



W E L C O M E



U.S. Department of Transportation  
Office of the Assistant Secretary for  
Research and Technology

# Welcome



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The screenshot shows the homepage of the ITS Professional Capacity Building Program website. At the top, it identifies the United States Department of Transportation, Office of the Assistant Secretary for Research and Technology, and the Intelligent Transportation Systems Joint Program Office. A navigation menu includes links for About, ITS Training, Knowledge Exchange, Technology Transfer, ITS in Academics, and Media Library. A central banner features a photo of people in a classroom and a blue text box that reads: "Welcome to ITS Professional Capacity Building. The ITS PCB Program is the U.S. Department of Transportation's leading program for delivering ITS training and learning resources to the nation's ITS workforce." Below this, a "FREE TRAINING" section lists: "Web and Blended Courses from CITE", "ITS Standards Training", and "Upcoming T3 Webinars". On the right, a "WHAT'S NEW" section lists: "New Web-Based Training from ITS Joint Program Office" (Connected Vehicle Reference Implementation Architecture Training), "New NHI Course" (Systems Engineering for Signal Systems), "New ITS Case Study Available" (National ITS Architecture), and "Added to T3 Archive" (Learn from the Experts: Open Data Policy Guidelines for Transit and Saving Lives and Keeping Traffic Moving).

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# ACTIVITY



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Office of the Assistant Secretary for  
Research and Technology

**T203 Part 1 of 2:  
How to Develop Test Cases for an ITS  
Standards-based Test Plan, Part 1 of 2**

## Instructor



**Manny Insignares**  
**Vice President Technology**  
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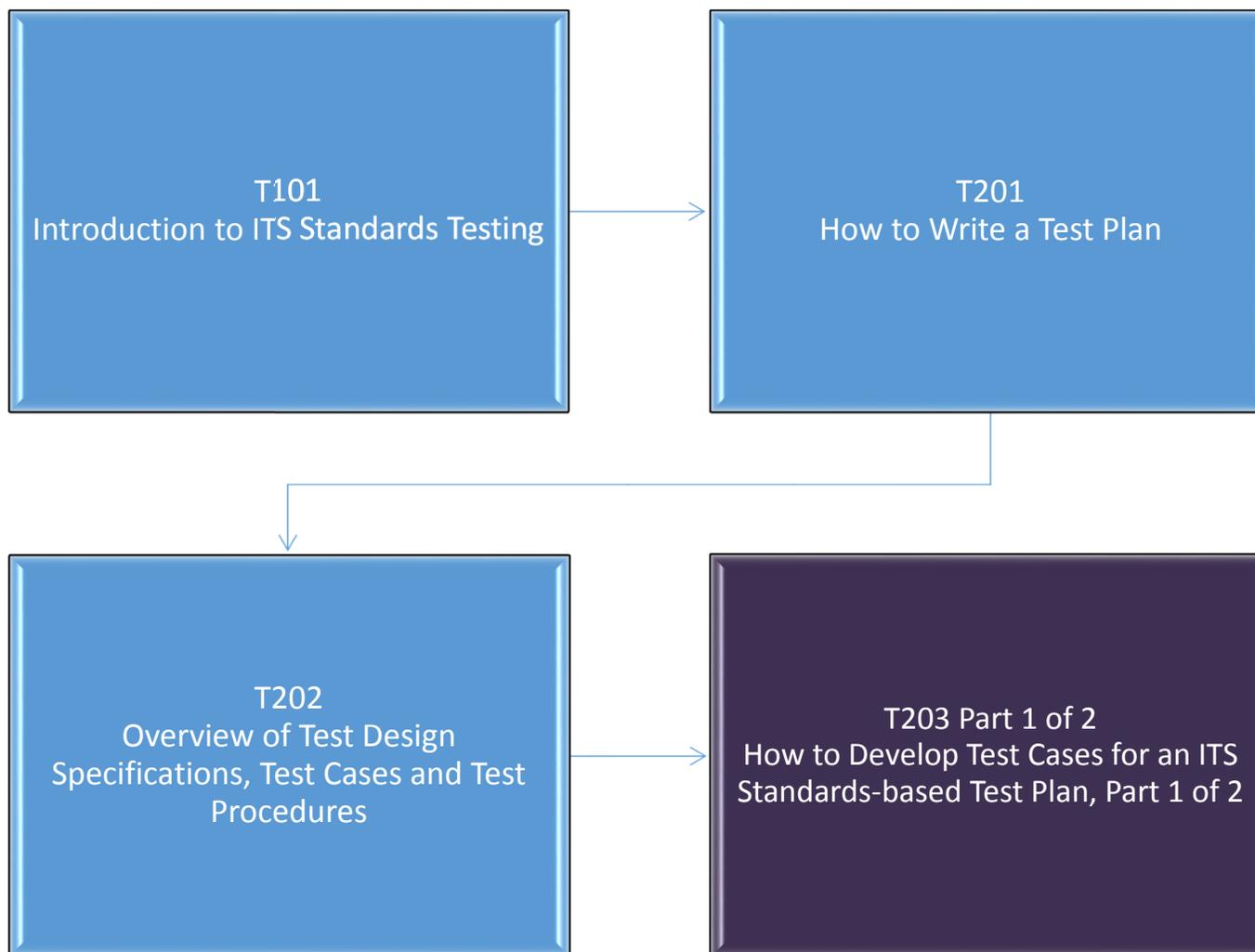
# Target Audience

- Traffic management and engineering staff
- Maintenance staff
- System developers
- Testing personnel
- Private and public sector users including manufacturers

## Recommended Prerequisite(s)

- T101: Introduction to ITS Standards Testing
- T201: How to Write a Test Plan
- T202: Overview of Test Design Specifications, Test Case Specifications, and Test Procedures

# Curriculum Path (Testing)



# List of Acronyms Used in this Module

ASN.1	Abstract Syntax Notation 1
C2C	Center-to-Center (Information Exchange)
C2F	Center-to-Field (NTCIP Devices)
CCTV	Closed Circuit Television
DMS	Dynamic Message Sign
ESS	Environmental Sensor Station
MIB	Management Information Base
NRTM	Needs to Requirements Traceability Matrix
NTCIP	National Transportation Communications for ITS Protocol
PRL	Protocol Requirements List
PDU	Protocol Data Unit
RTM	Requirements Traceability Matrix
RTCTM	Requirements to Test Case Traceability Matrix

## List of Acronyms Used in this Module (cont.)

TMDD	Traffic Management Data Dictionary
TDS	Test Design Specification
TCS	Test Case Specification
SE	System Engineering
SEP	System Engineering Process
XML	Extensible Markup Language

# Learning Objectives

## Part 1 of 2:

1. Review the role of test cases within the overall testing process.
2. Discuss ITS data structures used in NTCIP and Center-to-Center standards (TMDD) and provide examples.
3. Find information needed to develop a test case.
4. Explain test case development.

## Part 2 of 2:

5. Handle standards that are with and without test documentation.
6. Develop a Requirements to Test Case Traceability Matrix (RTCTM).
7. Identify types of testing.
8. Recognize the purpose of test logs and test anomaly report.

