

Phase 1 Operational Readiness Plan (ORP)

Vehicle-to-Everything (V2X) Accelerator: Connecting the West – Utah Department of Transportation

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List of Acronyms and Abbreviations

AGET	Assured Green End Time
AGP	Assured Green Period
API	Application Programming Interface
ASN.1	Abstract Syntax Notation One
ATMS	Advanced Traffic Management System
ATSPM	Automated Traffic Signal Performance Measures
BSM	Basic Safety Message
C-V2X	Cellular V2X
CDOT	Colorado Department of Transportation
CI	Connected Intersection
CIMMS	Connected Intersection Message Monitoring System
CIPT	Connected Intersection Preferential Treatment
ConOps	Concept of Operations
CSW	Curve Speed Warning
CTI	Connected Transportation Interoperability
CTW	Connecting the West
CV	Connected Vehicle
CVAZ	Connected Vehicle Acceleration Zone
CV PFS	Connected Vehicle Pooled Fund Study
DHCP	Dynamic Host Configuration Protocol
DMV	Department of Motor Vehicles
DNS	Domain Name System
DOT	Department of Transportation
FHWA	Federal Highway Administration
GM	General Motors
HMI	Human Machine Interface
Hz	Hertz
I-215	Interstate 215
I-25	Interstate 25
I-70	Interstate 70
ICMP	Internet Control Message Protocol
IP	Internet Protocol
ISS	Integrity Security Services
ITIS	International Traveler Information System
ITS	Intelligent Transportation System
LiDAR	Light Detection and Ranging
MAP	Map Data Message

ngTMDD	Next Generation Traffic Management Data Dictionary
NTCIP	National Transportation Communications for Intelligent Transportation Systems Protocol
OBP	On-Board Processor
OBU	On-Board Unit
ODE	Operational Data Environment
OEM	Original Equipment Manufacturer
OER	Octet Encoding Rules
ORDP	Operational Demonstration Readiness Plan
ORP	Operational Readiness Plan
PCAP	Packet Capture
RLVW	Red Light Violation Warning
RPU	Remote Processing Unit
RSE	Roadside Equipment
RSU	Roadside Unit
RTCM	Radio Technical Commission for Maritime Services
RTM	Requirements Traceability Matrix
RWIS	Road Weather Information System
SAE	SAE International
SCM	Signal Command Module
SCMS	Security Credential Management System
SDD	System Design Document
SDSM	Sensor Data Sharing Message
SDX	Situation Data Exchange
SI	Signalized Intersection
SNMP	Simple Network Management Protocol
SPaT	Signal Phase and Timing
SRM	Signal Request Message
SSID	Service Set Identifier
SSM	Signal Status Message
STP	System Test Plan
STRS	System Test Results Summary
SWIW	Spot Weather Impact Warning
SyRS	System Requirements Specification
TIM	Traveler Information Message
TLS	Transport Layer Security
TMC	Traffic Management Center
TOC	Traffic Operations Center
TRUST	Transforming Roads: Unleashing Smart Technologies

TSC	Traffic Signal Controller
TSP	Transit Signal Priority
UDOT	Utah Department of Transportation
UI	User Interface
UPER	Unaligned Packet-Enabling Code
USDOT	United States Department of Transportation
UTA	Utah Transit Authority
UTC	Coordinated Universal Time
V2X	Vehicle-to-Everything
V2X MMS	Vehicle-to-Everything Maintenance and Management System
VRU	Vulnerable Road User
VSL	Variable Speed Limit
WYDOT	Wyoming Department of Transportation

1 Introduction

This document is the Operational Readiness Plan (ORP) for the Connecting the West (CTW) Program. The CTW Program is part of the United States Department of Transportation's (USDOT)'s Saving Lives with Connectivity: Accelerating Vehicle-to-Everything (V2X) Deployment grant program (often referred to as the V2X Accelerator program) aiming to showcase interoperable, large-scale V2X benefits to drive Original Equipment Manufacturer (OEM) investment. The CTW Program is led by Utah Department of Transportation (UDOT) with partners Wyoming Department of Transportation (WYDOT) and Colorado Department of Transportation (CDOT). The CTW efforts will also include local agencies within each state, some of which will be partners in the process and others as participants. This ORP is a key step in deployment for the CTW Program.

1.1 Document Purpose

The ORP was created for the CTW Program and provides an overview of both a comprehensive set of tests and supporting demonstrations that together establish operational readiness. When testing is completed satisfactorily and demonstrations are suitably successful, the deployment will be considered ready to move into the operational phase.

Testing will be used to verify that the system performs according to requirements that are documented in the CTW System Requirements Specification (SyRS) document. Nine tests are documented in the System Test Plan (STP) section of this ORP. The STPs focus on testing the ability for existing system expansion and testing interoperability; any existing processes and procedures are not included in the STP (i.e. any test procedures as a normal deployment process for deploying new RSUs). As such, the focus for the nine STPs relate to full system testing to ensure that all CTW requirements in the SyRS are met.

Demonstrations will show that the system performs as expected in key use cases and scenarios and are documented in the Operational Readiness Demonstration Plan (ORDP) section of this ORP. Demonstrations differ from tests in that they exhibit a set of selected end-to-end system capabilities central to the deployment concept of operations. Select demonstrations will be conducted as a live, real-time activity where success and failure are directly observable.

1.2 Document Overview

This ORP contains the following sections:

- Section 2: System Test Plan (STP)
- Section 3: Operational Demonstration Readiness Plan (ORDP)
- Section 4: Responsibilities
- Section 5: Schedule
- Section 6: Approvals

- Section 7: Risks and Contingencies
- Section 8: Requirements Traceability Matrix (RTM)

2 System Test Plan (STP)

This System Test Plan (STP) portion of the ORP provides details about the Test Plans, test cases, and test procedures the CTW team developed to verify the CTW system performs according to documented the CTW SyRS.

The CTW Program expands upon existing systems for the states (Colorado, Utah, Wyoming) and establishes interoperability of existing systems. The STP and corresponding SyRS thus focus on testing the ability for existing system expansion and testing interoperability—any existing processes and procedures in place at the existing states are not included in the STP (i.e., any test procedures as a normal deployment process for deploying new RSUs). Thus, while various unit/component and integration testing activities will occur before and after device installation to ensure functionality, the focus for the nine STPs described below primarily relate to full system testing to ensure that all CTW SyRS are met.

The remainder of this STP section includes sections on test identifiers, verifications methods, and test documentation, which describes nine STPs that will verify each CTW SyRS.

2.1 Test Identifiers

The CTW test identifiers follow the format:

STP-X: <Test Description>

Where:

X is a required sequentially increasing number, starting at “1” and represents the System Test Plan number.

Within each STP, there are multiple test cases that are numbered as Test Case X-Y, where:

X represents the STP.

Y represents the test case number within that STP.

The nine STPs with associated test cases are:

- STP-1: Central System Create and Exchange Event Reports.
 - o Test Case 1-1: Test Central Systems Generation of Next Generation Traffic Management Data Dictionary (ngTMDD) Event Reports.
 - o Test Case 1-2: Send ngTMDD Event Reports to the Situation Data Exchange (SDX).
 - o Test Case 1-3: Central Systems Consume ngTMDD Event Feeds from the SDX.

- STP-2: Central Systems Support Traveler Information Message (TIM) Exchanges.
 - o Test Case 2-1: Test Central Systems Generation of TIMs.
 - o Test Case 2-2: Send TIMs to the SDX.
 - o Test Case 2-3: Confirm receipt of each TIM at the SDX.
 - o Test Case 2-4: Sending Updates to TIMs.
 - o Test Case 2-5: Expire TIMs.
 - o Test Case 2-6: Receive and Process J2735 Messages at Central Systems.
 - o Test Case 2-7: Central System Retrieval of TIMs from Other CTW States.
- STP-3: Central Systems Create and Disseminate TIMs.
 - o Test Case 3-1: Test Central Systems Ingest BSM Data from Newly Deployed Roadside Units (RSUs).
 - o Test Case 3-2: Create Curve Speed Warning (CSW) Messages Near Newly Deployed RSUs.
 - o Test Case 3-3: Configure Central Systems to Generate TIMs for Downstream Road Conditions, Statewide Coverage, and Adjacent State Events.
 - o Test Case 3-4: Third-Party Systems Are Able to Access and Use TIMs Made Available through the SDX.
- STP-4: Central Systems Support Data Storage.
 - o Test Case 4-1: Validate Central System Data Storage of Basic Safety Message (BSM) Data for Expanded CTW Sites.
 - o Test Case 4-2: Validate Central System Data Storage of TIM Data for Expanded CTW Sites.
 - o Test Case 4-3: Validate Central System Data Storage of Signal Request Message (SRM)/Signal Status Message (SSM) Data for Expanded CTW Connected Intersections (CIs) Supporting Connected Intersection Preferential Treatment (CIPT).
 - o Test Case 4-4: Validate Central System Data Storage of Persistent CI Message Data for Expanded CTW CIs (Map Data Message [MAP], Signal Phase and Timing [SPaT]).
 - o Test Case 4-5: Validate UDOT Central System Data Storage of Sensor Data Sharing Message (SDSM) Data for Expanded CTW CIs with Vulnerable Road User (VRU) Safety Systems.
- STP-5: Central Systems Monitor Field Equipment Health.
 - o Test Case 5-1: Validate Central System Monitoring for Expanded CI Sites.
 - o Test Case 5-2: Validate Central System Monitoring for Expanded Connected Roadway Sites.
 - o Test Case 5-3: Validate Central System Monitoring Detects Offline RSU.
- STP-6: Field Equipment Compatibility.
 - o Test Case 6-1: Field Equipment Compatibility – Receipt of J2735, Connected Transportation Interoperability (CTI)-4501, and SAE International (SAE) J3224 compliant messages with interoperable Security Credential Management System (SCMS) signatures.

- o Test Case 6-2: Field Equipment Compatibility – Sending J2735-Compliant Messages With Interoperable SCMS Signatures.
- o Test Case 6-3: Field Equipment Compatibility – Expanded Connected Roadway Sites Interoperable with Legacy Central Systems.
- STP-7: Field Equipment Deployment Locations.
 - o Test Case 7-1: Field Equipment Deployment Locations – Expansion Sites Support Transit, Snowplow, and Emergency Vehicle Use.
 - o Test Case 7-2: Field Equipment Deployment Locations – Connected Roadway Sites to Address Needs.
- STP-8: SCMS Top-Off Without Cellular Communications.
 - o Test Case 8-1: SCMS Top-Off Without Cellular Communications.
 - o Test Case 8-2: Verify RSU Receipt and Security Validation of Post-Top-Off Signed Messages.
- STP-9: Vehicle System Compatibility.
 - o Test Case 9-1: Vehicle Systems Receive and Process Messages in SAE J2735 Versions.
 - o Test Case 9-2: Vehicle Systems Generate and Transmit Messages in a Supported J2735 Version and Are Interoperable to Legacy Systems.
 - o Test Case 9-3: Cross-State Message Handling.

2.2 Verification Methods

The following verification methods are used to verify the CTW SyRS. Refer to Section 8 where each Requirement is mapped to each Verification Method.

- **Inspection:** A verification through a visual comparison (e.g., inspecting the location where Field Equipment are deployed to determine if they are along transit routes).
- **Demonstration:** A requirement that the system can demonstrate without external test equipment (e.g., a Central System demonstrating that event reports are created).
- **Analysis:** A requirement that is met indirectly through a logical conclusion or mathematical analysis of a result (e.g., comparing the timestamp of message creation and receipt by another system or analyzing the pedestrian crash rate at an intersection compared to the statewide average crash rate per intersection).
- **Test:** A requirement that requires some external piece of test equipment (e.g., an on-board unit (OBU) to receive messages).

2.3 Test Documentation

This section describes the test documentation and artifacts that will be produced and where those test artifacts will be stored. This includes Test Plans and testing results.

2.3.1 Test Plans

This section includes the test plans that will be used to verify and validate the functioning CTW system. Each Test Plan is described using the same Test Plan template that includes sections describing the STP and its objective, requirements verified, setup and configuration, detailed test cases, and specific test procedures.

2.3.1.1 Test Plan STP-1: Central System Create and Exchange Event Reports

Brief Description:

All CTW Central Systems will generate fully formatted (ngTMDD) event reports. The events that are sent to the SDX will be sent within 1 minute of creation. Central Systems must verify the SDX has confirmed receipt of the event report and continue attempting to send the event until receipt is confirmed. Updated events must be sent to the SDX within 1 minute of the change of the event. Central Systems shall be capable of receiving and sending ngTMDD event reports to/from the SDX to ensure consistent and interoperable event reports are exchanged.

Test Plan STP-1 will test that all CTW Central Systems generate event reports as fully formatted ngTMDD messages. Note: This STP will not test whether the event reports accurately describe the events (i.e., these are details related to each state's event reporting processes), only that any event reports that are generated are fully formatted and are communicated, as required.

STP-1 will also test that the event reports generated, along with any updates and expirations, are shared with the SDX within 1 minute of their creation or modification. The SDX will confirm receipt of the reports and make the reports available for Central Systems to retrieve. Finally, STP-1 will test that CTW Central Systems consume event reports from the SDX that are within the geographic area defined for each Central System.

As described below, the test will involve the following test cases:

- **Test Case 1-1: Test Central Systems Generation of ngTMDD Event Reports.** This test case will verify the ability of each CTW state to create 10 different event reports in accordance with the ngTMDD event specifications.
- **Test Case 1-2: Send ngTMDD Event Reports to the SDX.** This test case will verify that each CTW Central System is capable of sending the 10 ngTMDD events created in Test Case 1-1 to the SDX system for distribution to other CTW states to consume.
- **Test Case 1-3: Central Systems Consume ngTMDD Event Feeds from the SDX.** This test case will verify that each CTW Central System is capable of connecting to the SDX and consuming ngTMDD messages in the geographic area defined by each Central System.

