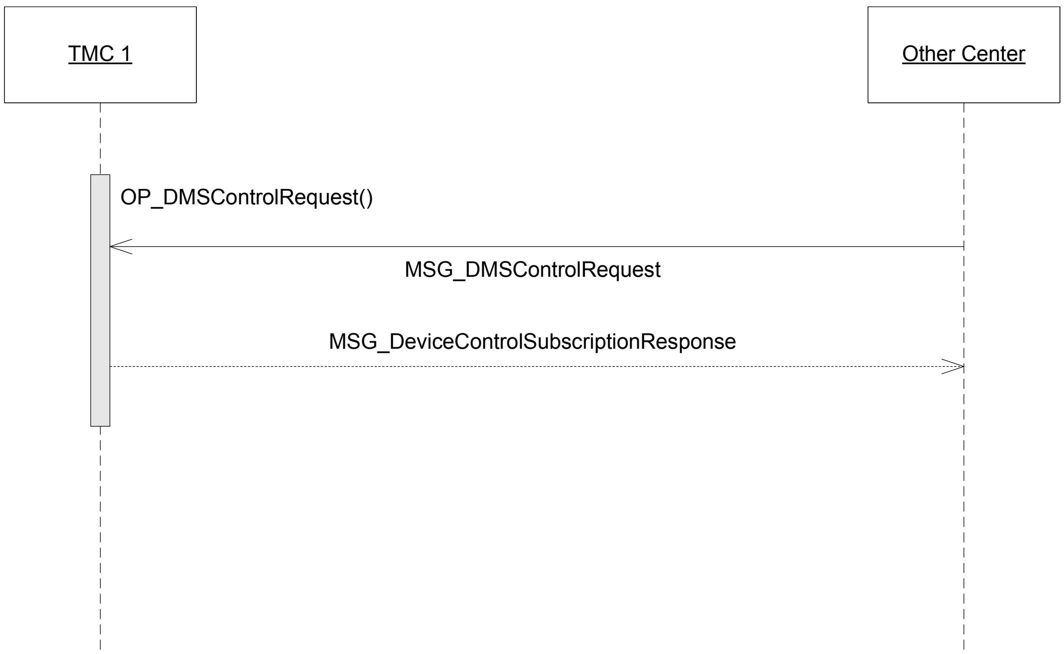
3 Use Cases are identified for step 2 of the operational scenario:

1. UC101 - Provide DMS Control
2. UC102 - Provide DMS Inventory
3. UC103 - Provide DMS Status

Note the change of name from *traffic control coordination* (architecture flow) to standards-based name *MSG_DMSControlRequest* (TMDD standards message).

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

Figure 5-6. 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 5-5-4. 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;	

5.5 Test Case Development

Well written requirements are testable and trace back to the ConOps to ensure the specification and system satisfy the user needs of the 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.

During the development of a specification or a Request for Proposals (RFP), issues related to testing should be incorporated into project documentation in the form of a test plan. The actual test plan details (i.e., the test procedures themselves) do not have to be spelled out.

5.6 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, called a Needs-Requirements traceability, and 2) Requirements to Solution traceability, called a Requirements Traceability Matrix (RTM).

The Needs-Requirements Traceability tables is used to verify that the requirements defined trace to one or more user needs. Validation of whether the information content of the specification are correct will rely on the approval by stakeholders that all user needs are defined and that the requirements stated satisfy a particular user need. To the extent that the operational scenarios capture all system functions and human- and system-to-system interactions, then validation should be a straight-forward step.

An example Needs-Requirements Traceability is shown in the table below.

Table 5-5-5. Example Needs-Requirements Traceability

User Need Id	Operational Scenario	Use Case / Requirements	Dialog
UN003	OS001: Provide Regional Traffic Control TMC 1	UC101: Provide DMS Control	DL_C2C Provide DMS Control
		UC102: Provide DMS Inventory	DL_C2C Provide DMS Inventory
		UC103: Provide DMS Status	DL_C2C Provide DMS Status
UN002, UN001	OS002: Provide Traffic Information Dissemination TMC 1	UC201: Operator Interface for DMS Control	DL_OI DMS Control
		UC202: Operator Interface Monitor DMS Status	DL_OI DMS Monitor Status
		UC203: DMS Query Status	DL_DMS Query Status
		UC204: DMS Query Inventory	DL_DB Query DMS Inventory
UN001		UC301: DMS Activate Message	DL_DMS Activate Message

The dialog column shown is an player in bridging the requirements to design and then implementation and testing. This is shown below.