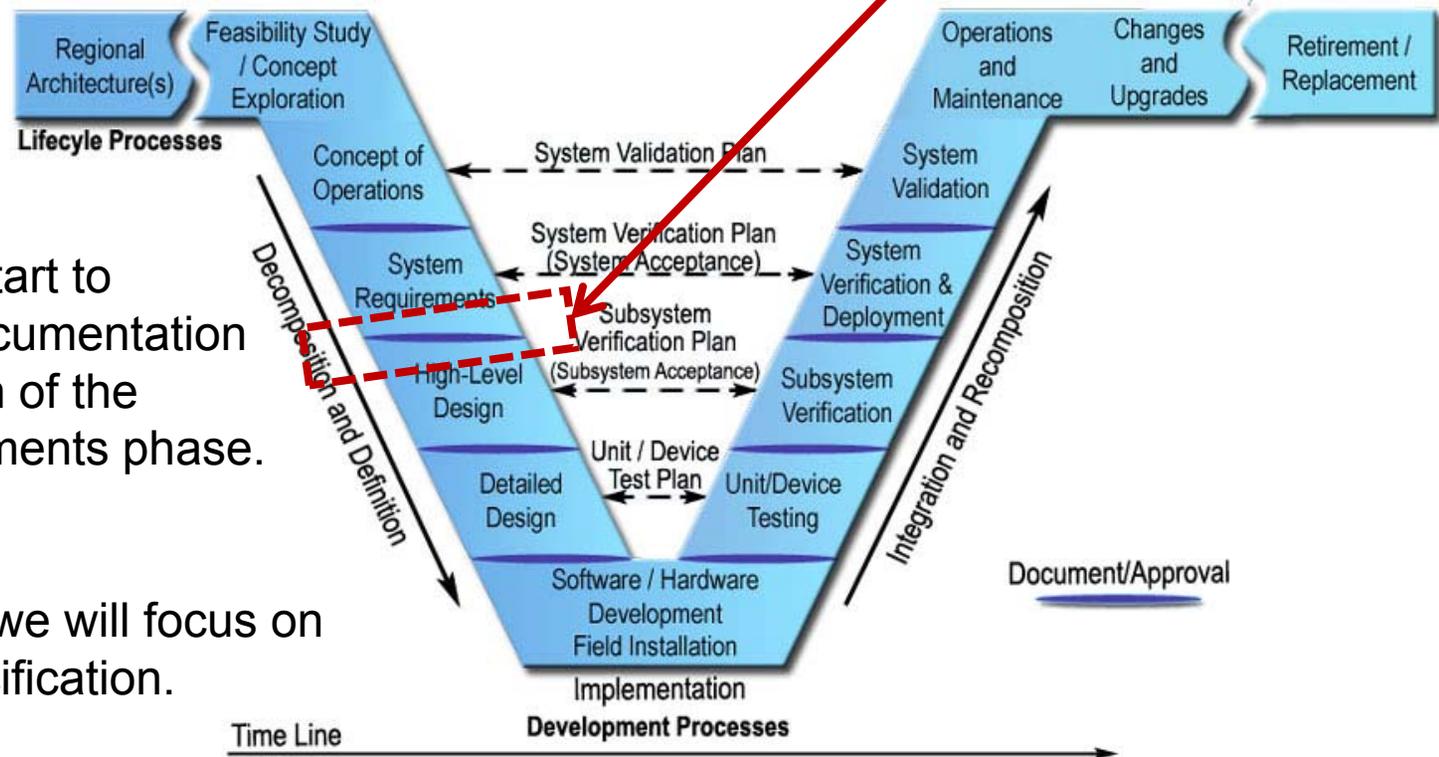
# Learning Objective 1: Review the Role of Test Cases Within the Overall Testing Process

- Review test documentation as defined in IEEE Std 829
- Show test cases in relationship to test plans, test designs, and test procedures
- Review ITS standards testing approaches and advantages of IEEE Std 829-based testing

## Brief Review of Module T202

- **Module T202** provided the context of the testing life cycle; what to test and when to test during System Engineering life cycle:
  - Provided overview of testing documentation, including Test Design Specifications, Test Cases, and Test Procedures
  - Introduced IEEE Std 829-2008, a Standard for Software and System Test Documentation that guides on formats
  - This module teaches how to use IEEE approach (users can customize testing documentation for their specification)

# Beginning of a Project Level Test Process



Agencies can start to prepare test documentation after completion of the system requirements phase.

In this module, we will focus on Test Case Specification.

SE Life Cycle

# What is a Testing Process?

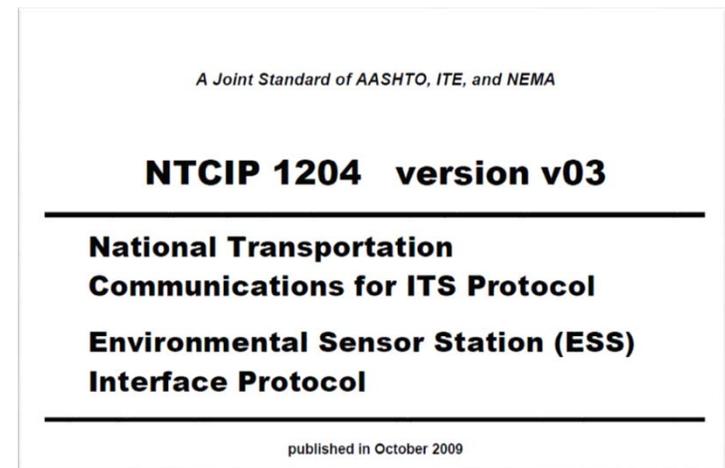
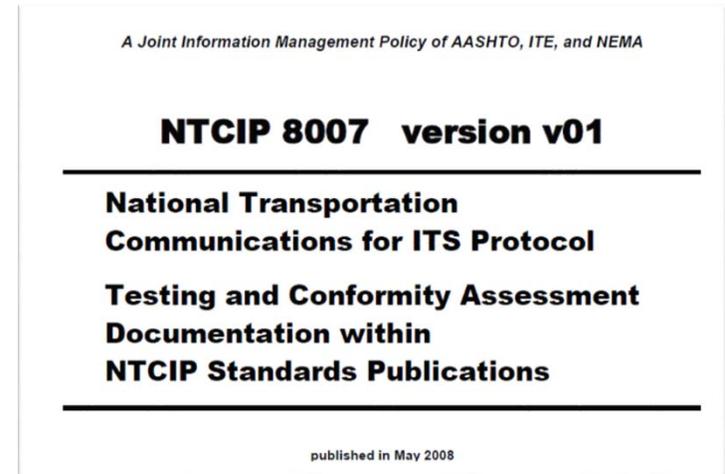
- The purpose of software and software-based systems testing is:
  - To help build quality into the software and system during the life cycle processes and to validate that the quality was achieved
  - To determine whether the products of a given life cycle activity conform to the requirements of that activity, and whether the product satisfies its intended use and user needs
  - Includes inspection, demonstration, analysis, and testing of software and software-based system products
  - To perform test activities in parallel with development efforts, not just at the conclusion of the development effort

# What is a Test Case?

- A test case specifies the inputs, outcomes, and conditions for execution of a test
- A test case is identified and included in a Test Case Specification (TCS) as part of an ITS project overall Test Plan
- This module teaches how to prepare a test case documentation by the agencies

# Approaches to Preparing Project Testing Documentation

1. ITS Standards Approach
2. IEEE Std 829 Approach

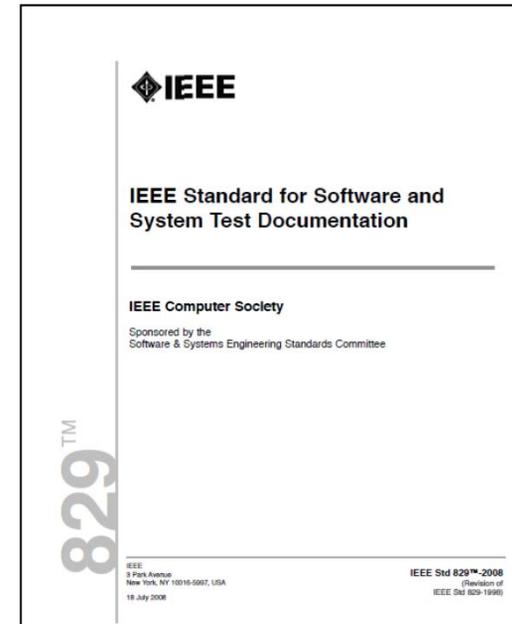


## IEEE Std 829 Testing Approach

- IEEE approach is applicable to all devices
  - Separates test cases and test procedures allows re-use of procedures
  - Includes a test plan and a method to split testing into test designs
  - Includes test reports
- IEEE approach can be more broadly applied (common format) across ITS, including center-to-center and center-to-field standards

# What does IEEE Std 829 Provide?

- Guidance and formats for preparing testing documentation:
  - Test Plan
  - Test Design Specification
  - Test Case Specification
  - Test Procedure Specification
  - Test Reports
    - Test Logs
    - Test Anomaly Report
    - Test Report
- Testing professionals across ITS are familiar with these definitions-formats