Test Objective:

The objective of STP-1 is to verify that Central Systems can create and send ngTMDD messages from the CTW Central System and that the events are consumed by other states. CTW states need systems that can exchange reports for events happening near the borders so that systems can coordinate messaging as well as responses to events that impact roadways and drivers throughout all three CTW states. Test objectives include:

- Verify a consistent approach to creating and exchanging event reports that describe Traffic Management Center (TMC) and ground events (such as road closures, weather events, and road construction) among CTW states using the SDX.
- Verify that each state's Central System generates event reports using state-defined methods and source data.
- Identify and verify the content and frequency of reports generated by each CTW Central System.
- Verify that all CTW Central Systems event reports follow the CTW Program-agreed structure.
- Verify that event reports are shared with the SDX from the Central System within 1 minute of their creation.
- Verify that updated reports are shared with the SDX within 1 minute of modification.
- Verify that report expirations are shared with the SDX within 1 minute of expiration.
- Verify that CTW Central Systems obtain reports from the SDX within the defined frequency (less than 1 minute).

Requirements to be Verified:

The CTW System Requirements to be verified by STP-1 are:

- CS-1.1 Event report content. Central Systems shall create event reports that describe current roadway conditions or activities on the road that are expected to impact drivers. Final decisions on thresholds will be at each state's discretion.
- CS-1.2 Event report sources. Central Systems in each CTW state shall acquire data or other content from local sources to generate event reports.
- CS-1.3 Event report timing. Central Systems shall acquire and process local data and content to create or update event reports at a frequency that is determined by each state and may vary based on the type of event.
- CS-1.4 Event report structure. Central Systems shall create event reports that follow the CTW agreed-upon structure developed during the design process.
- CS-2.1 Timing of Interstate event exchange. Central Systems shall initiate the process to send event reports to the SDX within 1 minute of the event report being created.
- CS-2.2 Confirmation of Interstate event exchange. Central Systems shall continue the process of attempting to send event reports to the SDX until the event exchange is confirmed.
- CS-3.1 Share updates of events. Central Systems shall send event report updates to the SDX within 1 minute after the event is updated, following the same process as the initial send.
- CS-3.2 Share expiration of events. Central Systems shall send event report expirations of events with the SDX within 1 minute after the event is determined to be expired.
- CS-15.1 Frequency of acquiring Event Reports from SDX. Central Systems shall acquire event reports from the SDX at a frequency defined locally by each CTW state.
- CS-15.2 Parameters of Event Report queries from SDX. Central Systems shall query the SDX for event reports within a geographic boundary set by the Central Systems and defined locally by each CTW state.

Test Location(s):

- Utah Testing: UDOT Central System and SDX production environment
- Colorado Testing: CDOT Central System and SDX production environment
- Wyoming Testing: WYDOT Central System and SDX production environment

Test Duration:

The duration of STP-1 is shown in Table 1 below and anticipated as follows:

- Test setup and configuration: Approximately 1 day per test case (can be performed simultaneously).
- Test data collection period: 1 day per test case (can be performed simultaneously).
- Data analysis and results documentation: Approximately 3 days per test case following completion of the data collection period (can be performed simultaneously).

Additional time may be required depending upon test failure remediation measures, estimated as follows:

- Additional 1–3 days if one or more minor issues are identified in the results of the original test case.
- Additional 3–5 days if significant issues are identified in the results of the original test case.

Table 1: Estimated Duration to Conduct STP-1

Source: CTW Team, April 2026

Test Case	Setup	Data Generation/ Collection	Analysis	Total Estimated Days	Reserved for Remediation and Testing
Test Case 1-1	1 day	1 day	3 days	5 days	3-5 days
Test Case 1-2	1 day	1 day	3 days	5 days	3-5 days
Test Case 1-3	1 day	1 day	3 days	5 days	3-5 days

Prerequisite Test Setup and Configuration:

The prerequisites needed to execute STP-1 are as follows:

- Central System in each CTW state fully operational.
- SDX fully operational, and each state's CTW connection to the SDX operational.
- Timing and performance verification:
 - o Implement monitoring to measure time between:
 - Event detection and report creation.
 - Report creation and SDX receipt.
 - Report update and SDX receipt.
 - Report expiration and SDX receipt.

- o Validate that all transmissions occur within 1 minute.
- Content and format validation:
 - o Validate that all reports conform to the CTW-defined structure (ngTMDD event structure), as defined in the CTW System Design Document (SDD) Chapter 9.
 - o Confirm required fields are populated.
 - o Confirm updates and expirations maintain required structure.
- End-to-end verification:
 - o Confirm Central Systems receive acknowledgment from the SDX.
 - o Verify the SDX makes reports available for retrieval by subscribing Central Systems.
 - o Confirm Central Systems retrieve reports at $\leq$ 1-minute intervals.

2.3.1.1.1 Test Cases (Including Procedures, Data, Anticipated Results, and Test Failure Remediation Approach)

2.3.1.1.1.1 Test Case 1-1: Test Central Systems Generation of ngTMDD Event Reports

Summary of Test Case 1-1:

Test Case 1-1 will require each CTW state (Wyoming, Utah, and Colorado) to independently select 10 event types that are expected to be commonly generated during normal operations (e.g., road closures, lane restrictions, weather events, construction, incidents, special events, and maintenance activities).

Each CTW state will use its Central System to generate 10 fully formatted ngTMDD event reports from local event data sources (i.e., 10 different events per state). Each event report generated must comply with the ngTMDD Event schema and data exchange specifications.

Assets to be used to complete Test Case 1-1 will include:

- UDOT, CDOT, and WYDOT Central Systems (event creation modules and data ingestion pipelines).
- Local data feeds (e.g., Advanced Traffic Management System [ATMS], Road Weather Information System [RWIS], maintenance systems, etc.) if automated event reporting is conducted.

General description of roles:

- Central Systems generate ngTMDD event reports automatically or through operator input.
- Test observers verify content, structure, and timestamps.

Anticipated Results of Test Case 1-1:

- Central Systems generate ngTMDD event reports correctly according to the ngTMDD schema.
- Each event report includes ngTMDD event message values for at least the following fields: event ID, event type (International Traveler Information System [ITIS] codes), location, effective time, and expiration time.

- Event reports accurately reflect the event information as provided by the source data feeds configured at each of the state Central Systems.

Test Case 1-1 Test Procedures:

The steps and procedures that will be followed to complete the test procedures for Test Case 1-1 include:

1. Within each CTW state, use the Central System user interface (UI) to manually create at least 10 ngTMDD event reports representing different event types (i.e., containing information to generate 10 different types of TIMs as defined by the CTW Program effort). Alternatively, CTW states can observe 10 automatically created ngTMDD event reports from live or simulated data feeds (e.g., ATMS, RWIS, and maintenance management system).
2. Note the time that each event report was created.
3. Validate the generated ngTMDD message structure matches the ngTMDD specification and all required fields (identified in the Anticipated Results of Test Case 1-1 information above) are populated.

Test Case 1-1 Test Data:

- ngTMDD event reports generated at Central Systems, with creation time recorded (manually or automatically).

Test Case 1-1 Measurement/Verification Method:

- Visual demonstration of each Central System that show ngTMDD event reports are created in the system.
- Inspection of logs of each Central System (if available).
- Visual comparison of the data in the event report messages against ngTMDD specification. Additionally, the SDX will reject any messages not conforming to the correct ngTMDD format.
- Comparison of event storage in the Central System timestamp to message creation timestamp.

Test Case 1-1 Pass/Fail Criteria:

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

Each CTW state's Central System must pass, and may do so independently.

The test passes if the Central System for each CTW state successfully performs the following:

- Generates 10 ngTMDD event reports from manual entry or automatically using local event data.
- Each event report conforms to the ngTMDD schema.
- Required fields (as defined in the CTW SDD - Chapter 9) are populated and formatted correctly.

Fail Criteria: The test fails when:

- Any of the 10 event reports are missing.

- Messages are incomplete or missing required fields.
- Messages are rejected by the SDX because they do not conform to ngTMDD schema. The SDX will automatically reject messages not conforming to the ngTMDD; therefore, schema validation tools are not required for this testing.

Test Case 1-1 Test Failure Remediation:

- Remediation of a partial failure if one or more event reports are not generated:
 - o Examine Central System event creation capabilities.
 - o Validate data feed configuration.
 - o Review event trigger thresholds (if automated event creation was anticipated).
- Remediation of a partial failure if one or more event reports are incomplete:
 - o Verify mapping logic between source data and ngTMDD fields.
 - o Confirm required fields are properly configured.
- Remediation if event reports do not meet ngTMDD schema:
 - o Validate schema version alignment.
 - o Correct transformation logic.
 - o Re-run schema validation.

After identifying and resolving issues, repeat testing as indicated above.

2.3.1.1.1.2 Test Case 1-2: Send ngTMDD Event Reports to the SDX

Summary of Test Case 1-2:

Each CTW Central System will send the 10 ngTMDD event reports created in Test Case 1-1 to the SDX within 1 minute of their creation. These events shall include locations near interstate borders to enable consumption testing by neighboring states.

Examples:

- Wyoming events along I-80 near the Utah border (within 50 miles) for Utah consumption.
- Utah events along Interstate 70 (I-70) (within 50 miles) for Colorado consumption.
- Colorado events along Interstate 25 (I-25) (within 50 miles) for Wyoming consumption.

Assets to be used to complete Test Case 1-2 will include:

- UDOT, CDOT, and WYDOT Central Systems (to send event reports created in Test Case 1-1 to the SDX).
- SDX production environment.

General description of roles:

- Central Systems send event reports automatically to the SDX within 1 minute of creation.

- Test observers verify delivery of event reports.

Anticipated Results of Test Case 1-2:

- Each ngTMDD event report is received by the SDX within 1 minute of creation and the SDX returns confirmation (HTTP 200 or defined acknowledgment).

Test Case 1-2 Test Procedures:

The steps and procedures that will be followed to complete the test procedures for Test Case 1-2 include:

1. Within each CTW state, Test Case 1-1 is completed, and it is verified that the ngTMDD event reports are created in/by the Central System.
2. There should be no additional manual interaction required. The Central System will send the event report to the SDX within 1 minute of the event report creation.
3. If the Central System encounters an error sending the event report, it will continue attempts to send the event report until successful.
4. Manual observation and recording of the SDX data and logs to confirm the timestamp of when the event report was received by the SDX.

Test Case 1-2 Test Data:

- Test Case 1-1 outcome of ngTMDD event reports generated at Central Systems, with creation time recorded (manually or automatically).
- ngTMDD event reports received successfully by the SDX, with timestamps of when messages were received.

Test Case 1-2 Measurement/Verification Method:

- Visual inspection of the SDX interface to determine if event reports were received.
- Inspection of each state's Central System logs to verify that event reports were sent to the SDX.
- Inspection of SDX ingestion logs to verify that event reports were received.
- Compare event creation timestamp to the SDX receipt timestamp.

Test Case 1-2 Pass/Fail Criteria:

Each CTW state must pass and may do so independently.

Pass Criteria:

The test passes if:

- All 10 ngTMDD event reports per state are sent to the SDX.
- SDX confirms receipt of each message.
- SDX receipt occurs within 1 minute of each event creation.

Fail Criteria:

The test is considered a failure if:

- Any ngTMDD event report is not received by the SDX.
- SDX receipt occurs later than 1 minute after event creation.
- No acknowledgment is returned to the sending Central System.

Test Case 1-2 Test Failure Remediation:

If messages from any CTW state are not received:

- Examine Central System transmission logs for the state's Central System.
- Verify endpoint configuration.
- Confirm SDX ingestion service availability.

If message delivery to the SDX exceeds 1 minute from any CTW state:

- Analyze network latency.
- Inspect queuing or batching configurations.
- Validate SDX processing time.
- Inspect Central System logs to determine latency issue.

After identifying and resolving issues, repeat tests as indicated above.

2.3.1.1.1.3 Test Case 1-3: Central Systems Consume ngTMDD Event Feeds from the SDX

Summary of Test Case 1-3:

In Test Case 1-1, ngTMDD event reports will have been created by each CTW Central System. In Test Case 1-2, each CTW Central System will have sent the event reports to the SDX. Test Case 1-3 will involve the CTW Central Systems pulling/consuming event reports from the SDX that are within the geographic area defined for each Central System. For example, the Utah Central System will connect to the SDX and consume all event reports in their geographic boundary of interest, including those event reports uploaded by Wyoming and Colorado Central Systems.

By executing Test Case 1-3, this consumption of event reports will be successfully demonstrated.

Testing will occur while events transmitted in Test Case 1-2 remain active.

Assets to be used to complete Test Case 1-3 will include:

- UDOT, CDOT, and WYDOT Central Systems (to consume event reports from the SDX that were shared to the SDX in Test Case 1-2).
- SDX production environment.

General description of roles:

- Event reports created in Test Case 1-1 and shared in Test Case 1-2 will be in the SDX.
- Central Systems will automatically connect to the SDX at locally defined time intervals and consume all event reports with locations defined that are within the defined subscription boundary for the consuming Central System.
- Test observers verify that the Central Systems download event reports from the SDX.
- Test observers verify that the Central Systems do not download event reports describing events outside the subscription area.

Expected Results of Test Case 1-3:

- Central Systems retrieve interstate ngTMDD event reports within 1 minute of the SDX publishing them.
- Retrieved messages maintain schema integrity.
- Events are displayed or stored correctly within the Central System.
- Only events in the defined area are ingested and processed.

Test Case 1-3 Test Procedures:

1. Each CTW state will configure Central Systems to subscribe to the SDX, including subscription boundaries of interest to consume SDX messages.
2. CTW Central Systems will automatically connect to the SDX at locally defined time intervals and consume any messages in the subscription boundary.
3. Demonstrate visibility of these events in each state's Central System interface.
4. Demonstrate that available events outside of the subscription boundary are not ingested.