Key fields from the Requirements Traceability table are shown below.

Table 5-5-6. Example Requirements Traceability Table Fields

Use Case Requirement	Dialog	DataConcepts Identified in Dialog
Use Case Requirement Identifier	Data Concept Type. Eg., Dialog, Message, or Data Element.	The name or id of the data concept that satisfies the requirement

Table 5-5-7. Example Requirements Traceability

Use Case Requirement	Dialog	DataConcepts Identified in Dialog
UC101	DL_C2C Provide DMS Control	DL_C2C Provide DMS Control; MSG_DMSControlRequest; MSG_DeviceControlSubscriptionResponse

The Requirements Traceability Matrix (RTM) verifies that requirements trace to a "data concept": dialog, message, or data element, data frame. In this way, the traceability table can be used to verify and validate that the detailed design satisfies one or more information exchange requirements. RTMs are contained in the two specification examples provided with this guide.

5.7 A Look at Things to Come: Tracing from the Specification and Test Procedures

Diligence in tracing between steps and following this methodology outlined above provides a way to specify dialogs cleanly and as a result allows development of detailed test procedures. The table below shows an example Dialog Worksheet that ties the dialogs developed during the requirements phase to the implementation details of the detailed design phase.

Table 5-5-8. Example Dialog Worksheet Table Fields

Dialog	Dialog Sequence Step	Dialog Attributes	DataConcept Defined in MIB or XML Schema
Dialog Name	For dialogs with multiple steps the order of communication exchanges	Inputs: Outputs: Protocol: Encoding	The name or id of the data concept that satisfies the requirement.

Table 5-5-9. Example Dialog Worksheet for Center-to-Center

Dialog	Sequence Step	Dialog Attributes	DataConcept Defined in XML Schema
DL_C2C Provide DMS Control	1	**Inputs**: MSG_DMSControlRequest **Outputs**: MSG_DeviceControlSubscription Response **Protocol**: HTTP **Encoding**: SOAP	dmsControlRequest deviceControlSubscriptionResponse

A dialog worksheet for the DMS Communications Dialog Active Message (see figure below) is shown in the next few tables.