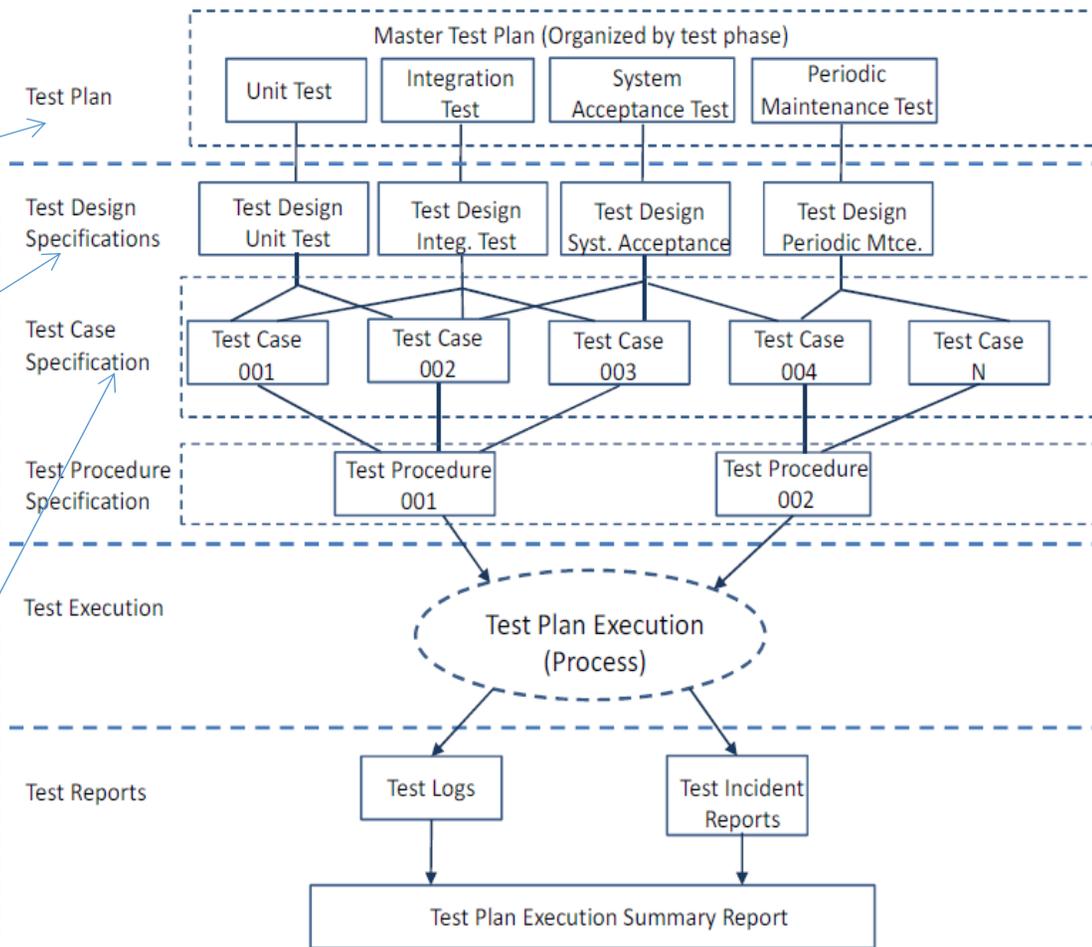


# Testing Documentation Structure (IEEE Std 829)

**Test Plan** describes the overall approach to testing

**Test Design Specification** describes which requirements are to be tested and associated test cases

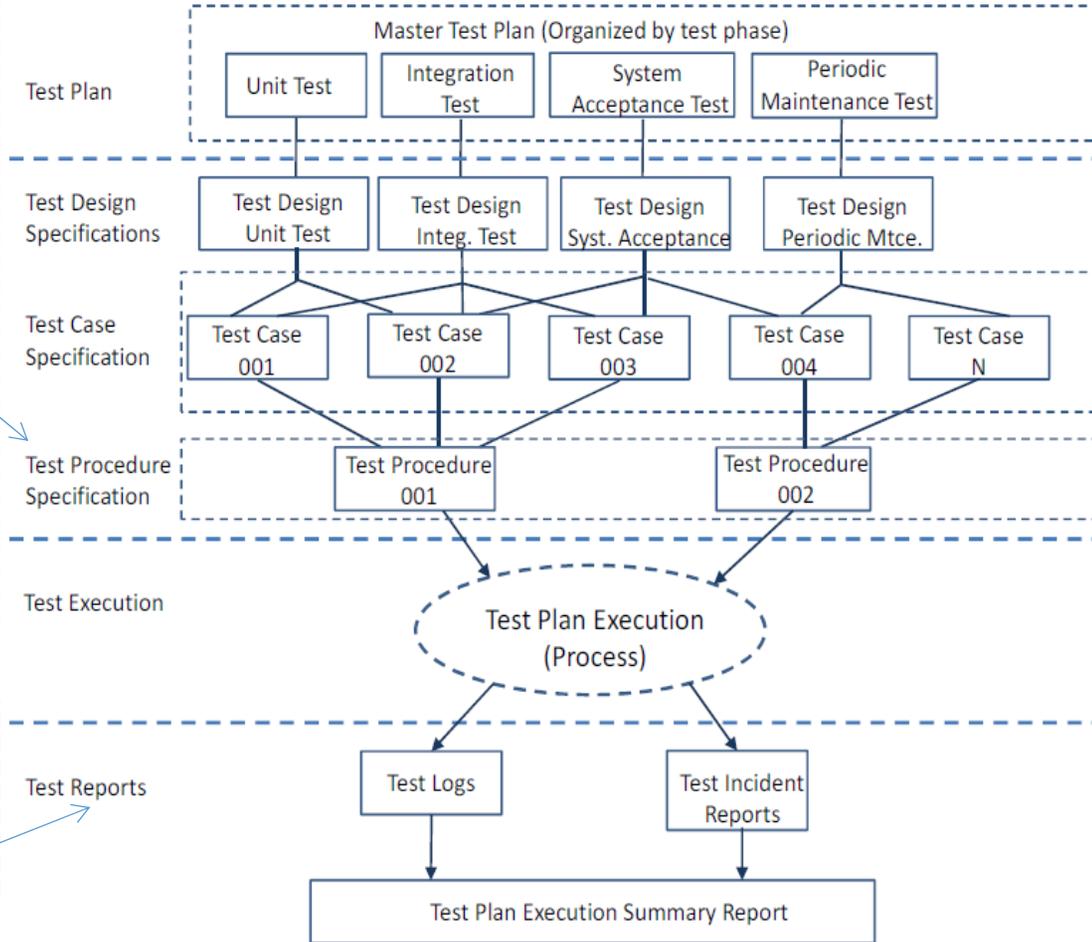
**Test Case Specification** identifies objectives and inputs, outcomes, and conditions for execution of a test



# Testing Documentation Structure (cont.)

- **Test Procedure Specification** defines the steps to execute a test
- Multiple Test Cases may reference a single Test Procedure
- Test Procedures may be more costly to develop than Test Cases

- **Test Reports: Test Logs, Test Anomaly Reports, Test Report**



## Key Differences Between the Two Approaches

- IEEE standard approach is applicable to all ITS standards including C2C and C2F
- IEEE standard approach separates test cases from test procedures while previous efforts combined both such as per NTCIP 8007 information report
- IEEE standard approach allows re-use of test procedures, where agencies typically place more efforts
- IEEE standard approach includes a test plan and method to split testing into test designs, and includes test reports

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**Which of the following IEEE Std 829-based component describes data inputs and outputs to be tested?**

**Answer Choices**

- a) Test Plan
- b) Test Case Specification
- c) Test Design Specification
- d) Test Procedure Specification

## Review of Answers



a) Test Plan

*Incorrect. Test plan describes overall approach.*



b) Test Case Specification

***Correct! Test Case Specification focuses on data input and output requirements to be tested.***



c) Test Design Specification

*Incorrect. Test Design Specification specifies the requirements to be tested and which test cases are associated with which requirements.*