Test Case 1-3 Test Data:

- Test Case 1-2 outcome of ngTMDD event reports received successfully by the SDX, with timestamps of when messages were received.
- ngTMDD event reports received successfully in Test Case 1-3 by Utah, Colorado, and Wyoming Central Systems, with timestamps of when messages were received.
- Confirmation that the event reports received are accessible for users of the Central Systems (i.e., the event reports are in the Central System and can be viewed by users of the Central System).

Test Case 1-3 Measurement/Verification Method:

- Inspection of Central System ingestion logs.
- Comparison of SDX published timestamp to Central System receipt timestamp.
- Visual demonstration of event display in Central System UI.
- Comparison of SDX publish timestamp to Central System receipt timestamp.
- Visual demonstration of event display in Central System UI.

Test Case 1-3 Pass/Fail Criteria:

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

Each CTW state must pass and may do so independently. The test passes if:

- The Central System retrieves all applicable ngTMDD event reports within its subscription boundary.
- Retrieval frequency is no greater than the time configured by each state's system.
- Events outside the boundary are not consumed.

Fail Criteria: Test fails when:

- Interstate event reports are not retrieved.
- Retrieval frequency exceeds the configured timeframe set in the state's Central System for event ingest.
- Messages are corrupted or rejected by the consuming Central System.

Test Case 1-3 Test Failure Remediation:

If events are not retrieved:

- Confirm subscription boundaries are configured correctly.
- Verify SDX topic configuration.
- Inspect polling or streaming configuration.

If ingestion fails:

- Validate schema compatibility.
- Confirm parser configuration.
- Review error logs for message rejection causes.

If delays exceed the configured time period:

- Inspect SDX Kafka feed configuration.
- Validate streaming consumer settings.
- Review network and SDX performance.

After identifying and resolving issues, repeat testing as indicated above.

2.3.1.2 Test Plan STP-2: Central Systems Support TIM Exchanges

Brief Description:

Test Plan STP-2 will test that the CTW Central Systems in each state generate several different TIMs and subsequently send those TIMs to the SDX and retrieving TIMs from the SDX when appropriate. STP-2 will involve the following:

- The creation of three different TIMs by each CTW Central System. This will test the ability to create the different TIMs in accordance with the TIM interoperability decisions.
- The sending, updating, and expiring of the TIMs created in each state to the SDX. Since the SDX is a live system, the TIMs selected to be sent to the SDX will be "benign" TIMs (e.g., those that if received by a traveler would not cause any unnecessary diversions such as a CSW) and in locations that do not impact heavy traffic. These TIMs sent to the SDX will also be updated and expired quickly so as to minimize the exposure of these "test TIMs."
- Each CTW Central System receiving TIMs from the SDX that were sent to the SDX from other states for the geographic area of interest (i.e., Utah Central System retrieving TIM created by Colorado for an area in Colorado near the Utah border).

All CTW Central Systems will generate fully formatted ASN.1 UPER-Abstract Syntax Notation One (ASN.1) Unaligned Packed Encoding Rules (UPER)-encoded TIMs. The TIMs that are sent to the SDX will be sent within 1 minute of creation. Central Systems must continue sending each TIM until the SDX confirms receipt. Updates to TIMs and TIM expirations must also be sent to the SDX within 1 minute of the change. Central Systems shall be capable of receiving and sending J2735 messages over cellular V2X (C-V2X) communications in the 2016, 2020, and 2024 versions.

Additional TIM testing is performed in STP-3; therefore, extensive TIM testing is not planned in this STP.

Test Objective:

The objective of STP-2 is to verify the ability of Central Systems to send and receive TIMs messages. All CTW states and drivers (i.e., system end-users) require systems to be deployed and operated in a consistent, interoperable, and secure manner to ensure trust. The system must be trusted by third parties to be used and to provide information to end-users. To evaluate the success of this communication, STP-2 objectives are to:

- Verify that all Central Systems are creating fully formatted ASN.1 UPER-encoded TIMs that conform to the agreed upon CTW TIM format.
- Verify that all Central Systems are sending TIMs to the SDX within 1 minute after creating fully formatted ASN.1 UPER-encoded TIMs.
- Verify that SDX is receiving the sent TIMs and that Central Systems continue sending TIMs until receipt is confirmed.
- Verify that updates to TIMs are sent to the SDX within 1 minute after the TIM is updated, following the same process as the initial TIM sent.
- Verify that TIM expirations are sent to the SDX within 1 minute after the TIM expiration is determined by the Central System, following the same process as the initial TIM send.

- Verify that Central Systems can receive and correctly process J2735 messages in all required versions (2016, 2020, and 2024).
- Verify that Central Systems can generate and send J2735 messages over C-V2X communications according to the specified versions (2016, 2020, and 2024).

Requirements to be Verified:

The CTW System Requirements to be verified by STP-2 are:

- CS-4.1 Timing of TIM exchanges. Central Systems shall send TIMs to the SDX within 1 minute after the fully-formed, ASN.1 UPER-encoded TIM is generated.
- CS-4.2 Confirmation of TIM exchanges. Central Systems shall continue the process of sending TIMs to the SDX until the TIM exchange is confirmed.
- CS-5 Update TIMs in SDX. Central Systems shall send updated TIMs to the SDX within 1 minute after the TIM is updated, following the same process the initial TIM sent.
- CS-6 Expire TIMs in SDX. Central Systems shall send TIM expirations to the SDX within 1 minute after the TIM expiration is determined by the Central System, following the same process as when sending the initial TIM.
- CS-7.1 Central Systems receive J2735 messages. Central Systems shall be capable of receiving and processing messages as defined in J2735 standards in all of the following versions: 2016, 2020, and 2024.
- CS-7.2 Central Systems send J2735 messages. Central Systems shall generate all messages to be exchanged using C-V2X communications as defined by J2735 according to one of the following versions: 2016, 2020, or 2024.

Test Location:

- Utah Testing: UDOT Traffic Operations Center (TOC) and SDX
- Colorado Testing: CDOT and SDX
- WYDOT Testing: WYDOT and SDX

Test Duration:

The duration of STP-2 is shown in Table 2 below and anticipated as follows:

- Testing is planned to be completed in 2 days, 8 hours per day to complete the seven test cases outlined below.
- Additional time may be required for testing, estimated as follows:
 - o Additional 1–4 days: If one or more minor issues are identified in one or more CTW states, the CTW team may require time to troubleshoot, reconfigure systems to mitigate the issues, and begin testing again.
 - o Additional 4–10 days: If significant issues are identified in one or more CTW states, the CTW Program will require time to troubleshoot, mitigate the issues, and begin testing again.

Table 2: Estimated Duration to Conduct STP-2*Source: CTW Team, April 2026*

Test Case	Setup	Data Generation/ Collection	Analysis	Total Estimated Days	Reserved for Remediation and Retesting
Test Case 2-1	1 day	2 days	3 days	6 days	4-10 days
Test Case 2-2	1 day	2 days	3 days	6 days	4-10 days
Test Case 2-3	1 day	2 days	3 days	6 days	4-10 days
Test Case 2-4	1 day	2 days	3 days	6 days	4-10 days
Test Case 2-5	1 day	2 days	3 days	6 days	4-10 days
Test Case 2-6	1 day	2 days	3 days	6 days	4-10 days
Test Case 2-7	1 day	2 days	3 days	6 days	4-10 days

Prerequisite Test Setup and Configuration:

The prerequisites needed to execute the test procedures are as follows:

- Central System in each CTW state is fully operational.
- SDX fully operational, and each state CTW connection to the SDX is operational:
 - o Note that a Beta version of the SDX will be used for testing TIMs that are more invasive, such as road closures. Otherwise, the live SDX will be used for testing.
- Timing and performance verification:
 - o Implement monitoring to measure the time between TIM creation/update/expiration at Central Systems and receipt at the SDX.
- End-to-end interoperability verification:
 - o Confirm that Central Systems receive acknowledgment from SDX for each TIM and update.

Ensure all exchanges are secure, interoperable, and trusted by third-party systems.

2.3.1.2.1 Test Cases (Including Procedures, Data, Anticipated Results, and Test Failure Remediation Approach)

2.3.1.2.1.1 Test Case 2-1: Test Central Systems Generation of TIMs

Summary of Test Case 2-1:

Each CTW state will create three TIMs they feel will be common TIMs expected to be created during normal operations of the CTW Program. These TIMs will be those that are included in the TIM Interoperability document. Each TIM generated must comply with one of the required J2735 versions (2016, 2020, or 2024).

Assets to be used to complete Test Case 2-1 will include:

- Central Systems (TIM creation, communications to the SDX).
- SDX.

General description of roles:

- Test team will manually create TIMs.
- Test team will monitor Central Systems to observe when TIMs are created.

Anticipated Results of Test Case 2-1:

- Central Systems generate TIMs correctly in ASN.1 UPER format. Every TIM generated adheres to one of the J2735 versions (2016, 2020, or 2024).

Test Case 2-1 Test Procedures:

The approach to generating TIMs to complete this testing is described as follows:

- Each CTW state will create three TIMs using one or both of the following procedures:
 - o **Mandatory Procedure:** Within each CTW state, use the Central System UI to manually create a TIM. Testers will note the time that each TIM was created using the Coordinated Universal Time (UTC) format HH:MM:SS to a level of precision of whole seconds.
 - o **Optional Procedure:** Within each CTW state, observe an automatically created TIM (e.g., a Spot Weather Impact Warning [SWIW] TIM created based on input from the ATMS or other data source). Observe the TIM automatically being created without operator input. Testers will note the time that each TIM was created.
- The locations of two of the TIMs created should be in areas that the other CTW states will subscribe to. As such, the other CTW states will receive those TIMs from the SDX to best represent real-world application. The other TIM will be in an area of the state that the other two CTW states have not subscribed to test that the other CTW states do not retrieve these from the SDX. The location areas are summarized in Table 3.
 - o Wyoming TIMs will be in areas near the Utah border to allow demonstration of Utah's Central System downloading these TIMs from the SDX.
 - o Colorado TIMs will be in areas along I-25 to allow demonstration of Wyoming's Central System downloading these TIMs from the SDX.
 - o Utah's TIMs will be in areas along I-70 to allow demonstration of Colorado's Central System downloading these TIMs from the SDX.

Table 3: Summary of TIM Location Areas*Source: CTW Team, April 2026*

TIM Number	Utah	Wyoming	Colorado	Expected Outcome
TIM #1	I-80, < 10 miles from the Wyoming border	I-80, < 10 miles from the Utah border	I-25, < 10 miles from the Wyoming border	Retrieved from the SDX by other CTW sites
TIM #2	I-70 < 10 miles from the Colorado border	I-25 < 10 miles from the Colorado border	I-70 < 10 miles from UT border	Retrieved from the SDX by other CTW sites
TIM #3	Within the Salt Lake City metro area	Within the Cheyenne metro area	Within Denver metro area	Not retrieved from the SDX by other CTW sites

Test Case 2-1 Test Data:

- Three TIMs created by each CTW state's Central System (nine total).
- Capture of data in supporting systems that was used to automatically generate TIMs (if automatically generated).

Test Case 2-1 Measurement/Verification Method:

- Visual demonstration of each CTW state's Central System interface logs and database to determine if the three TIMs are created and stored in the Central System.
- Inspection of logs to verify TIMs are created.

Test Case 2-1 Pass/Fail Criteria:

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

Each CTW state's Central System may pass this test independently of other states (e.g., Colorado may pass while Utah does not pass). Only states that do not pass will require retesting.

The functionality test passes if the Central System for each CTW state successfully performs the following:

- Generates three TIM.;
- Generates each TIM as a fully formatted ASN.1 UPER-encoded J2735 TIM (version 2016, 2020, or 2024).

Fail Criteria:

The test case fails if any of the three TIMs attempted to be created are missing or do not follow one of the J2735 required versions. The SDX includes a built-in message validation tool to identify these errors.

Test Case 2-1 Failure Remediation:

- If one or more TIMs are not generated or are missing:
 - o Examine Central System capabilities for generating TIMs.
 - o Change input parameters used to generate TIMs to see if this corrects the problem and to understand why it has failed
 - o Examine the input data/message sources contributing to TIM generation to identify which TIM has issues generating.
- If one of more of the TIMs is incomplete:
 - o Check Central System procedures to ensure configuration supports full TIM creation.
 - o Examine the input data/message sources contributing to TIM generation.
- If one or more TIMs are not ASN.1 UPER encoded:
 - o Examine Central System process and/or configurations for encoding.
- If TIM does not meet one of the J2735 Standards:
 - o Examine Central System configurations for creating TIMs according to standards.
- After identifying and resolving issues, repeat tests as indicated above.

2.3.1.2.1.2 Test Case 2-2: Send TIMs to the SDX

Summary of Test Case 2-2:

The Central Systems in each CTW state will send TIMs created for Test Case 2-1 to the SDX within 1 minute of their creation.

Assets to be used to complete Test Case 2.2:

- Central Systems in each CTW state.
- SDX.

General description of roles:

- No manual intervention is required for Test Case 2-2. The TIMs created in Test Case 2-1 will be sent automatically to the SDX by the Central Systems in each state.

Anticipated Results of Test Case 2-2:

- Each TIM that is created in each Central System is received by the SDX within 1 minute of creation.

Test Case 2-2 Test Procedures:

1. Once TIMs are created as part of Test Case 2-1, without manual intervention, the Central Systems in each CTW state will send the TIMs created for Test Case 2-1 to the SDX within 1 minute of their creation.
2. Test participants will verify that TIMs were sent by examining Central System logs of data exchanges and the SDX logs of messages received.

Test Case 2-2 Test Data:

- CTW Central System logs of messages exchanged.
- SDX database and exchange log.