Figure 5-7. DMS Dialog Activate Message

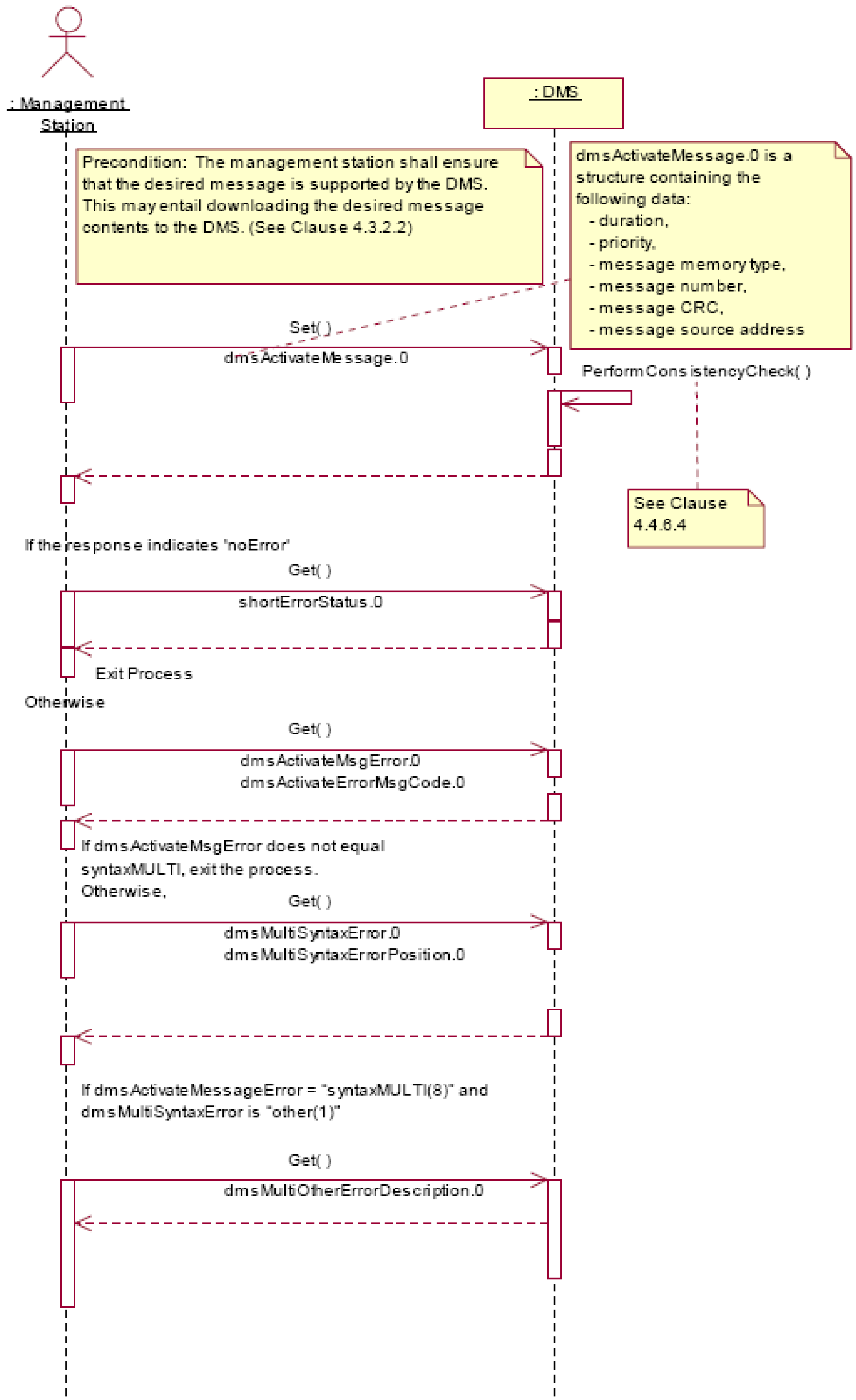


Table 5-5-10. Example Dialog Worksheet for Center-to-Field

Dialog	Sequence Step	Dialog Attributes	DataConcept Defined in MIB
DL_ActivateMessage	1	**Inputs**: DMS_SetActivateMessage **Outputs**: Return **Protocol**: SNMP **Encoding**: OER	dmsActivateMessage
	2	**Inputs**: DMS_GetShortErrorStatus **Outputs**: Return **Protocol**: SNMP **Encoding**: OER	shortErrorStatus

If an error is returned from the sign, continue:

Dialog	Sequence Step	Dialog Attributes	DataConcept Defined in MIB
DL_ActivateMessage	3	**Inputs**: DMS_GetActivateMsgError **Outputs**: Return **Protocol**: SNMP **Encoding**: OER	dmsActivateMsgError dmsActivateErrorMsgCode

If a MULTI error is returned from the sign, continue:

Dialog	Sequence Step	Dialog Attributes	DataConcept Defined in MIB
DL_ActivateMessage	4	**Inputs**: DMS_GetMultiSyntaxError **Outputs**: Return **Protocol**: SNMP **Encoding**: OER	dmsMultiSyntaxError dmsMultiSyntaxErrorPosition
	5	**Inputs**: DMS_GetMultiOtherErrorDescription **Outputs**: Return **Protocol**: SNMP **Encoding**: OER	dmsMultiOtherErrorDescription

5.8 Dialog Worksheet Summary

The dialog worksheets provide sufficient detail for developers/implementers and can be used for testing of the dialogs implementation.

The dialog worksheet provide details for:

- Communication Exchanges (Sequence of Inputs and Outputs)
- Protocol
- Encoding
- MIB or XML Schema Data Concept Reference