d) Test Procedure Specification

*Incorrect. Test procedures outlines steps.*

# Summary of Learning Objective #1

## Review the Role of Test Cases Within the Overall Testing Process

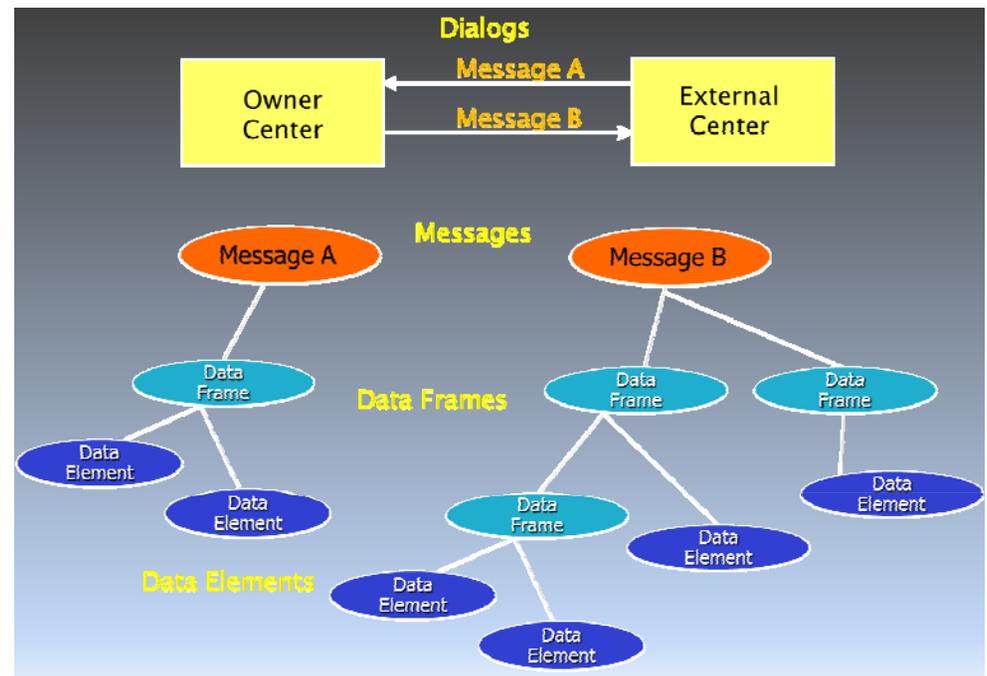
- Reviewed test documentation structure as defined in IEEE Std 829
- Discussed test cases in relationship to test plans, test designs, and test procedures
- Review ITS standards testing approaches and IEEE Std 829-based testing approach and key difference

# Learning Objective #2: Discuss ITS Data Structures Used in NTCIP and Center-to-Center Standards (TMDD) and Provide Examples

- Review data structure of ITS information and provide examples
- Discuss how a test case verifies the **correct structure of the data** as specified in the standards
- Discuss how a test case verifies the **correct value of the data** (range-syntax) **and data types** to conform the standards

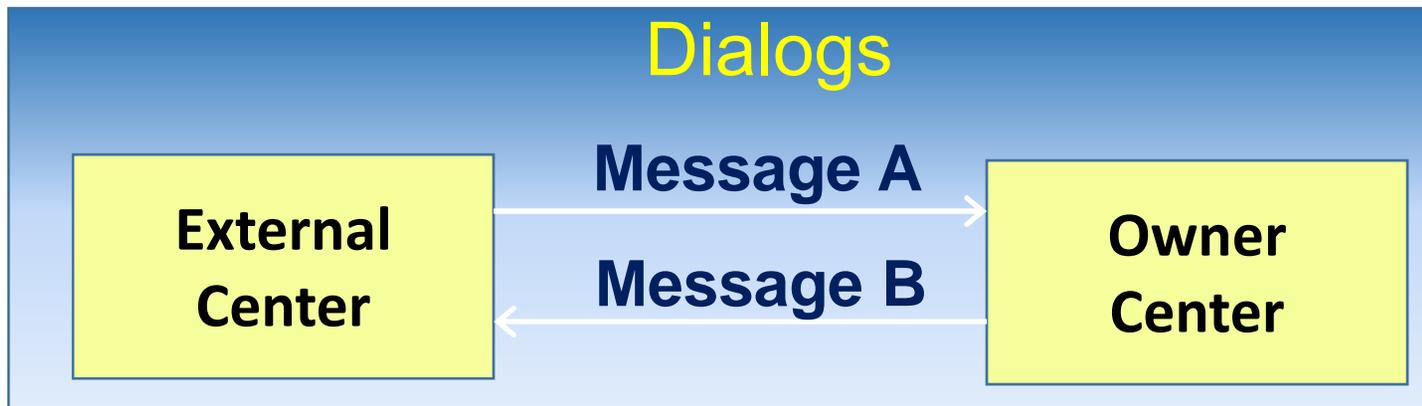
# Example: Information Exchange Between ITS Centers

- Centers exchange information using **Dialogs**
- Dialogs contain **Messages**
- Messages are formed with **Data Frames** and **Data Elements**



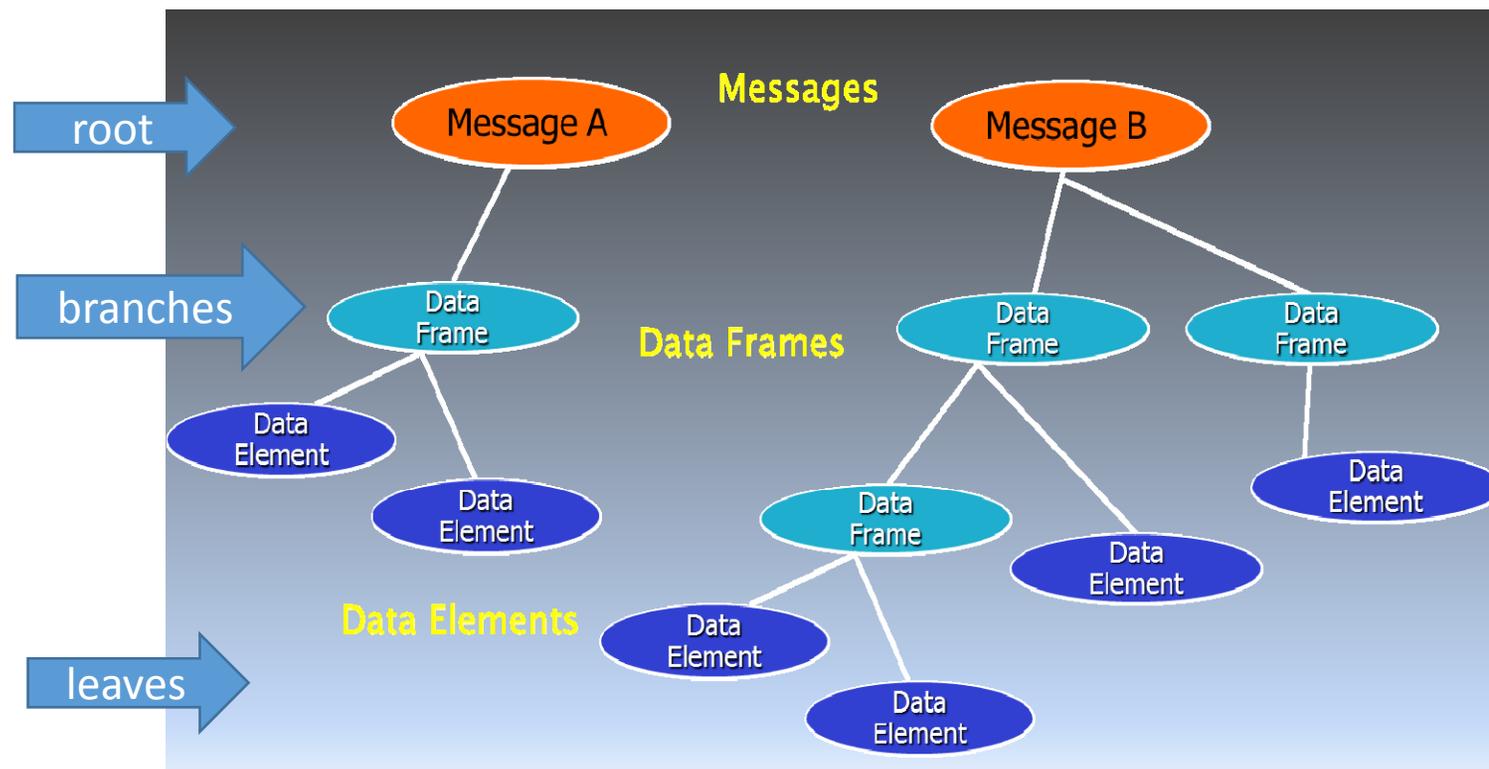
## What does Testing Verify? (Information Exchange Standards)

- Testing verifies the **correct sequence** of information being exchanged:
  - Standardized **Dialogs** specify the correct sequence of information exchanges