Test Case 2-2 Measurement/Verification Method:

- Visual demonstration, inspection of logs of the Central System and SDX.
- Measurement of time between TIM creation and SDX receipt; verification of timestamps in Coordinated Universal Time (UTC) format of HH:MM:SS for hours, minutes, and seconds.

Test Case 2-2 Pass/Fail Criteria:

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

Each CTW state's Central System may pass this test independently of other states (e.g., Colorado may pass while Utah does not pass). Only states that do not pass will require retesting. The functionality of the SDX to receive TIMs is required for any state to pass. Individual Central System testing will pass if the following occur and are observed:

- All three TIMs created by the Utah Central System as part of this STP are sent to the SDX and the SDX confirms receipt within 3 seconds from the SDX Application Programming Interface (API) call.
- All three TIMs created by the Colorado Central System as part of this STP are sent to the SDX and the SDX confirms receipt within 3 seconds from the SDX API call.
- All three TIMs created by the Wyoming Central System as part of this STP are sent to the SDX and the SDX confirms receipt within 3 seconds from the SDX API call.

Test passes if each TIM is received by the SDX within 1 minute of being created.

Fail Criteria:

- Test fails when any TIMs created in Test Case 2-1 are not received by SDX within 1 minute.

Test Case 2-2 Failure Remediation:

- If the test fails because one or more TIMs are not received by the SDX:
 - o Examine logs of Central Systems to confirm that TIMs were sent.

- o Example functionality of the SDX to ensure there is nothing preventing TIMs from being received from CTW sites.
- If one of more of the TIMs are received but the time from TIM creation to receipt by the SDX exceeds 1 minute:
 - o Examine communication logs to determine where excessive delays are occurring and seek solutions to these delays.
 - o Test the CTW Central System communications and validate that other communications are occurring within expected time periods.
 - o Check to ensure that the SDX hosting and communications is not introducing delay due to external impacts such as network congestion or hardware limitations.
- After identifying and resolving issues, repeat tests as indicated above.

2.3.1.2.1.3 Test Case 2-3: Confirm Receipt of Each TIM at the SDX

Summary of Test Case 2-3:

A core functionality of the SDX is to confirm receipt of TIMs. This provides validation to the CTW Central Systems that the TIMs were received. If receipt is not confirmed, CTW Central Systems are required to continue sending the TIMs until receipt is confirmed. This confirmation of receipt avoids unnecessary resending of TIMs. This procedure will inspect the SDX to confirm that it acknowledges receipt and that confirmation is sent to the CTW Central System that sent the TIM.

This procedure will be conducted in association with Test Case 2-2. Each time a CTW Central System sends a TIM to the SDX, data logs will be reviewed to verify that confirmation of receiving the TIM was delivered from the SDX to the appropriate CTW Central System.

Assets to be used to complete Test Case 2-3 will include:

- Central Systems in each CTW state.
- SDX.

General description of roles:

- No manual intervention is required for Test Case 2-3. The TIMs sent to the SDX in Test Case 2-2 will be used for the CTW test team to observe and validate that the SDX sends confirmation that the messages were received.

Anticipated Results of Test Case 2-3:

The SDX acknowledges receipt of each TIM by delivering a notice of confirmation to the CTW Central System that sent the TIM. Confirmations are observed by inspection of logs.

Test Case 2-3 Test Procedures:

The steps and procedures that will be followed include:

1. Once TIMs are sent to the SDX in Test Case 2-2, without manual intervention, the SDX will send a confirmation to the CTW Central System that sent the message.

2. Members of the test team will inspect the logs of both the SDX and the Central System to confirm that the confirmation was sent by the SDX and received by the Central System.

Test Case 2-3 Test Data:

- CTW Central System logs.
- SDX database and exchange log.

Test Case 2-3 Measurement/Verification Method:

- Visual demonstration, inspection of logs of the Central System to determine if confirmation was received, and SDX logs to determine if confirmation was sent.

Test Case 2-3 Pass/Fail Criteria:

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

This test passes if the SDX acknowledges the receipt of each of the TIMs sent to it by the Central Systems within 3 seconds of the SDX API call.

Fail Criteria: Test fails if one or more of the TIMs does not result in the SDX delivering a notice of receipt.

Test Case 2-3 Test Fail Remediation:

- If delivery of one or more TIMs occurs without the appropriate CTW Central System receiving a notice of receipt within 3 seconds of the SDX API call:
 - o Examine logs of SDX to confirm if the notice of receipt was sent and resolve if not.
 - o Examine the CTW Central System to ensure that notifications are being received and not blocked or omitted.
- After identifying and resolving issues, repeat tests as indicated above.

2.3.1.2.1.4 Test Case 2-4: Sending Updates to TIMs

Summary of Test Case 2-4:

Each of the TIMs created in Test Case 2-1 will be updated during this test case. Updates may extend the location, change the ITIS phrases used, or other changes. Once updated, this test case will test that the updated TIMs are sent from the Central Systems in each state to the SDX. This test will also test that the Central Systems continue sending TIMs until confirmation is received by the SDX.

Test Case 2-4 is expected to be performed in parallel with Test Case 2-2 and 2-3, where the TIMs created and sent to the SDX are updated.

Assets to be used to complete Test Case 2-1 will include:

- Central Systems (TIM update, communications to SDX).
- SDX.

General description of roles:

- Test team will manually update TIMs as needed.
- Test team will monitor the SDX and query the logs to confirm when the updated TIMs were received.

Anticipated Results of Test Case 2-4:

- Updated TIMs are received by SDX within 1 minute of the update.
- Central Systems continue sending TIMs until receipt confirmation is received.

Test Case 2-4 Test Procedures:

The steps and procedures that will be followed to complete the test procedures for Test Case 2-4 include:

1. In each CTW state, testers will update the three TIMs shared to the SDX during Test Case 2-2 above. Updates to the TIMs will include as a minimum:
 - a. Changing the valid location.
 - b. Changing the ITIS codes included (e.g., adding and/or removing ITIS codes).
2. After updating the TIMs, CTW states will send the updated TIM to the SDX and confirm receipt and update of the TIM on SDX.

Test Case 2-4 Test Data:

- CTW Central System logs of messages exchanged.
- SDX database and exchange log.

Test Case 2-4 Measurement/Verification Method:

- Visual demonstration and inspection of logs of the Central System and SDX.
- Measurement of time between TIM creation and SDX receipt; verification of timestamps.
- Validation that all Central Systems continued sending TIMs until receipt was confirmed.

Test Case 2-4 Pass/Fail Criteria:

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

Each CTW state's Central System may pass this test independently of other states (e.g., Colorado may pass while Utah does not pass). Only states that do not pass will require retesting. The functionality of SDX to receive and send confirmation of updated TIMs is required for any state to pass. Individual Central System testing will pass if the following occur and are observed:

- All three TIMs updated in the Utah Central System as part of this STP are sent to the SDX within 1 minute of the update and the SDX confirms receipt within 3 seconds from the SDX API call.
- All three TIMs updated in the Colorado Central System as part of this STP are sent to the SDX within 1 minute of the update and the SDX confirms receipt within 3 seconds from the SDX API call.

- All three TIMs updated in the Wyoming Central System as part of this STP are sent to the SDX within 1 minute of the update and the SDX confirms receipt within 3 seconds from the SDX API call.
- The SDX will pass when it successfully receives the nine TIM updates from the CTW Central Systems and updates the TIMs in the SDX.

Fail Criteria:

Test fails for individual states when any of the 3 TIM updates sent are not received by SDX within 1 minute or if the SDX does not send a confirmation of the receipt of the TIM.

Test Case 2-4 Test Failure Remediation:

- If one or more TIM updates are not received by the SDX:
 - o Examine functionality of the appropriate Central System to determine if updated TIMs are being generated correctly.
 - o Examine functionality of the appropriate Central System to confirm that updates are being pushed to the SDX by verifying version number...
- If one of more of the TIM updates are not received by the SDX within the one-minute time window:
 - o Examine logs to confirm that TIM is configured to send within one minute from the update.
 - o Examine communication logs in SDX to determine where excessive delays are occurring and seek solutions to these delays.
 - o Test the CTW communications and understand if other communications are occurring within expected time periods and the delay is isolated to TIM updates. Use this outcome to search for additional solutions.
- After identifying and resolving issues, repeat tests as indicated above.

2.3.1.2.1.5 Test Case 2-5: Expire TIMs

Summary of Test Case 2-5:

Each of the nine TIMs (three per state) updated in Test Case 2-4 will be expired during this procedure to test that the expiration of a TIM removes it not only from the Central System but also that the expiration is communicated to the SDX so as the TIM is also removed from the SDX.

Assets to be used to complete Test Case 2-5 will include:

- Central Systems (TIM expire, communications to SDX).
- SDX (removal of TIM when expiration is received).

General description of roles:

- Test team will manually expire the TIMs.
- Test team will monitor the SDX and query the logs to confirm when the expired TIMs were expired in the SDX and removed.

Anticipated Results of Test Case 2-5:

- TIMs are expired and removed from active TIMs in each Central System.
- SDX receives expiration messages within 1 minute of each TIM being expired and removes it from the SDX.

Test Case 2-5 Test Procedures:

1. The three TIMs updated in Test Case 2-4 will expire, using one or both of the following procedures:
 - a. **Mandatory Action:** Within each CTW state, the Central System UI can be used to manually expire a TIM (i.e., TIM is no longer active). When expired, each CTW Central System sends expiration notifications to the SDX. Testers will then note the time that each TIM was expired manually.
 - b. **Optional/Automated Action:** Within each CTW state, observe an automatically created TIM (e.g., a SWIW TIM created based on input from the ATMS or other data source). Observe the TIM expire automatically because the conditions no longer exist. In addition to automatically expiring the TIM, each CTW Central System sends expiration notifications to the SDX. Testers will note the time that each TIM was expired and time it was removed from the SDX.
2. Members of the test team will examine logs of the Central System and SDX to confirm that the expirations of TIMs were sent within 1 minute of them being expired and that the SDX has removed the TIMs and sent confirmation back to the Central System.

Test Case 2-5 Test Data:

- CTW Central System logs of messages exchanged.
- SDX database and exchange log.

Test Case 2-5 Measurement/Verification Method:

- Visual demonstration and inspection of logs of the Central System and SDX.
- Measurement of time between TIM expiration and SDX receipt.
- Measurement of time between SDX receipt and send of confirmation.
- Measurement of time between SDX receipt and the removal of the TIM from the SDX.

Test Case 2-5 Pass/Fail Criteria:

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

Each CTW state's Central System may pass this test independently of other states (e.g., Colorado may pass while Utah does not pass). Only states that do not pass will require retesting. The functionality of SDX to receive expirations of TIMs and remove TIMs is required for any state to pass. Individual Central System testing will pass if the following occur and are observed:

- All three TIMs created and shared to the SDX by the Utah Central System in Test Case 2-4 are expired at the expected time (i.e., either upon manual expiration or are expired automatically as conditions change).
- All three TIMs created and shared to the SDX by the Colorado Central System in Test Case 2-4 are expired at the expected time (i.e., either upon manual expiration or are expired automatically as conditions change).
- All three TIMs created and shared to the SDX by the Wyoming Central System in Test Case 2-4 are expired at the expected time (i.e., either upon manual expiration or are expired automatically as conditions change).
- The SDX will pass when it successfully receives the nine TIM expirations from the CTW Central Systems and removes the nine TIMs from the SDX.

Fail Criteria:

Test fails when any of the following occur:

- Utah: Any one of the three TIMs created and shared by the UDOT Vehicle-to-Everything Maintenance and Management System (V2X MMS) are not expired by the Central System.
- Colorado: Any one of the three TIMs created and shared by the CDOT V2X MMS are not expired by the Central System.
- Wyoming: Any one of the three TIMs created and shared by the WYDOT V2X MMS are not expired by the Central System.
- Any one of the nine expirations are not received by the SDX and the TIMs removed.

Test Case 2-5 Failure Remediation:

- If one or more TIM do not expire as expected in the Central System:
 - Examine the appropriate Central System and adjust as needed.
- If one of more of the TIM expirations do not result in the SDX receiving the expiration and removing the TIM:
 - Examine logs of appropriate Central System to confirm that the TIM expiration was sent. Adjust as needed if TIM expirations are not being sent.
 - Examine the SDX to determine if the Central Systems are sending a proper TIM update to expire the TIM. Adjust the appropriate Central System as needed.
 - Examine the SDX to determine if TIMs are being removed when expirations are received. Adjust as appropriate.
- After identifying and resolving issues, repeat tests as indicated above.

2.3.1.2.1.6 Test Case 2-6: Receive and Process J2735 Messages at Central Systems

Summary of Test Case 2-6:

Test Case 2-6 will test whether the CTW Central Systems in each state can receive and process the appropriate J2735 messages in all required versions (2016, 2020, and 2024). This is not a procedure to

test only the interface to the SDX but also to ensure that Central Systems are able to process J2735 messages that are received in other ways, such as through RSUs receiving BSMs. For compatibility purposes, CTW Program requirements require OBUs and RSUs to broadcast J2735 messages in at least one of the required J2735 versions, but Central Systems must be able to receive and process all versions.

Assets to be used to complete Test Case 2-6 will include:

- CTW Central Systems.
- SDX.
- RSU.

General description of roles:

- Enable SDX to send TIMs to each Central System.
- Enable RSUs to forward BSMs in as many J2735 versions as are operational.

Anticipated Results of Test Case 2-6:

- Central Systems correctly request, receive, and process incoming J2735 messages for all message versions that are supported by current field and Vehicle Systems. The TIMs will be received from the SDX, while the BSMs will be received from the RSUs.