# Verifying the Correct Structure of Information

- ITS standards specify the tree-like exact structure of information

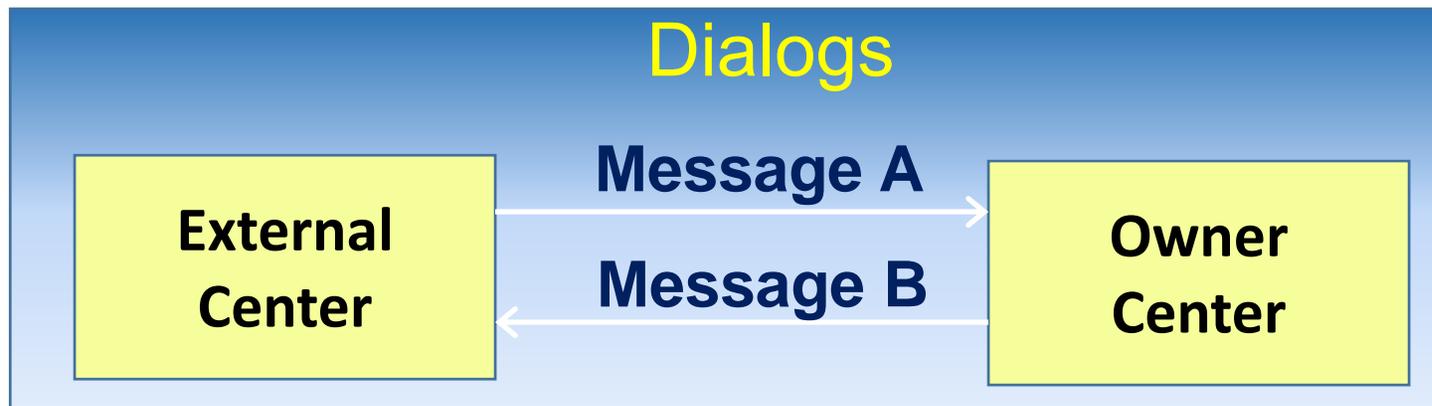


# Data Structure Is Tree-Like (Hierarchical)

- **Messages** (Root level)
  - Root element in the hierarchy of data exchanged between centers
  - A message is made up of data frames and data elements
  
- **Data Frames** (Branch level)
  - Reusable bundles of data elements and other data frames
  
- **Data Elements** (Leaf level)
  - Leaves in the hierarchy of data structure
  - Provide value constraints for data content

## How?

- **Test Case Specification (TCS) Identifies:**
  - Inputs (Message A)
  - Outcomes-Predicted results (Message B)
  - Execution conditions (sequence): Owner Center responds with Message B upon receipt of Message A from External Center



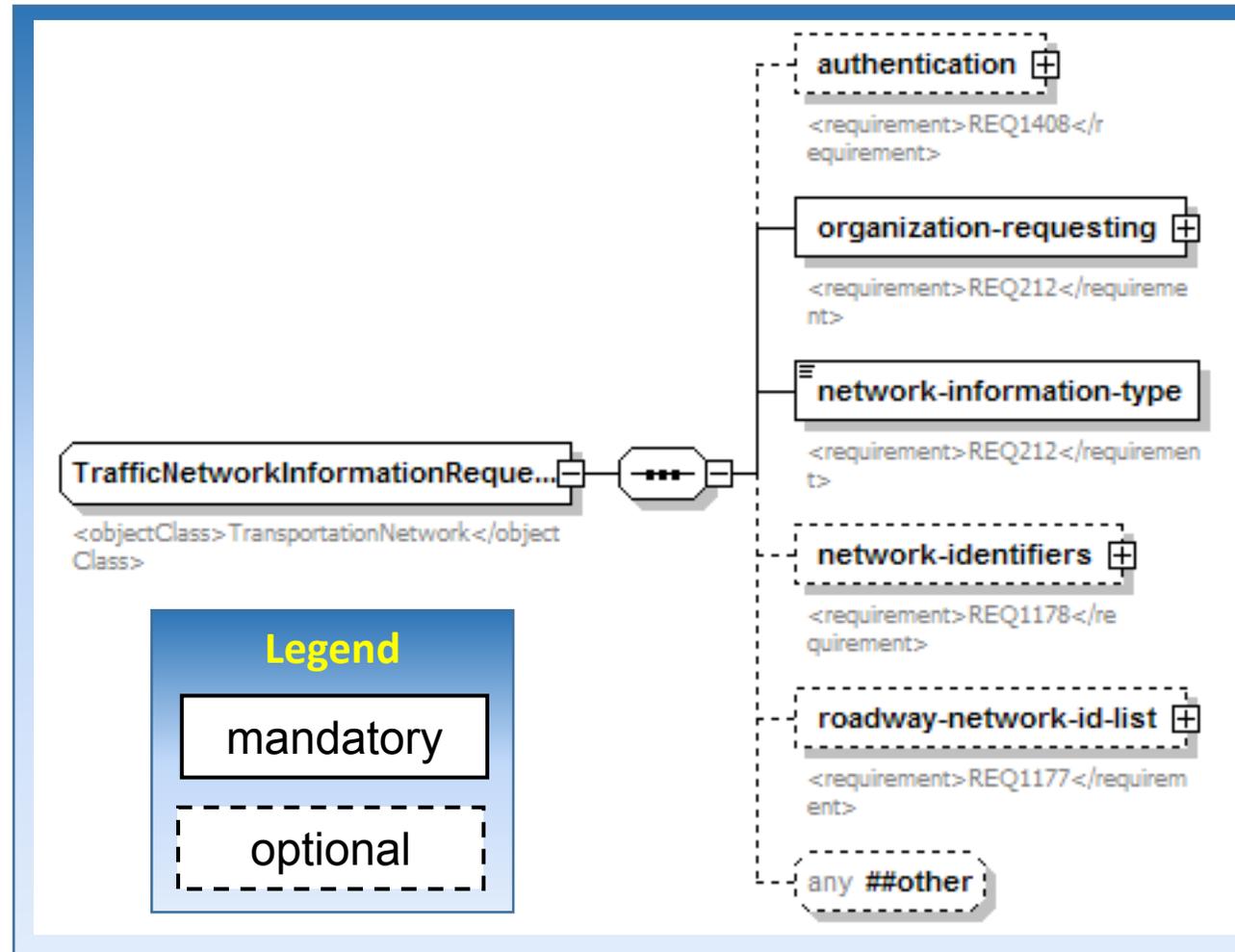
## Example: Center-to-Center Dialog

- Only specified sequence of messages and combinations are valid
  - linkStatusRequestMsg is used to make the request
  - linkStatusMsg contains the response



# Example: Center-to-Center Data Structure of linkStatusRequestMsg

- linkStatusRequestMsg is of type TrafficNetworkInformationRequest



## Constraints on Content of Data Values

- Device Standards: Testing verifies the **correct value** of object instance and protocol data units (PDUs)
- ITS standards use XML format for C2C information exchange data and ASN.1 for C2F NTCIP device data
- Typical data value constraints are:
  - Data type such as text or number
  - Enumerations such as a list of valid values
  - Text length
  - Numerical value ranges such as 0-255 in NTCIP Objects

*(Note: some devices use 0 as value to turn OFF a Device, 1 to turn ON, Ramp Meter Control standard uses 1-255 range)*

## Example: Center-to-Field Device (ESS)

- Only number values are valid: Values 1 through 12.

**Constraint:**  
**Number Value**  
SYNTAX INTEGER

**Constraint: Value Range**  
1 to 12

**5.6.10.10 Wind Sensor Situation**  
windSensorSituation OBJECT-TYPE

SYNTAX INTEGER {

**other (1), unknown (2), calm (3), lightBreeze (4), moderateBreeze (5), strongBreeze (6), gale (7), moderateGale (8), strongGale (9), stormWinds (10), hurricaneForceWinds (11), gustyWinds (12)}**

ACCESS read-only

STATUS mandatory

DESCRIPTION "<Definition>Describes the weather and travel situation in terms of wind from staffed stations only. Specific ranges for these values are defined in the Glossary of Meteorology.

<DescriptiveName>WindSensor.situation:code

gustyWinds defined by a peak and a lull of greater than 46.3 tenths of meters per second within a 2 minute period.

<Data Concept Type>Data Element"

::= { windSensorEntry 10 }

Source: NTCIP 1204 v03

# Examples of Constraints on Data Structure

- **C2F NTCIP Devices:**

- Management Information Base (MIB)
- ASN.1 Object Value specification

- **C2C TMDD (Volume II - Design):**

- XML Value specification
- ASN.1 Value specification

- **Data Structure:**

- Message
- Data Frames
- Data Elements

# What is the Purpose of a Test Case?

- To verify the requirements related to information exchanged between two systems by:
  - Verifying the sequence of information exchanged is correct:
    - Standards use dialogs to define information exchange sequence
  - Verifying the structure of information exchanged is correct
    - Standards define the order of Messages-Data Frames-Data Elements
  - Verifying the content of information exchanged is correct
    - Standards define the valid value rules (e.g., value ranges) for data exchanged

## Relationship of Test Case to Requirements

- Purpose: To test monitoring capability stated by a requirement
- A Requirement to Test Case Traceability Matrix (RTCTM) relates the test case to requirement(s) being tested.