Test Case 2-6 Test Procedures:

For this test case, the following procedures will be performed:

1. At least three J2735 BSMs will be created in each of the required J2735 versions (total of nine BSMs).
2. A least three J2735 TIMs will be created in each of the required J2735 versions (total of nine TIMs).
3. Discuss with the CTW team what additional J2735 messages will be received by the Central Systems and need to demonstrate various versions.
4. These J2735 messages will be communicated to each CTW state's Central System, and the ability of each system to receive and process these messages will be revealed.

Test Case 2-6 Test Data:

- Record of TIMs and BSMs sent to the Central Systems.
- Data logs of Central Systems showing message exchanges and message storage.

Test Case 2-6 Measurement/Verification Method:

- Record the time of TIM and BSM data sent to Central Systems.
- Visual demonstration and inspection of logs of the Central System to confirm if messages sent were received.
- Inspection to determine that Central System databases properly stored messages.

Test Case 2-6 Pass/Fail Criteria:

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

Each CTW state's Central System may pass this test independently of other states (e.g., Colorado may pass while Utah does not pass). Only states that do not pass will require retesting. The functionality of the Central System receiving and processing J2735 TIMs is required for any state to pass. Individual Central System testing will pass if the following occur and are observed:

- Test passes if the Central System in Utah correctly processes incoming J2735 messages for all supported versions.
- Test passes if the Central System in Colorado correctly processes incoming J2735 messages for all supported versions.
- Test passes if the Central System in Wyoming correctly processes incoming J2735 messages for all supported versions.

Fail Criteria:

Test fails when messages are not processed correctly or are discarded.

Test Case 2-6 Failure Remediation:

- If one or more J2735 messages are not received and stored properly:
 - o Determine the version of the J2735 standard for the message that was not received and stored. Examine the Central System configurations to ensure they are configured properly to receive and store messages using this version of J2738.
 - o Examine the messages that are generated and sent to confirm they adhere to the J2738 standard. If not, repeat test with valid J2735 messages.
- After identifying and resolving issues, repeat tests as indicated above.

2.3.1.2.1.7 Test Case 2-7: Central System Retrieval of TIMs from Other CTW States

Summary of Test Case 2-7:

Test Case 2-7 will test whether the CTW Central Systems in each state receive and process the appropriate TIMs from the SDX in all J2735 versions according to the Traveler Information Message (TIM) Documentation Version 1.0 developed by the CTW program team. In Test Case 2-1, at least three of the TIMs sent by each state were located in fringe areas with other CTW states. These are the TIMs that will be within the query area that the other Central Systems use when querying messages from the SDX. Therefore, the nine TIMs (three per state) will be received by other CTW state Central Systems.

Assets to be used to complete Test Case 2-7 will include:

- CTW Central Systems.
- SDX.

General description of roles:

- Inspect Central Systems after Test Case 2-2 (i.e., where TIMs were sent to the SDX) to confirm that each CTW state Central System has TIMs created in other CTW states.

Anticipated Results of Test Case 2-7:

- Central Systems correctly request, receive, and process TIMs from the SDX that are within the geographic boundary they subscribe to in the SDX.
- Observers logged in and viewing Central Systems in each state are able to view TIMs from neighboring CTW states.

Test Case 2-7 Test Procedure:

Note: Prior to executing Test Case 2-7, each CTW Central System will be configured to connect to the SDX and request active TIMs for the geographic area of interest. For example, Utah may subscribe to the geographic area of Wyoming along the northern border of Utah. Also, Utah may subscribe to the geographical area of I-70 in Colorado.

Test Case 2-2 described each CTW state's Central System generating and sending TIMs to the SDX for these "fringe" areas to support this procedure.

Activities in Test Case 2-7 will occur following Test Case 2-2, while the events shared to the SDX are still active and before they are expired. Activities will include:

1. Central Systems in each state will be configured to retrieve TIMs from the SDX for selected areas in other CTW states (e.g., Utah V2X MMS expected to be configured to retrieve TIMs for portions of the I-80 corridor in proximity of 100 miles of Utah).
2. After Wyoming has demonstrated the generation and sharing of TIMs to the SDX, observers in Utah will check the Utah Central System to assess if the system has received the TIMs that Wyoming has created and are within the geographic area that Utah subscribed to in the SDX.
3. After Utah has demonstrated the generation and sharing of TIMs to the SDX, observers in Colorado will check the Colorado Central System to assess if the system has received the TIMs that Utah has created and are within the geographic area that Colorado subscribed to in the SDX.
4. After Colorado has demonstrated the generation and sharing of TIMs to the SDX, observers in Wyoming will check the Wyoming Central System to assess if the system has received the TIMs that Colorado has created and are within the geographic area that Wyoming subscribed to in the SDX.

Test Case 2-7 Test Data:

- TIMs stored in each CTW state Central System that were created in other states.

Test Case 2-7 Measurement/Verification Method:

- Inspection of logs of each CTW state Central System to confirm that the TIMs created in fringe areas of other states were received successfully.

Test Case 2-7 Pass/Fail Criteria:

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

Each CTW state's Central System may pass this test independently of other states (e.g., Colorado may pass while Utah does not pass). Only states that do not pass will require retesting. The functionality of the Central System retrieving TIMs that are generated by the other two CTW states is required for any state to pass. Individual Central System testing will pass if the following occur and are observed:

- Test passes in Utah if the UDOT V2X MMS downloads and ingests all TIMs created in the area of interest that UDOT has configured their V2X MMS to retrieve TIMs for (i.e., some from WYDOT and some from CDOT).
- Test passes in WYDOT if the WYDOT ODE downloads and ingests all TIMs created in the area of interest that WYDOT has configured their ODE to retrieve TIMs for (i.e., some from UDOT and some from CDOT).
- Test passes in CDOT if the CDOT ODE downloads and ingests all TIMs created in the area of interest that CDOT has configured their ODE to retrieve TIMs for (i.e., some from UDOT and some from WYDOT).

Fail Criteria:

Test fails if any TIMs created in areas that CTW systems are configured to retrieve from the SDX and the TIMs are not retrieved.

Test Case 2-7 Failure Remediation:

- If one or more TIMs in the defined boundary area of the SDX that the Central System is querying are not retrieved:
 - o Check to ensure that the TIMs created are within the query area. Adjust if needed and retest.
 - o Work with Trihydro to ensure that the query area is properly defined and the Central System in pulling messages in the area desired. Work with Trihydro to adjust the query area, as needed.
 - o Examine the Central System functionality to retrieve messages from the SDX and make any needed adjustments.
- After identifying and resolving issues, repeat tests as indicated above.

2.3.1.3 Test Plan STP-3: Central Systems Create and Disseminate TIMs

Brief Description:

Test Plan STP-3 verifies that CTW Central Systems (UDOT, CDOT, and WYDOT) can expand their capabilities to create and disseminate TIMs that reflect downstream, statewide, and adjacent-state roadway conditions. The test validates that TIMs are structured according to CTW Program-adopted guidance included in Traveler Information Message (TIM) Documentation Version 1.0, developed by the CTW program team, are transmitted to and retrieved from the SDX within required timing thresholds and

distributed to RSUs for appropriate rebroadcast. It also confirms interoperability across state systems, SDX, RSUs, OBUs, and third-party traveler information platforms while maintaining message integrity, security, and performance under increased TIM volumes. This test will involve the following.

- The creation of three different CSW messages for roadway curves near deployed RSUs.
- The creation and distribution to new and existing RSUs and the SDX of 10 different situational awareness TIMs to describe downstream roadway conditions. This will test that the TIM conforms to the CTW-adopted guidance and that the correct RSU is always identified for broadcasting these messages and new RSUs are correctly broadcasting TIMs.
- The creation of 10 event reports that originate from adjacent states and prompt the creation of related TIMs that are distributed to RSUs and the SDX.
- The consumption of active TIMs within a user-defined geographic boundary and the redistribution of 10 relevant TIMs to bordering state RSUs. Test that redistributed TIMs remain intact (no loss of content or format) when transferred from one state's system through SDX to another state's RSUs.

All CTW Central Systems will generate fully formatted (J2735) TIM messages that comply with the CTW TIM standards. The TIMs that are sent to RSUs and the SDX will be sent within 1 minute of creation. Central Systems must verify both RSUs and the SDX have confirmed receipt of the TIM and continue attempting to send the TIM until receipt is confirmed. Updated TIMs must be sent to the SDX within 1 minute of the change of the TIM. Central Systems shall be capable of receiving and sending TIM messages to ensure consistent and interoperable messages are exchanged.

Test Objective:

The CTW states need systems that can generate and distribute TIMs as well as consume TIMs reports for events happening near the borders. This will provide system connectivity to coordinate and distribute messaging about events and conditions that impact roadways and drivers throughout all three CTW states. This test will:

- Confirm that Central Systems can ingest BSM data from new RSUs deployed in the project and that the data is properly processed, including any available BSM part 2 data. This will then be stored for use in downstream functions.
- Validate that CSW messages are generated not only for existing coverage areas but also for roadway curves near the newly deployed RSUs.
- Ensure that TIMs are created to describe downstream roadway conditions relative to expansion RSUs and that the correct RSU is always identified for broadcasting these messages.
- Assess whether Central Systems can generate TIMs describing statewide roadway conditions and confirm that these TIMs are consistently shared through the SDX.
- Verify that TIMs and event information originating from adjacent states are considered and, when appropriate, transformed into TIMs that inform travelers approaching those state boundaries.
- Confirm that all TIMs meet the CTW Program-adopted guidance for structure, content, and best practices, including message clarity, consistency, and accuracy.
- Verify the accuracy of the newly created TIMs.

- Confirm that event reports received from other CTW states result in the timely creation of appropriate TIMs.
- Verify that Central Systems can query the SDX for active TIMs within a user-defined geographic boundary and that results are accurate and complete
- Validate that Central Systems can retrieve TIMs from SDX at different frequencies (as configured locally) and that no messages are missed.
- Check whether TIMs acquired from the SDX can be distributed to RSUs for rebroadcast when the valid geographic region of the TIM is within a configured upstream distance of an adjacent states RSU.
- Ensure that distributed TIMs remain intact (no loss of content or format) when transferred from one state's system through the SDX to another state's RSUs.
- Confirm that timing requirements are met for all TIM exchanges, including creation, update, expiration, and rebroadcast, with no delays beyond 1 minute.
- Validate end-to-end interoperability across states, RSUs, SDX, and third-party traveler information systems to ensure consistent traveler messaging.
- Confirm that security requirements are preserved when exchanging TIMs, ensuring data integrity and trustworthiness.

Requirements to be Verified:

The CTW System Requirements verified by this test procedure are:

- CS-8 Expand ingest of SWIW-related data. Central Systems shall be capable of receiving, processing, and storing BSMS received from additional RSUs deployed in the CTW project.
- CS-9 Expand locations supported by CSW messages. Central Systems shall increase creation of CSW messages to include messages for curves near expansion RSUs.
- CS-10.1 Expand TIM locations to include additional RSU locations. Central Systems shall create TIMs, when appropriate, that describe conditions downstream of the additional RSUs added in this project and identify the appropriate RSU for broadcast. Determination of what is appropriate is to be defined by each state and is expected to vary by TIM.
- CS-10.2 Expand TIM locations to include all areas of the state. Central Systems shall create TIMs, when appropriate, that describe conditions anywhere in the state to be shared through the SDX. Determination of what is appropriate is to be defined by each state and is expected to vary by TIM.
- CS-10.3 Expand TIM locations to include other states. Central Systems shall consider TIMs and Event Reports received from adjacent states and create TIMs, when appropriate, that communicate the information to travelers heading in the direction of the adjacent states' events. Determination of what is appropriate is to be defined by each state and is expected to vary by TIM.
- CS-13 TIMs' adherence to documented best practices. Central Systems shall generate the content and structure of TIMs in a way that adheres to CTW-agreed TIM guidance and best practices documented in the design process.
- CS-14 SDX functionality. Existing SDX functions should be able to exchange the additional number of TIMs generated from expanded CTW locations.

- CS-16 Create TIMs based on other states' event reports. Central Systems should create TIMs based on the Event Reports received from other CTW states.
- CS-17.1 Location-based query of SDX TIMs. Central Systems may query the SDX for active TIMs within a geographic boundary set by the Central Systems and defined locally by each CTW state.
- CS-17.2 Acquire TIMs from other CTW states. Central Systems may acquire TIMs from the SDX at a frequency determined by each site.
- CS-18 Distribute TIMs received from other states. Central Systems may distribute TIMs that were acquired from the SDX to RSUs for broadcast if the TIM valid region is within a defined distance (to be defined individually by each state) downstream of the RSU location.

Test Locations:

- Utah Testing: UDOT Central System and SDX production environment
- Colorado Testing: CDOT Central System and SDX production environment
- Wyoming Testing: WYDOT Central System and SDX production environment

Test Duration:

The duration of test cases that make up STP-3 will vary based on the three tasks and the number of trials for success. The expected duration of each test case is provided in Table 4.

Table 4: Estimated Duration to Conduct STP-3

Source: CTW Team, April 2026

Test Case	Setup	Data Generation/Collection	Analysis	Total Estimated Days	Reserved for Remediation and Retesting
Test Case 3-1	1 working day	7 calendar days	2 working days	10 calendar days	3-7 working days
Test Case 3-2	1 working day	7 calendar days	2 working days	10 calendar days	3-7 working days
Test Case 3-3	1 working day	7 calendar days	2 working days	10 calendar days	3-7 working days
Test Case 3-4	1 working day	7 calendar days	2 working days	10 calendar days	3-7 working days

Prerequisite Test Setup and Configuration:

- Central System configuration for testing:
 - o Ensure logging captures:
 - TIM creation timestamp.
 - Transmission timestamp.
 - SDX receipt confirmation timestamp.

- TIM retrieval timestamp.
- SDX configuration:
 - o Enable SDX logging of receipt timestamps.
- Timing and performance verification:
 - o Implement monitoring to measure time between:
 - Event detection and TIM creation.
 - TIM creation and SDX receipt.
 - TIM update and SDX receipt.
 - TIM expiration and SDX receipt.

2.3.1.3.1 Test Cases (Including Procedures, Data, Anticipated Results, and Test Failure Remediation Approach)

2.3.1.3.1.1 Test Case 3-1: Test Central Systems Ingest BSM Data from Newly Deployed RSUs

Summary of Test Case 3-1:

Test Case 3-1 verifies that CTW Central Systems (UDOT and CDOT) can successfully ingest, process, validate, and store BSMS received from newly deployed RSUs as part of the project expansion.

The procedure will confirm that:

- BSM Part I and Part II data elements are received (when available).
- Messages conform to applicable SAE J2735 standards (2016, 2020, or 2024 as implemented).
- Messages are processed without loss or corruption.
- Messages are stored and made available for downstream functions (e.g., SWIW processing, analytics).
- Message ingestion occurs within acceptable latency thresholds of 1 second.

The test will include both live field transmission and controlled/simulated BSM transmission, if required.

Assets to be used to complete Test Case 3-1 will include:

- Newly deployed RSUs.
- OBUs on Utah transit vehicles.
- General Motors (GM) vehicle with capability to broadcast BSM Part II messages (although it is not known if all Part II messages will be included).
- OBUs on CDOT vehicles (or project team vehicles).
- Central Systems (ingestion services, storage modules).
- Network infrastructure (C-V2X backhaul).
- Log monitoring tools.

- J2735 validation tools (if available).

General description of roles:

- RSUs receive BSM broadcasts and forward messages to Central Systems.
- Central Systems ingest, validate, process, and store BSM data.
- Test observers monitor logs and validate message integrity.

Anticipated Results of Test Case 3-1:

- Central Systems successfully ingest BSM Part I and Part II messages (that are supported by the GM vehicle) from newly deployed RSUs.
- Messages conform to the configured SAE J2735 version (2016, 2020, or 2024 as implemented).
- Message receipt rate of a minimum of 95% under nominal operating conditions. Note that experience has shown that 100% performance is not always possible; 95% is used to enable some downtime.
- BSM ingestion latency (RSU to Central System receipt) does not exceed 1 second under normal network conditions.
- Messages are stored and accessible for downstream functions.
- Any malformed messages are properly logged and rejected.

Test Case 3-1 Test Procedures:

The steps and procedures that will be followed to complete the test procedures for Test Case 3-1 include within each applicable CTW state (UDOT and CDOT for newly deployed RSUs):

1. Drive an OBU-equipped vehicle broadcasting BSMS to pass by all newly deployed RSUs in Colorado and by all newly deployed RSUs on Interstates and Rural Corridors in Utah. The OBUs will broadcast BSMS. In Utah, this OBU-equipped vehicle will be the GM vehicle that is broadcasting BSM Part I and Part II messages (Note: It is not clear if all Part II elements will be included and any omission of Part II elements will not cause a failure of this test). The RSUs will receive BSMS. The RSUs will transmit BSMS to the Central System. Members of the test team will make note of the time the OBU equipped vehicle is driven past each RSU for comparison later.
2. For five locations in both Utah and Colorado, conduct a drive-by of the selected locations (slowing briefly if needed) and select a 30-second time when the OBU-equipped vehicle is within range of the RSU. Note that an in-range time of 30 seconds is the baseline, but may be as little as 20 seconds if there are geography or speed issues that limit the in-range drive-by time of an RSU.

Using the Central Systems in Colorado and Utah, check the BSMS received and communicated to the Central System during the 30 second time period. This number of BSMS should be 10/second (i.e., at least 285 BSMS during the 30 second window).

The five locations in Utah will be at CIs that do not have regular transit bus traffic and therefore are exposed to fewer OBUs than other CIs. They will be representative locations that are not contiguous to each other to achieve a spread of locations. The five locations in Colorado will be at newly deployed RSUs along I-70. The OBUs will broadcast BSMS. The RSUs will receive BSMS.

The RSUs will transmit BSMs to the Central System. Test team members will make note of the time the OBU-equipped vehicle is parked next to each RSU for comparison later.

3. The Utah test team will identify five transit vehicles driving their regular route while broadcasting BSMs during either the AM or PM peak period when high volumes of BSMs are expected from the overall fleet of equipped transit vehicles. Identify five intersections that each vehicle will cross to identify a time-window when the vehicle is expected to pass the intersections (estimated to be within range of each RSU for a minimum of 10 seconds) to generate a minimum of 100 BSMs per RSU.

The OBUs will broadcast BSMs. The RSUs will receive BSMs. The RSUs will transmit BSMs to the Central System. Members of the test team will make note of the locations of intersections identified.

The Utah test team will attempt to intentionally corrupt a BSM message (this is not something that has been done yet but will be attempted by the test team). This corrupted BSM will be broadcast to enable the test team to determine how the RSU and/or Central System react to reject or flag the message.

4. Record timestamps at:
 - a. BSM broadcast from OBU/test device.
 - b. Central System receipt from the RSU.
 - c. Central System processing/storage.
5. Inspect Central System logs and databases to confirm:
 - a. Messages are received.
 - b. Required fields are populated.
 - c. Malformed message(s) are rejected.
 - d. No corruption or truncation occurred.
 - e. Messages are stored for downstream processing.
 - f. The high-volume BSM traffic in Utah related to transit vehicles are stored appropriately and did not cause any ingestion issues.

Optional procedure:

- Introduce malformed or intentionally corrupted BSM messages to verify rejection handling and logging.

Test Case 3-1 Test Data:

- Central System ingestion logs.
- BSM data.

Test Case 3-1 Measurement/Verification Method:

- Inspection of Central System ingestion logs.
- Timestamp comparison (end-to-end latency measurement).

- Database validation of stored BSM data.
- Schema validation against SAE J2735 standard.

Test Case 3-1 Pass/Fail Criteria:

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

Each CTW state deploying new RSUs (Colorado and Utah) may pass independently.

The test passes if the Central System for each state successfully performs the following:

- Ingests at or above the required threshold of transmitted BSM Part I messages per RSU.
- Ingests all available BSM Part II messages (if supported).
- Processes and stores messages without corruption.
- 90% or greater of the new RSUs successfully forward at least 95% of all received BSMS to the Central System for processing.

Fail Criteria: Test fails when any of the following occur:

- BSM messages are not received by the Central System.
- Message loss exceeds acceptable threshold (greater than 5% under nominal conditions).
- Messages are corrupted or improperly parsed.
- Ingestion latency consistently exceeds 1 second.
- Part II data (when transmitted) is not processed or stored.
- 10% or more of the new RSUs fail to forward at least 95% of received BSMS to the backend Central System.
- Errors are not logged or reported.

Test Case 3-1 Test Failure Remediation:

If BSMS are not received:

- Verify RSU configuration and backhaul connectivity.
- Initiate a defined diagnosis and repair process for RSUs failing to receive or forward the expected BSM.
- Confirm correct endpoint configuration in Central System.
- Inspect firewall and network routing settings.

If message loss occurs:

- Analyze network bandwidth and packet loss.
- Review RSU buffering and forwarding configuration.

- Validate Central System ingestion throughput capacity.

If latency exceeds threshold:

- Examine network latency.
- Review queuing or batching mechanisms.
- Optimize ingestion service performance.

If parsing errors occur:

- Validate J2735 version compatibility.
- Review message decoding configuration.
- Confirm schema alignment.

If Part II data is missing:

- Confirm OBU/test device configuration.
- Verify RSU forwarding configuration supports Part II.

After identifying and resolving issues, repeat testing as indicated above.

2.3.1.3.1.2 Test Case 3-2: Create CSW Messages Near Newly Deployed RSUs

Summary of Test Case #2:

Test Case 3-2 will test that newly deployed RSUs at identified curve locations are properly configured to receive CSW TIMs from the Central System and broadcast CSW TIM messages in accordance with CTW Program requirements and applicable SAE J2735 standards.

The procedure validates:

- Proper configuration of Central Systems to generate CSW TIMs.
- Correct J2735 message encoding.
- Broadcast over C-V2X communications.
- Reception and decoding by OBUs or certified test receivers.
- Geographic accuracy and advisory speed accuracy.
- Secure transmission using valid certificates.

Testing will be conducted at a minimum of five field locations where new RSUs have been installed as part of the CTW Program. Selected locations will be where operational CSW TIMs are defined and the new RSUs are located upstream to broadcast the TIM to test vehicles with OBUs.

Assets to be used to complete Test Case 3-2 will include:

- Central Systems (Colorado and Utah).
- RSUs.

- OBUs.

General description of roles:

- CTW team members will create CSW TIMs in the Central System.
- Test team members will monitor Central Systems and RSUs to observe CSW TIM delivery to the RSU and RSU broadcast.
- Test team members will inspect logs to verify CSW TIMs are broadcast.

Anticipated Result of Test Case 3-2:

- CSW TIMs are successfully created and delivered to appropriate RSU.
- RSUs correctly broadcast the CSW TIM.
- OBUs correctly display the TIM upon entry into the CSW zone.

Test Case 3-2 Test Procedures:

The steps and procedures that will be followed to complete the test procedures for Test Case 3-2 include:

1. Deposit CSW TIM onto RSU:
 - a. Create and configure CSW TIM for a given curve downstream of the new RSU.
 - b. Deposit CSW TIM onto new RSU,
 - c. Verify the TIM is being broadcast via RSU forwarded messages and the OBU received message logs.
2. Validate message encoding and content:
 - a. Decode captured CSW TIM messages.
 - b. Verify:
 - i. Message type conforms to SAE J2735 Standards.
 - ii. Advisory speed matches configured value.
 - iii. Geographic reference matches configured curve location.
 - iv. Required fields are populated.
 - v. J2735 version matches configured standard.
 - vi. Verify message conforms to the CTW standards.
3. Verify vehicle reception:
 - a. Drive a vehicle equipped with an OBU through the RSU broadcast zone.
 - b. Capture OBU-received message logs for receipt of TIM message.
 - c. Confirm advisory speed and curve information are correctly decoded and displayed/logged.

Test Case 3-2 Test Data:

- RSU logs

- OBU logs

Test Case 3-2 Measurement/Verification Method:

- Inspection of RSU-forwarded broadcast messages.
- Broadcast frequency measurement from the RSU-forwarded broadcast messages.
- OBU received message log inspection.
- Visual confirmation of advisory display (if applicable).

Test Case 3-2 Pass/Fail Criteria:

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

Utah and Colorado may pass independently.

The test passes if:

- CSW TIM messages are correctly configured, generated, and broadcast from the selected set of newly deployed RSUs.
- Messages conform to SAE J2735 (correct version).
- Advisory speed and geographic information are accurate.
- OBUs/test receivers consistently receive and correctly decode messages.
- Secure transmission is verified.
- Configuration modifications behave as expected.

Fail Criteria:

Test fails when:

- The CSW TIM fails to deposit on an RSU.
- The RSU fails to broadcast the CSW TIM.
- The OBU receiving the TIM fails to display in the given CSW area.

Test Case 3-2 Failure Remediation:

If RSU is not broadcasting CSW TIM:

- Verify RSU is online.
- Confirm RSU has CSW TIM and is broadcasting.
- Verify Central System is capable of depositing CSW TIM onto new RSUs.

After identifying and resolving issues, repeat tests as indicated above.

2.3.1.3.1.3 Test Case 3-3: Configure Central Systems to Generate TIMs for Downstream Road Conditions, Statewide Coverage, and Adjacent State Events

Summary of Test Case #3:

Test Case 3-3 verifies that CTW Central Systems are properly configured to generate TIMs for:

- Downstream roadway conditions within the state.
- Statewide roadway coverage.
- Events occurring in adjacent CTW states.

The procedure validates that TIMs are:

- Generated based on configured geographic and operational rules.
- Encoded in accordance with applicable SAE J2735 standards (2016, 2020, or 2024).
- Properly structured per CTW TIM interoperability guidance.
- Generated for both local and interstate-relevant events.
- Distributed appropriately via SDX.

This test ensures that Central Systems support consistent, interoperable, and trusted TIM generation within the state boundaries.

Assets to be used to complete Test Case 3-3 will include:

- Central Systems (each CTW state+).
- RSUs.
- OBUs.
- SDX.

General description of roles:

- CTW team members will configure TIM creation in the Central Systems.
- Test team members will monitor Central Systems and RSUs to observe TIM creation and delivery to the RSU and RSU broadcast.
- Test team members will inspect logs to verify CSW TIMs are broadcast.

Anticipated Results of Test Case 3-3:

- Central Systems correctly generate TIMs for downstream road conditions.
- TIMs are generated across the full statewide network.
- Border and adjacent-state-relevant events result in properly configured and redistributed TIMs.
- TIMs conform to CTW format and SAE J2735 requirements.
- TIMs are encoded correctly and contain accurate geographic and advisory information.

- TIMs are transmitted to SDX within 1 minute.
- Updates and expirations are transmitted within 1 minute.
- Adjacent states can retrieve and interpret the TIMs as intended.

Test Case 3-3 Test Procedures:

The steps and procedures that will be followed to complete the test procedures for 3-3 include:

1. Trigger downstream road condition event:
 - a. Introduce or simulate 10 different roadway events (e.g., incident, weather event, closure) at disperse locations along routes that involve RSUs, including bordering locations near each of the corresponding CTW states.
 - b. Confirm the Central System generates the TIMs covering downstream roadway segments as configured in valid J2735 formats that also conform to the CTW TIM standards.
 - c. Confirm upstream RSUs receive associated TIMs.
 - d. Confirm SDX receives all generated TIMs.
 - e. Record timestamp of event detection and TIM generation.
2. Verify statewide TIM generation:
 - a. Introduce or simulate 10 events in geographically separate regions of the state that are not near RSUs.
 - b. Confirm the Central System generates TIMs regardless of region, consistent with statewide coverage configuration and distributes the TIM messages to the SDX.
 - c. Confirm the Central System generates the TIMs in valid J2735 formats that also conform to the CTW TIM standards.
3. Verify adjacent state event handling:
 - a. Simulate or activate an event near a state border or along an interstate corridor impacting adjacent CTW states.
 - b. Confirm adjacent State Central System queries the corresponding TIM from the SDX.
 - c. Confirm adjacent state Central System deposits TIM on relevant RSU near state border.
 - d. Verify that TIM content appropriately describes location, direction, and expected impact to cross-border travelers.
4. Validate TIM structure and encoding:
 - a. Capture generated TIM messages.
 - b. Decode messages using certified analyzer.
 - c. Verify:
 - i. TIM conforms to CTW Program-agreed format.
 - ii. ASN.1 UPER encoding is correct (if applicable).
 - iii. J2735 version matches configured standard.