NTCIP 1204 v03.08  
Page 154

<b>Requirement</b>		<b>Test Case</b>	
<b>ID</b>	<b>Title</b>	<b>ID</b>	<b>Title</b>
3.5.1.1.2	Retrieve Compressed Station Metadata		
		C.2.3.1.2	Retrieve Compressed Station Metadata
3.5.1.1.3	Configure ESS Manager		
		C.2.3.1.1	ESS Characteristics
3.5.1.2	ESS Status Monitoring Requirements		
3.5.1.2.1	Retrieve ESS Door Status		
		C.2.3.1.3	Retrieve ESS Door Status
3.5.1.2.2	Retrieve Battery Status		
		C.2.3.1.4	Retrieve Battery Status

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## Which of the following defines the structure and data content of inputs and outputs?

### Answer Choices

- a) Data Dictionary Standard (e.g., NTCIP 1204 ESS, TMDD)
- b) Protocol Requirements List (PRL)
- c) Requirements to Test Case Traceability Matrix (RTCTM)
- d) All of the above

## Review of Answers



a) Data Dictionary (e.g., NTCIP 1204 ESS, TMDD)

**Correct! A data dictionary specifies the structure of data and constraints of valid values for data content.**



b) Protocol Requirements List (PRL)

*Incorrect. The PRL traces requirements to needs, and allows you to specify optional requirements for a specific project.*



c) Requirements to Test Case Traceability Matrix (RTCTM)

*Incorrect. The RTCTM traces test cases to the requirements the test case verifies.*



d) All of the above

*Incorrect. Only a) above is correct.*

## Summary of Learning Objective #2

### Discuss ITS Data Structures used in NTCIP and Center-to-Center Standards (TMDD) and Provide Examples

- Reviewed data structure of ITS information with examples
- Discuss how a test case verifies the correct structure of the data as specified in the standards
- Discussed how a test case verifies the correct value of the data (range-syntax) and data types to conform the standards

# Learning Objective #3: Find Information Needed for a Test Case

- What information is needed:
  - Relevant User Needs for Project
  - Relevant Requirements
  - Relevant Design (dialogs, data elements, and valid values)
- Where to find content for a Test Case for C2C standards (TMDD)
- Where to find content for a Test Case for C2F standards (NTCIP)

# Where to Find C2C Standards Content

- Requirements and dialogs are identified by project level **Needs to Requirements Traceability Matrix (NRTM)**
- Dialogs identifies **inputs and outputs** needed to develop the test case specification

TMDD v03 NRTM

Each project tailors this matrix

UN ID	User Need	Reqmt Type	Req ID	Requirement	Conformance	Support
2.5.2.2	Travel Time Data for Roads				Optional	Yes/No
				Dialogs for Link Based Information		
			3.5.3.3.2.1	Send Link Status Information Upon Request	M	Yes/No/NA
			3.5.3.3.2.2	Publish Link Status Information	Subscription:O	Yes/No/NA
			3.5.3.3.2.3	Subscribe to Link Status Information	Subscription:O	Yes/No/NA
				Request Message		
			3.5.3.3.2.4	Contents of the Link Status Request	M	Yes
			3.5.3.1.1	Contents of the Traffic Network Information Request	M	Yes
			3.5.3.1.1.1	Required Traffic Network Information Request Content	M	Yes
			3.5.3.1.1.2.1	Authentication	O	Yes/No
			3.5.3.1.1.2.1.1	Operator Identifier	O	Yes/No
			3.5.3.1.1.2.2	Roadway Network Identifier	O	Yes/No
			3.5.3.1.1.2.3	Traffic Network Identifier	O	Yes/No
				Response Message		
			3.5.3.3.2.5	Contents of the Link Status Information	M	Yes
			3.5.3.3.2.5.1	Required Link Status Information Content	M	Yes
			3.5.3.3.2.5.2.1	Restrictions	O	Yes/No
			3.5.3.3.2.5.2.2	Link Name	O	Yes/No
			3.5.3.3.2.5.2.3	Link Direction	O	Yes/No
			3.5.3.3.2.5.2.4	Link Travel Time	M*	Yes/No
			3.5.3.3.2.5.2.11	Status Date and Time Change Information	O	Yes/No
				Error Report Message		
			3.4.4.1	Contents of the Error Report	M	Yes
			3.4.4.1.1	Required Error Report Contents	M	Yes
			3.4.4.1.2.1	Restrictions	O	Yes / No



# Example of a Project Level NRTM

UN ID	User Need	Reqmt Type	Req ID	Requirement	Conformance	Support
2.5.2.2	Travel Time Data for Roads				Optional	Yes/No
			Dialogs for Link Based Information			
			3.5.3.3.2.1	Send Link Status Information Upon Request	M	Yes/No/NA
			3.5.3.3.2.2	Publish Link Status Information	Subscription:O	Yes/No/NA
			3.5.3.3.2.3	Subscribe to Link Status Information	Subscription:O	Yes/No/NA
			Request Message			
			3.5.3.3.2.4	Contents of the Link Status Request	M	Yes
			3.5.3.1.1	Contents of the Traffic Network Information Request	M	Yes
			3.5.3.1.1.1	Required Traffic Network Information Request Content	M	Yes
			3.5.3.1.1.2.1	Authentication	O	Yes/No
			3.5.3.1.1.2.1.1	Operator Identifier	O	Yes/No
			3.5.3.1.1.2.2	Roadway Network Identifier	O	Yes/No
			3.5.3.1.1.2.3	Traffic Network Identifier	O	Yes/No
			Response Message			
			3.5.3.3.2.5	Contents of the Link Status Information	M	Yes
			3.5.3.3.2.5.1	Required Link Status Information Content	M	Yes
			3.5.3.3.2.5.2.1	Restrictions	O	Yes/No
			3.5.3.3.2.5.2.2	Link Name	O	Yes/No
			3.5.3.3.2.5.2.3	Link Direction	O	Yes/No
			3.5.3.3.2.5.2.4	Link Travel Time	M*	Yes/No
			3.5.3.3.2.5.2.11	Status Date and Time Change Information	O	Yes/No
			Error Report Message			
			3.4.4.1	Contents of the Error Report	M	Yes

# A Section of NRTM Tailored For Project-Specific Needs

UN ID	User Need	Reqmt Type	Req ID	Requirement	Conformance	Support
2.5.2.2	Travel Time Data for Roads				Optional	Yes/No
		Dialogs for Link Based Information				
			3.5.3.3.2.1	Send Link Status Information Upon Request	M	Yes/No/N A
			3.5.3.3.2.2	Publish Link Status Information	Subscription:O	Yes/No/N A
			3.5.3.3.2.3	Subscribe to Link Status Information	Subscription:O	Yes/No/N A

Section of the tailored RTM that corresponds with the requirements identified from the NRTM above. Section covering User Needs 2.5.2.2 is shown below.