- iv. Required ITIS codes and geographic references are present.
- v. Start time, duration, and advisory content are accurate.
- 5. Verify distribution to the SDX:
 - a. Confirm generated TIMs are transmitted to SDX within 1 minute of creation.
 - b. Verify receipt confirmation from the SDX.
 - c. Confirm TIMs are available for retrieval by other CTW states.
- 6. Modify and expire TIMs:
 - a. Update an active TIM (e.g., modify advisory or geographic coverage).
 - b. Confirm update is generated and transmitted within 1 minute.
 - c. Expire the TIM.
 - d. Confirm expiration message is transmitted and reflected in SDX.
 - e. Confirm Adjacent States update and expire related TIM.

Test Case 3-3 Test Data:

- TIM generation logs
- SDX logs
- Message packets

Test Case 3-3 Measurement/Verification Method:

- Inspection of Central System configuration interface.
- Review of event detection and TIM generation logs.
- Timestamp comparison (event, TIM creation, SDX receipt).
- Message capture and decode using certified analyzer.
- Inspection of SDX logs.
- Confirmation of retrieval by adjacent state systems.
- Inspection of SDX to confirm receipt of TIMs.

Test Case 3-3 Pass/Fail Criteria:

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

Adjacent states will need to coordinate this test. Tests will be run in state pairs including, Utah/Colorado, Utah/Wyoming, and Colorado/Wyoming.

The test passes if:

- Downstream, statewide, and adjacent-state TIM generation rules function as configured.

- All generated TIMs conform to CTW Program-defined structure.
- TIMs are encoded per applicable SAE J2735 version.
- Transmission to SDX occurs within 1 minute of creation, update, and expiration.
- Adjacent state systems successfully retrieve and redistribute relevant TIMs.

Fail Criteria: The test fails if any of the following occur:

- TIMs are not generated for downstream conditions.
- TIMs are not produced in all regions.
- Border or interstate-relevant TIMs fail to redistribute appropriate TIMs.
- TIM structure or encoding does not conform to CTW Program or J2735 standards.
- TIM transmission exceeds 1 minute.
- Updates or expirations are not transmitted correctly.
- Adjacent state systems cannot retrieve relevant TIMs.

Test Case 3-3 Test Failure Remediation:

- Review geographic boundary configuration.
- Validate downstream coverage logic and corridor definitions.
- Confirm ITIS coding and advisory configuration.
- Inspect J2735 version settings and encoding process.
- Verify SDX connectivity and acknowledgment handling.
- Adjust configuration rules and retest affected scenarios.

After identifying and resolving issues, repeat testing as indicated above.

2.3.1.3.1.4 Test Case 3-4: Third Party Systems Are Able to Access and Use TIMs Made Available Through the SDX

Summary of Test Case 3-4:

Test Case 3-4 will test that authorized third-party systems (verified by Waze access) can access and use TIMs made available through the SDX. The following will be validated:

- TIMs transmitted from CTW Central Systems to the SDX are accessible to authorized third parties (including Waze).
- TIMs conform to the CTW Program-defined format and applicable SAE J2735 standard versions (2016, 2020, or 2024).
- Third-party systems can retrieve TIMs at the defined frequency.
- TIMs can be decoded, interpreted, and integrated into third-party applications.
- Access control, security, and data integrity are maintained.

- Updates and expirations are correctly reflected in third-party systems.

This test ensures that TIM exchanges are handled in a consistent, interoperable, secure, and trusted manner for external users. Please note that multiple third-party platforms access the SDX but only Waze has a system that enables validation and receipt of messages.

Assets to be used to complete Test Case 3-4 will include:

- Central Systems (each CTW state).
- SDX – including logs documenting access by third parties.

General description of roles:

- Test team members will monitor Central Systems and SDX to observe TIM creation and delivery third parties through access to SDX logs.

Anticipated results of Test Case 3-4:

- TIMs generated by CTW Central Systems are transmitted to SDX and forwarded to Waze.
- Waze successfully ingests and displays (or logs) the event data.
- Event location and attributes match original TIM.
- Updates are reflected correctly.
- Expirations remove or deactivate events.
- Propagation timing is within 10 minutes.
- Secure transmission and authorized access are confirmed.

Test Case 3-4 Test Procedure:

The steps and procedures that will be followed to complete the test procedures for Test Case 3-4 include:

1. Confirm Waze for Cities data portal configuration:
 - a. Verify that the CTW Program (or participating state agency) has an active Waze for Cities partnership.
 - b. Confirm SDX-to-Waze data sharing integration is enabled (via API, feed, or approved data-sharing method).
 - c. Confirm proper credentials and endpoint configurations are active.
 - d. Verify Waze feed endpoint or submission portal is operational.
 - e. Confirm logging is enabled for outbound data to Waze.
2. Generate test TIMs in CTW Central System:
 - a. Generate at least 10 TIMs in a test corridor:
 - i. TIMs should be of a type that Waze consumes (e.g., lane closure, road closure, roadway hazard, etc.).

1. Note that these TIMs will have to be either live event feeds or harmless events that do not impact Waze routing algorithms, etc.
 - ii. Test should generate new TIMs, update these TIMs and then expire the same TIMs.
- b. Ensure TIMs:
 - i. Conform to CTW TIM format.
 - ii. Use correct J2735 version (2016, 2020, or 2024).
- c. Confirm TIMs are transmitted to SDX and receipt is acknowledged.
- d. Record timestamps for:
 - i. TIM creation.
 - ii. SDX receipt.
 - iii. SDX forwarding/publication to Waze integration feed.
3. Verify Waze receipt and ingestion:
 - a. Access the Waze for Cities Data Portal dashboard.
 - b. Confirm the relevant events appear in the Waze system.
 - c. Verify event attributes match TIM content:
 - i. Location accuracy.
 - ii. Advisory description.
 - iii. Event type.
 - iv. Duration.
 - d. Confirm updates are reflected appropriately.
 - e. Confirm expiration removes or deactivates the event.
 - f. If direct dashboard visibility is not available:
 - i. Obtain ingestion confirmation via Waze data logs or partner reporting tools.
 - ii. Confirm event appears in Waze traffic map (if publicly visible and applicable).
4. Validate timing of propagation:
 - a. Compare timestamps:
 - i. TIM creation, SDX receipt.
 - ii. SDX publication, Waze ingestion.
 - b. Confirm propagation occurs within 5 minutes to the Waze for Cities portal from the time of TIM creation/update/removal.
5. Validate data integrity and accuracy:
 - a. Compare original TIM content to what is reflected in Waze.
 - b. Confirm:
 - i. Location coordinates align with map placement.

- ii. Event type is properly interpreted.
- iii. No truncation or misclassification occurs.
- c. Confirm no duplicate or stale events remain after expiration.

Test Case 3-4 Test Data:

- SDX transmission logs.

Test Case 3-4 Measurement/Verification Method:

- SDX transmission logs.
- Timestamp comparison.
- Waze for Cities Data Portal dashboard inspection.
- Waze ingestion confirmation logs.
- Public Waze map verification (if applicable).

Test Case 3-4 Pass/Fail Criteria:

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

States will be able to run this test independently.

The test passes if:

- Waze receives TIM-derived event data from SDX.
- Event location and content match original TIM.
- Updates to TIMs are observed as updates on the Waze site. For example, the event type could be changed, and the event will need to show on Waze with the new event type.
- Expired events are no longer available on the Waze site.
- No data corruption is observed.
- Observed propagation timing is documented and within 5 minutes of TIM generation.

Fail Criteria:

The test fails if any of the following occur:

- Waze does not receive TIM data.
- Event location or attributes are incorrect.
- Updates are not reflected.
- Expired events remain active.
- Data corruption or truncation occurs.

- Feed interruption causes duplication or inconsistent state.

Test Case 3-4 Failure Remediation:

- Verify SDX-to-Waze endpoint configuration.
- Confirm API credentials and authentication.
- Validate TIM-to-Waze field mapping logic.
- Review geographic coordinate formatting.
- Inspect propagation logs within the SDX.
- Re-run test after corrective action.
- After identifying and resolving issues, repeat testing as indicated above.

2.3.1.4 Test Plan STP-4: Central Systems Support Data Storage

Brief Description:

STP-4 will evaluate the ability of each CTW state's Central System to scale existing resources to process and support additional deployed V2X devices and evaluate whether all messages being ingested to the Central System are stored. As new V2X equipment is installed, states will collect additional V2X messages from these sites and ingest them into their Central Systems. The systems must accommodate the resulting increases in data ingestion, storage, and computational demand while continuing to support both existing and newly deployed V2X services as part of the CTW Program. Test cases are identified by V2X message type to validate that Central Systems can provide extra capacity based on CTW state deployment updates.

To align with CTW deployments, testing is assigned by state as follows:

- UDOT: Executes test cases 4-1, 4-2, 4-3, 4-4, and 4-5.
- CDOT: Executes test cases 4-1 and 4-2.
- WYDOT: Executes test case 4-2.

At the conclusion of the data generation period, data analysis will be performed with the CTW state Central System to verify performance metrics in addition to data retention requirements.

The tests may be conducted simultaneously and should use routine data flows (where possible) so that tests represent normal operational capabilities.

Test Objective:

Ensure that the CTW Central Systems can scale to support additional V2X message storage as RSUs are deployed under the CTW Program.

- Verify that the Central Systems can reliably receive, process, and store V2X messages.
- Verify that sufficient capacity is provisioned to handle increased V2X message ingress from newly installed RSUs without performance degradation.

Requirements to be Verified:

The CTW System Requirements to be verified by conducting STP-4 include:

- CS-11.1 Support storage for additional BSM data. Central Systems shall provide capacity to store BSM messages collected by RSUs added by the CTW Program to meet the retention policies of each CTW state.
- CS-11.2 Support storage for additional TIMs. Central Systems shall provide capacity to store the additional TIMs created by the expanded functions in CTW, to meet the retention policies of each CTW state.
- CS-11.3 Support storage for additional SRMs and SSMs. Central Systems shall provide capacity to store the additional SRMs and SSMs created and exchanged for the expanded CIs supporting CIPT, to meet the retention policies of each CTW state.
- CS-11.4 Support storage for additional CI data. Central Systems shall provide capacity to store the additional SPaT, MAP, and Radio Technical Commission for Maritime Services (RTCM) messages and associated data created and exchanged for the expanded CIs, to meet the retention policies of the CTW state adding CIs.
- CS-11.5 Support storage for SDSM messages. Central Systems shall provide capacity to store the SDSM messages created and exchanged in support of the VRU Safety Systems added in Utah to meet the retention policies of the state of Utah.

Test Location:

- Utah Testing: UDOT Central System
- Colorado Testing: CDOT Central System
- Wyoming Testing: WYDOT Central System

Test Duration:

The duration of STP-4 is shown in Table 5 below. Note that data collection may span weekends.

Table 5: Estimated Duration to Conduct STP-4

Source: CTW Team, April 2026

Test Case	Setup	Data Generation/ Collection	Analysis	Total Estimated Days	Reserved for Remediation and Retesting
Test Case 4-1	1 working day	3 calendar days	2 working days	6 calendar days	3-7 working days
Test Case 4-2	1 working day	3 calendar days	2 working days	6 calendar days	3-7 working days
Test Case 4-3	1 working day	2 calendar days	2 working days	5 calendar days	3-7 working days
Test Case 4-4	1 working day	3 calendar days	2 working days	6 calendar days	3-7 working days

Test Case	Setup	Data Generation/ Collection	Analysis	Total Estimated Days	Reserved for Remediation and Retesting
Test Case 4-5	1 working day	3 calendar days	2 working days	6 calendar days	3-7 working days

Prerequisite Test Setup and Configuration:

The prerequisites needed to execute the following test cases are as follows:

- Hardware provisioning, installation, and configuration:
 - o All additional V2X equipment is installed either on the roadside (RSUs) or within vehicles (OBUs).
 - o Configure message forwarding on CTW installed RSUs (and SCMs in Utah) to the Central System's ingest endpoints for relevant message types per CTW state requirements.
- Central System configuration:
 - o CTW state-defined retention policy is configured in the Central System.
 - o UT Central System approach to deduplication is understood and has been incorporated into the analyses for each Test Case.
 - o Configure each Central System to track performance metrics regarding the processing and storing of the V2X messages.
 - o Configure the Central Systems in each CTW state to automatically generate TIMs based on local processes and thresholds.
 - o UDOT test team has determined a set of "test TIMs" that will be created during this test.
- Ensure data generation:
 - o Ensure roadside equipment (RSUs/SCMs in Utah) will generate data required for each test case (for example, a Department of Transportation [DOT] may need to schedule a planned RSU drive-by test to ensure RSUs will receive BSM data during the test window)

2.3.1.4.1 Test Cases (Including Procedures, Data, Anticipated Results, and Test Failure Remediation Approach)

2.3.1.4.1.1 Test Case 4-1: Validate Central System Data Storage of BSM Data for Expanded CTW Sites

Summary of Test Case 4-1:

Test that Utah and Colorado CTW state Central Systems can support the data storage of additional BSM data collected from CTW Program-added RSUs for standard V2X traffic. This will be accomplished by:

- Testing to validate that BSMs received by CTW-deployed RSUs are transmitted to the Central Systems and stored in the database.
- Projecting the anticipated storage of BSMs over a 1-year timeframe to understand the capacity needs for storing BSMs and comparison against Central System storage.