RTSMIP-DXFS Requirement ID	Requirement	DC Type	TMDD Vol II DC Instance Name	TMDD Vol II DC ID	TMDD Vol II DC Class Name
3.5.3.3.2.1	Send Link Status Information Upon Request	dialog	dILinkStatusRequest	3.1.13.2	dILinkStatusRequest
3.5.3.3.2.2	Publish Link Status Information	dialog	dILinkStatusUpdate	3.1.34.2	dILinkStatusUpdate
3.5.3.3.2.3	Subscribe to Link Status Information	dialog	dITrafficNetworkInformationSubscription	3.1.19.1	dITrafficNetworkInformationSubscription

## Where to Find C2F Standards Content

- Requirements are identified by project level **Protocol Requirements List (PRL)**
- NTCIP SEP standards such as DMS provides a PRL
- Non-SEP standards such as CCTV must develop a project PRL

USER NEED SECTION NUMBER	USER NEED	FR SECTION NUMBER	FUNCTIONAL REQUIREMENT	CONFORMANCE	SUPPORT / PROJECT REQUIREMENT	ADDITIONAL PROJECT REQUIREMENTS
2.5.2.3	Control the Sign Face			M	Yes	
2.5.2.3.1	Activate and Display a Message			M	Yes	
		3.5.2.3.1	Activate a Message	M	Yes	
		3.5.2.3.3.5	Retrieve Message	M	Yes	
		3.5.2.3.6	Activate a Message with Status	Drum:M	Yes / NA	
		3.6.5 †	Supplemental Requirements for Message Activation Request	M	Yes	
		3.6.7 †	Supplemental Requirements for Locally Stored Messages	M	Yes	

## Where to Find C2F Standards Content (cont.)

- **Requirements Traceability Matrix (RTM)** references relevant design content needed to define the **inputs and outputs** for the test case specification
- NTCIP SEP standards such as DMS provides a RTM
- Non-SEP standards such as CCTV must develop a project RTM

Requirements Traceability Matrix (RTM)					
FR ID	Functional Requirement	Dialog ID	Object ID	Object Name	Additional Specifications
3.5.2.3	Control the Sign Face				
3.5.2.3.1	Activate a Message	4.2.3.1			
			5.7.3	dmsActivateMessage	
			5.11.2.1.1	shortErrorStatus	
			5.7.17	dmsActivateMsgError	
			5.7.24	dmsActivateErrorMsgCode	
			5.7.18	dmsMultiSyntaxError	
			5.7.19	dmsMultiSyntaxErrorPosition	
			5.7.20	dmsMultiOtherErrorDescription	

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## Which of the following will provide information on project needs for a C2C project?

### Sources of Information:

- a) Needs to Requirements Traceability Matrix (NRTM)
- b) Requirements to Test Case Traceability Matrix (RTCTM)
- c) Requirements Traceability Matrix (RTM)
- d) Design (dialogs, data elements, valid values)

## Review of Answers



a) Needs to Requirements Traceability Matrix (NRTM)

**Correct! NRTM identifies project needs for a C2C project.**



b) Requirements to Test Case Traceability Matrix (RTCTM)

*Incorrect. The RTCTM traces test cases to the requirements the test case verifies.*



c) Requirements Traceability matrix (RTM)

*Incorrect. The RTM traces requirements to design objects for C2F NTCIP standard based project.*



d) Design (dialogs, data elements, valid values)

*Incorrect. Project design does not trace to project needs.*

## Summary of Learning Objective #3

### Find Information Needed for a Test Case

- Reviewed content sources for a test case information for C2C standard such as TMDD
- Reviewed content sources for a test case information for C2F standards such as NTCIP-ESS

# Learning Objective #4: Explain Test Case Development

- Outline of a test case:
  - Suggested template
  - Required content
- Where do we find information for test case template?
  - Center-to-Center Standards (C2C)
  - Center-to-Field Standards (C2F)
- Discuss Positive/Negative Testing
- Additional test case Requirements

# Outline of a Test Case-Suggested Template (IEEE Std 829)

- Required Content of a test case:
  - Test case identifier
  - Objective
  - Inputs
  - Outcomes
  - Environmental needs
  - Special procedural requirements
  - Intercede dependencies

Test Case	
ID:	
Objective:	
Inputs:	
Outcome(s):	
Environmental Needs:	
Tester/Reviewer:	
Special Procedure Requirements:	
Intercede Dependencies:	

# Test Case Identifier

- Each test case requires a unique identifier to distinguish it from all other test cases.

Test Case	
<b>ID: TC001</b>	Title: Link Status Request-Response Dialog Verification (Positive Test Case)
<b>Objective:</b>	To verify system interface implements (positive test case) requirements for: <ol style="list-style-type: none"> <li>1) Link Status Request-Response Dialog message exchange</li> <li>2) Contents of the Link Status Request Message</li> <li>3) Contents of the Link Status Information Message</li> </ol> <p>The test case verifies that the dialog, request message content, and response message content are correct by sending a request message (verified to be correct) across the system interface, and verification that the response message is correct. Input and output specifications are provided to verify the request and response message are correct per the requirements for the request and response message.</p>
<b>Inputs:</b>	Use the input file linkStatusRequest.xml. See Test Case Input Specification TCIS001 - LinkStatusRequest (Positive Test Case).
<b>Outcome(s):</b>	All data are returned and verified as correct: correct sequence of message exchanges, structure of data, and valid value of data content. See Test Case Output Specification TCOS001 - LinkStatusInformation (Positive Test Case)
<b>Environmental Needs:</b>	No additional needs outside of those specified in the test plan.
<b>Tester/Reviewer</b>	M.I.
<b>Special Procedure Requirements:</b>	None
<b>Intercase Dependencies:</b>	None

## Test Case Objective

- **Purpose:** The objective identifies the purpose of the test case
- **Focus:** Describe the special focus of a particular test case and relation to other test cases
- **Priority:** Test case priority

## Test Case Objective: Focus

- Whether TC is for testing a dialog (i.e., correct sequence of message exchanges)
- Whether TC is testing correct structure and content of data
- Intercase dependencies
  - An example of an intercase dependency is when a test case to verify a publication dialog must be preceded by a complete and correct subscription dialog

## Test Case Objective: Priority

- Identifies the relative importance of accomplishing certain test cases in advance of others
- Priority is project specific
- Examples:
  - Specify the order of which devices to test (e.g., CCTV first, DMS next, etc.)
  - Specify that inventory and status dialogs shall be tested first, followed by the testing of device control dialogs
  - Specify that request-response dialogs shall be tested first, followed by subscription-publication dialogs
  - Specify that positive test cases shall be tested first, followed by negative test cases

## Test Case Inputs

- Specify each input required to execute each test case:
  - Some inputs will be specified by value (with tolerances where appropriate)
  - Some others such as constant tables or transaction files will be specified by name
  - Specify each input and timing of input(s) required to execute the test case

# Example Test Case Input Specification

Test Case Input Specification		
<b>ID: TCIS001</b>	Title: LinkStatusRequest (Positive Test Case)	
<b>Data Concept Name (Variable)</b>	Data Concept Type	Value Domain
<b>trafficNetworkInformationRequestMsg</b>	Message	
- organization-requesting	Data Frame	
- organization-id	Data Element	IA5String (SIZE(1..32))
- organization-name	Data Element	IA5String (SIZE(1..128))
- network-information-type	Data Element	1 = "node inventory" 2 = "node status" 3 = "link inventory" 4 = "link status" 5 = "route inventory" 6 = "route status" 7 = "network inventory"

## Test Case Outcome(s)

- Outcomes specify all outputs and the expected behavior (e.g., response time) required of the test items
- Provides representative value(s) (with tolerances where appropriate) for each required output and expected behavior

# Example Test Case Output Specification

Test Case Output Specification		
<b>ID: TCOS001</b>	Title: LinkStatusInformation (Positive Test Case)	
<b>Data Concept Name (Variable)</b>	Data Concept Type	Value Domain
<b>linkStatusMsg</b>	Message	
- link-status-item	Data Frame	
- organization-information	Data Frame	
- organization-id	Data Element	IA5String (SIZE(1..32))
- organization-name	Data Element	IA5String (SIZE(1..128))
- link-status-list	Data Frame	
- link	Data Frame	
- network-id	Data Element	IA5String (SIZE(1..32))
- link-id	Data Element	IA5String (SIZE(1..32))
- link-name	Data Element	IA5String (SIZE(1..128))
- link-status	Data Element	1 = "no determination" 2 = "open" 3 = "restricted" 4 = "closed"
- travel-time	Data Element	INTEGER (0..65535), units=seconds

# Sample Filled-in Test Case Specification

Test Case	
<b>ID: TC001</b>	Title: Link Status Request-Response Dialog Verification (Positive Test Case)
<b>Objective:</b>	<p>To verify system interface implements (positive test case) requirements for:</p> <ol style="list-style-type: none"> <li>1) Link Status Request-Response Dialog message exchange</li> <li>2) Contents of the Link Status Request Message</li> <li>3) Contents of the Link Status Information Message</li> </ol> <p>The test case verifies that the dialog, request message content, and response message content are correct by sending a request message (verified to be correct) across the system interface, and verification that the response message is correct. Input and output specifications are provided to verify the request and response message are correct per the requirements for the request and response message.</p>
<b>Inputs:</b>	Use the input file linkStatusRequest.xml. See Test Case Input Specification TCIS001 - LinkStatusRequest (Positive Test Case).
<b>Outcome(s):</b>	All data are returned and verified as correct: correct sequence of message exchanges, structure of data, and valid value of data content. See Test Case Output Specification TCOS001 - LinkStatusInformation (Positive Test Case)
<b>Environmental Needs:</b>	No additional needs outside of those specified in the test plan.
<b>Tester/Reviewer</b>	M.I.
<b>Special Procedure Requirements:</b>	None
<b>Intercase Dependencies:</b>	None

## Positive Test Case

- Positive Test Case Inputs and Outputs include:
  - Data values within the range of values (or text length or format) specified in the standards
  - Data that are correctly structured as specified in the standard
  - All mandatory data values, including those optional elements in the standard made mandatory for a project

## Positive Test Case Data Example

```
<?xml version="1.0" encoding="UTF-8"?>
<trafficNetworkInformationRequestMsg>
  <authentication>
    <user-id>user</user-id>
    <password>pass</password>
  </authentication>
  <organization-requesting>
    <organization-id >ORG001</organization-id>
    <center-contact-list>
      <center-contact-details>
        <center-id>test</center-id>
      </center-contact-details>
    </center-contact-list>
  </organization-requesting>
  <network-information-type>link inventory</network-information-type>
</trafficNetworkInformationRequestMsg>
```

## Negative Test Case

- Negative Test Case inputs and outputs:
  - Include data values that are not within the range of values (or text length or format) specified in the standards.
  - May have data not correctly structured as specified in the standard
  - May have missing mandatory data elements, including those optional elements in the standard made mandatory for a project

# Negative Test Case Data Example

## Errors:

1. Invalid User Name and Password
2. Missing mandatory element  
<organization-id>, and
3. Extra element  
<depreciation-method> not defined in TMDD or project specific NRTM.

```

<?xml version="1.0" encoding="UTF-8"?>
<trafficNetworkInformationRequestMsg>
  <!-- Error: Invalid User Name and Password -->
  <authentication>
    <user-id>user</user-id>
    <password>incorrectpass</password>
  </authentication>
  <organization-requesting>
    <!-- Error: Missing TMDD Mandatory Element:-->
    <!-- organization-id -->
    <center-contact-list>
      <center-contact-details>
        <center-id>test</center-id>
      </center-contact-details>
    </center-contact-list>
    <!-- Error: Extra element not defined -->
    <depreciation-method>sum of the years digits
  </depreciation-method>
  </organization-requesting>
  <network-information-type>link inventory</network-information-
type>
</trafficNetworkInformationRequestMsg>

```

## Missing Elements and Incorrect Data Structure

- A missing element or incorrect structure of a message may be specified in the TCS inputs, perhaps referencing a file with an example

## Example Missing Elements

```
<?xml version="1.0" encoding="UTF-8"?>
<trafficNetworkInformationRequestMsg>
  <authentication>
    <user-id>user</user-id>
    <password>pass</password>
  </authentication>
  <organization-requesting>
    <organization-id>ORG001</organization-id>
    <center-contact-list>
      <center-contact-details>
        <center-id>test</center-id>
      </center-contact-details>
    </center-contact-list>
  </organization-requesting>
  <network-information-type>link
inventory</network-information-type>
</trafficNetworkInformationRequestMsg>
```

Correct Message

```
<?xml version="1.0" encoding="UTF-8"?>
<trafficNetworkInformationRequestMsg>
  <authentication>
    <user-id>user</user-id>
    <password>pass</password>
  </authentication>
  <organization-requesting>
    <!-- Missing Mandatory Element -->
    <center-contact-list>
      <center-contact-details>
        <center-id>test</center-id>
      </center-contact-details>
    </center-contact-list>
  </organization-requesting>
  <network-information-type>link
inventory</network-information-type>
</trafficNetworkInformationRequestMsg>
```

Incorrect Message: Missing  
Mandatory Element organization-id

## Example Incorrect Data Structure

```
<?xml version="1.0" encoding="UTF-8"?>
<trafficNetworkInformationRequestMsg>
  <authentication>
    <user-id>user</user-id>
    <password>pass</password>
  </authentication>
  <organization-requesting>
    <organization-id>ORG001</organization-id>
    <center-contact-list>
      <center-contact-details>
        <center-id>test</center-id>
      </center-contact-details>
    </center-contact-list>
  </organization-requesting>
  <network-information-type>link
inventory</network-information-type>
</trafficNetworkInformationRequestMsg>
```

Correct Message

```
<?xml version="1.0" encoding="UTF-8"?>
<trafficNetworkInformationRequestMsg>
  <authentication>
    <password>pass</password>
    <user-id>user</user-id>
  </authentication>
  <organization-requesting>
    <organization-id>ORG001</organization-id>
    <center-contact-list>
      <center-contact-details>
        <center-id>test</center-id>
      </center-contact-details>
    </center-contact-list>
  </organization-requesting>
  <network-information-type>link
inventory</network-information-type>
</trafficNetworkInformationRequestMsg>
```

Incorrect Message: Incorrect Sequence of Elements user-id and password

## Test Case Environmental Needs

- Describe the test environment needed for test setup, execution, and results recording
- Ideally, the test plan identifies environmental needs for conducting testing
- This section of the test case may simply reference the section of the test plan that identifies environmental needs if there are no special test case-specific needs
- In some instances, a test case may specify additional environmental needs or exceptions to environmental needs identified in the test plan or referenced test procedure

# Test Case Special Procedural Requirements

- Describes special constraints on test case execution
- Pre- and post-conditions for test case execution
- This section may reference the use of automated test tools not described in the test plan or referenced test procedure
- Exceptions to what is described in the test plan or referenced test procedure would be included in this section

## Test Case Intercase Dependencies

- Lists the identifiers of test cases that must be executed prior to this test case
- Summarize the nature of the dependencies
- For example, when testing subscription-publication dialogs, a subscription must take place (or be tested) prior to testing for a publication update

# ACTIVITY



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## Which of the following is part of the IEEE Std 829 Test Case Specification?

### Answer Choices

- a) Description and valid values of inputs and outputs
- b) Project Sponsor
- c) Steps to Conduct a Test
- d) Test Pass-Fail

## Review of Answers



a) Description and valid values of inputs and outputs

**Correct! The test case includes specification of inputs, including their value.**



b) Project Sponsor

*Incorrect. The project sponsor is not a formal part of a TC.*



c) Steps to Conduct a Test

*Incorrect. This feature is contained in a test procedure.*



d) Test Pass-Fail

*Incorrect. This feature is contained in a test procedure.*

# Summary of Learning Objective #4

## Understand Test Case Development

- Reviewed an outline of a test case and a suggested template with required content
- Discussed where do we find information for test case template for C2C and C2F standards
- Discussed positive/negative testing
- Reviewed additional test case requirements

# What We Have Learned

- 1) The role of test cases in relation to other test documents: test plan, test designs, test procedures, and test reports.
- 2) The purpose of a test case specification is to document the inputs, expected outcomes, and execution conditions for a test.

## What We Have Learned (cont.)

- 3) The outline for a test case specification is defined in IEEE Std 829.
- a) Test case identifier
  - b) Objective
  - c) Inputs
  - d) Outcomes
  - e) Environmental needs
  - f) Special procedural requirements
  - g) Intercase dependencies

## What We Have Learned (cont.)

- 4) ITS data dictionary standards constrain the structure of data and content of data of information exchanges between systems.
  
- 5) Walked through an example test case to learn how to develop one.

# Resources

- IEEE Std 829-2008 IEEE Standard for Software and System Test Documentation (<http://www.ieee.org>)
- IEEE Std 610-1990 Standard Glossary of Software Engineering Terminology 9 (<http://www.ieee.org>)
- NTCIP 8007 Testing and Conformity Assessment Documentation within NTCIP Standards Publications, <http://www.ntcip.org/library/>
- NTCIP 1204 v03 Environmental Sensor Station Interface Standard <http://www.ntcip.org/library/>
- Traffic Management Data Dictionary Version 3.03 <http://www.ite.org/standards/tmdd/>
- T202: Overview of Test Design Specifications, Test Case Specifications, and Test Procedures [http://www.pcb.its.dot.gov/stds\\_training.aspx](http://www.pcb.its.dot.gov/stds_training.aspx)

## Next Course Module

### T203 Part 2 of 2: How to Develop Test Cases for ITS Standards-based Test Plan, Part 2 of 2

#### Part 2 of 2:

5. Handle standards that are with and without test documentation
6. Develop a Requirements to Test Case Traceability Matrix (RTCTM)
7. Identify types of testing
8. Recognize the purpose of test logs and test anomaly report

# QUESTIONS?



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