Note: WYDOT does not have to conduct this test as they have no expanded devices from the CTW Program that would add BSM traffic to their Central System.

Over the data observation period:

- RSUs will forward all received BSMs to the Central System. BSMs will be generated by existing traffic broadcasting BSMs. In Colorado, this will consist, primarily, of CDOT vehicles equipped with OBUs. In Utah, this will consist of snowplows, transit buses, emergency vehicles, and the GM test vehicle.
- There will be targeted data collection as follows:
 - o In Colorado, CDOT (or test team) vehicles with OBUs will be driven past at least five CTW-deployed RSUs along I-70 to test that BSMs are properly received by these RSUs, transmitted to the Central System, and stored.
- The Central System will ingest and store forwarded BSM data based on CTW state policies
- The Central Systems' data storage will be monitored throughout the test.

Assets to be used to complete Test Case 4-1 will include:

- UDOT and CDOT Central Systems for BSM message ingestion, storage, and querying.
- UDOT and CDOT Central Systems for performance metrics.
- UDOT and CDOT RSUs.
- CDOT (or test team) V2X-equipped vehicles in Colorado.

General description of roles:

- In Utah, the drivers of transit buses operating daily will operate transit buses per normal operating procedures. These regular transit routes will routinely pass RSUs while broadcasting BSMs.
- A member of the CDOT team will drive a V2X-equipped vehicle by selected RSUs.
- Test team participants will monitor the BSMs stored in Central Systems and conduct analyses.

Anticipated Results of Test Case 4-1:

The Central System successfully stores BSM data collected during the duration of the test from newly installed CTW RSUs identified to be in-scope for the test.

Test Case 4-1 Test Procedures:

1. Complete the setup and configuration steps described in the "Prerequisite Test Setup and Configuration" section above that relate to BSM message generation. Confirm that RSUs are actively forwarding BSM messages to the Central System and that these messages are being processed and stored within a database that can be queried.
2. Define and record a test start time to mark the beginning of the data collection period (e.g., 10:00 a.m.). Data may have been received by the Central System prior to the start time; however, only messages received after the defined start time will be included in the test analysis.
3. Allow data collection to proceed for the planned test period beginning at the designated start time. During this period, periodically monitor the Central System to verify that message ingestion and

processing are functioning correctly. Monitoring will include high-level inspection of the number of BSMs received by each Central System to understand if the pattern of BSMs is as expected. For example, in Utah, there will be BSMs from buses along regular routes every 30 minutes. If there is a 60-minute period without BSMs from these RSUs, this will flag a potential issue to investigate and possibly need to pause the test.

4. Conduct the Colorado driving test to cause BSMs to be broadcast to RSUs, as described above.
5. After the data collection period has concluded, begin the analysis phase to evaluate the test results.
6. Query the UDOT Central System V2X message database to verify that BSM data from RSU deployments has been retained. Review the V2X message database as follows:
 - a. Confirm that the Central System was operational the entire time (i.e., had no unplanned outage when operations ceased).
 - b. Confirm that the number of BSMs ingested by the Central System matches the number of BSMs stored in the Central System with no more than 10% difference.
 - c. In Utah, examine the BSM records against a selected transit corridor to confirm BSMs from the corridor were received and stored.
 - d. Confirm that BSMs were received and stored for each test day that transit vehicles were operational.
7. Query the CDOT Central System V2X message database to examine the dates/times when V2X-equipped CDOT vehicles drove by the RSUs in-scope for this test. Examine the data to determine if BSMs are stored for each RSU.
8. Extrapolate the number of messages received and stored during the test period to estimate the data storage required to store a year of data in UDOT systems and two months of data in CDOT systems and compare this to data storage capacity.
9. Generate a written report (either generated by the Central System or created by the test team) reporting on the relevant data collected.

Test Case 4-1 Test Data:

The test data will consist of the following:

1. BSM messages contained in the Central Systems that are accessible through the UIs
2. Logs from each Central System of exchanges with RSUs providing number of BSMs received.
3. Dates/times when V2X-equipped CDOT vehicles drove past RSUs added in the CTW Program.

Test Case 4-1 Measurement/Verification Method:

To test whether messages being ingested to the Central System are stored:

- In Utah, examination of BSMs stored in the database. Look for any periods of time greater than 60 minutes when no BSMs were recorded in the database. These may indicate issues with BSM data storage and should be investigated to understand if other circumstances prevented buses from broadcasting BSMs during this time.

- In Colorado, coordinate with CDOT and the test team to understand times when CDOT vehicles broadcasting BSMs were driven past the RSUs with V2X equipped vehicles. Compare the BSM storage in the database during times when V2X equipped vehicles drive by the RSUs to determine if BSMs are stored.

To test whether total storage capacity is adequate:

- The total volume of data storage during the data collection time period will be extrapolated out to one year to estimate the annual BSM storage requirements for both Colorado and Utah.
- This will be considered together with outcomes of other STP-4 test cases to estimate total storage requirements to be compared with storage capacity.

Test Case 4-1 Pass/Fail Criteria:

The following definitions will be used to determine pass/fail outcomes of this test case. In this test case, individual states may pass. A failure in one state would not require the state that passed to retest.

Pass Criteria:

The test passes if the following conditions are met:

- UDOT pass criteria:
 - o Central System storage review shows BSMs are received from at least 95% of the RSUs expected to receive BSMs (i.e., transit vehicles passing), minus those with explainable issues.
 - o Number of BSMs stored during the test period is within 10% (to allow a margin of error) of the number of BSMs recorded in the Central System log as being received. Note: Deduplication of BSMs will need to be considered during this analyses.
 - o Extrapolation and estimate of data storage required for BSM storage for 1 year is within UDOT storage capacity.
- CDOT pass criteria:
 - o Central System storage review indicated BSM storage during times when CDOT vehicles are passing RSUs.
 - o Extrapolation and estimate of data storage required for BSM storage is within CDOT storage capacity.

Fail Criteria:

Each state test is considered a failure if the "pass" criteria defined above are not met.

Test Case 4-1 Test Failure Remediation:

- Partial RSU failure:
 - o Investigate forwarding configuration and network connectivity.
 - o Review performance metrics to ensure no systemic issues have occurred.
 - o Rerun the test for the affected RSU if necessary.

- Systemic failure:
 - o Investigate central ingestion pipelines or database performance.
 - o Identify root cause and restart the test once resolved.

2.3.1.4.1.2 Test Case 4-2: Validate Central System Data Storage of TIM Data for Expanded CTW Sites

Summary of Test Case 4-2:

Test Case 4-2 will test whether the TIMs generated and sent to RSUs and the SDX are being stored in the respective state Central System. Activities in Test Case 4-2 will also test that the Central Systems of all DOTs can support the data storage of additional TIMs created for the CTW Program-added RSUs.

Over the observation period:

- RSUs will forward all transmitted TIMs to the Central System where they will be stored.
- TIMs generated for the SDX will be stored in the Central System where they were created.
- The Central System's performance metrics will be monitored throughout the test.

Assets to be used to complete Test Case 4-2 will include:

- UDOT, CDOT, and WYDOT Central Systems for TIM creation, ingestion, storage, and querying.
- UDOT, CDOT, and WYDOT Central Systems for performance metrics.
- UDOT, CDOT, and WYDOT RSUs.

General description of roles:

- The test team will determine the approach for creating "test TIMs" for this test case (i.e., TIMs that will be created for a brief time to test that they are being stored and that may be broadcast to the public but may contain false information).
- A test team member from UDOT, CDOT, and WYDOT will create a limited number of TIMs each day during the test period. This can be unique TIMs for each day or TIMs that extend for the duration of the full test duration.
- UDOT, CDOT, and WYDOT Central System operators will monitor performance metrics and perform storage validation.

Anticipated Results of Test Case 4-2:

The Central System successfully stores TIMs collected during the duration of the test from all newly deployed RSUs. Performance metrics will be utilized to verify any issues with data processing and retention. Projection of the estimated number of TIMs will show that data storage is sufficient to support storage of TIMs for an entire year.

Test Case 4-2 Test Procedures:

1. Complete the setup and configuration steps described in the "Prerequisite Test Setup and Configuration" section above that relate to TIM generation. Confirm that RSUs are actively

forwarding TIMs to the Central System and that these messages are being processed and stored within a database that can be queried.

2. Define and record a test start time to mark the beginning of the data collection period (e.g., 10:00 AM). Data may have been received by the Central System prior to the start time; however, only messages received after the defined start time will be included in the test analysis.
3. During the test period, conduct normal operations of each state Central System, including the automatic creation of TIMs that each Central System operates.
4. In addition to Central Systems automatically generating TIMs (as described in the Prerequisite Test Setup and Configuration writeup above), operators in each CTW state will manually create five TIMs each day for broadcast by RSUs, leaving each TIM active long enough for broadcast at least for 1 minute. Manually record the date/time and content of the TIM for comparison later. The Central Systems are expected to receive communications from the RSUs that these TIMs were broadcast and store the TIMs.
5. Allow data collection to proceed for the test period beginning at the designated start time. During this period, periodically monitor the Central System to verify that message ingestion and processing are functioning correctly. Periodic monitoring will include looking for the manually entered TIMs each day to determine if they were stored by the Central System. If the daily periodic monitoring does not show these, the test case is a failure and test remediation must occur. Periodic monitoring will also track TIMs created automatically and examine the Central System to test that these are being stored.
6. After the data collection period has concluded, begin the analysis phase to evaluate the test results.
7. Query the UDOT, CDOT, and WYDOT Central Systems' databases to verify that TIM data from RSU deployments has been retained. As a minimum:
 - a. The five TIMs created each day in each state should be retained and database storage should represent the number of broadcasts for each TIM (e.g., TIMs are broadcast at 1 Hertz [Hz]).
 - b. Other TIMs that were already existing in the system when testing began.
 - c. Any TIMs that were created automatically by the Central Systems.
8. Generate a written report with the relevant data collected.

Test Case 4-2 Test Data:

The test data will consist of TIMs received and stored by the Central System.

1. TIMs that are contained in the Central Systems' databases. Accessible through the Central Systems' UIs.
2. Manual records of the date/time/content of the TIMs created each day by operators in each state.
3. Central system logs of TIMs automatically generated during the test period.
4. Observation of existing TIMs in the system when testing began.

Test Case 4-2 Measurement/Verification Method:

1. Inspection and analysis of Central System V2X message storage to determine if the TIMs created each day per state are stored in the system.
2. Check Central System logs to determine the number of automatically generated TIMs that were created and sent to RSUs. Compare these to the TIMs stored in the Central System to verify if all automatically created TIMs are stored.
3. Examine the data storage used for TIMs and extrapolate to a year of data to estimate TIM storage required to be compared to storage capacity for each Central System.

Test Case 4-2 Pass/Fail Criteria:

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

The test passes if the following conditions are met:

- Testing confirms that the five TIMs created in each state each day are stored in the database representing each time the TIM is broadcast by the RSU, with a margin of error of 5%.
- The Central Systems in each state are storing automatically created TIMs (if any are created).
- Extrapolation and estimate of data storage to 1 year is within the storage capacity of each state system.

Fail Criteria:

Each state test is considered a failure if the "pass" criteria defined above are not met.

Test Case 4-2 Test Failure Remediation:

- Partial RSU failure:
 - o Ensure that manually created TIMs remained active long enough for broadcast and retrieval by the Central System (understood that one minute meets this requirement). If not, repeat testing and expand the time the TIM is active.
 - o Investigate forwarding configuration and network connectivity.
 - o Review performance metrics to ensure no systemic issues have occurred.
 - o Rerun the test for the affected RSU if necessary.
- Systemic failure:
 - o Investigate central ingestion pipelines or database performance.
 - o Identify root cause and restart the test once resolved.

2.3.1.4.1.3 Test Case 4-3: Validate Central System Data Storage of SRM/SSM Data for Expanded CTW CIs Supporting CIPT

Summary of Test Case 4-3:

Test that the UDOT Central Systems can support the data storage of the SRMs and SSMs collected from CTW Program-added RSUs for standard UDOT priority and preemption V2X traffic. CDOT and WYDOT do not have to conduct this test as they have no expanded CI sites.

Over the data observation period:

- RSUs will forward all received SRM and transmitted SSM messages to the Central System.
- The Central System will ingest and store forwarded SRMs and SSMs based on CTW state policies.
- Two corridors where transit buses regularly operate will be monitored and expected SRM/SSM message storage will be analyzed, as described in detail below.

Assets to be used to complete Test Case 4-3 will include:

- UDOT Central System for SRM and SSM message ingestion, storage, and querying.
- UDOT RSUs.
- UDOT SCMs.

General description of roles:

- UDOT will execute this procedure.
- UDOT Central System operators will monitor performance metrics and perform storage validation.

Anticipated Results of Test Case 4-3:

For the five selected intersections, the number of SRMs and SSMs that move through the SCM during the test period will match the number of SRMs and SSMs stored in the UDOT Central System, within a margin of error of 5%.

Test Case 4-3 Test Procedures:

1. Complete the setup and configuration steps described in the “Prerequisite Test Setup and Configuration” writeup above that relate to SRM and SSM message generation. Confirm that RSUs are actively forwarding SRM and SSM messages to the Central System and that these messages are being processed and stored within a database that can be queried.
2. Define and record a test start time to mark the beginning of the data collection period (e.g., 10:00 a.m.). Data may have been received by the Central System prior to the start time; however, only messages received after the defined start time will be included in the test analysis.
3. Allow data collection to proceed for the observation period, beginning at the designated start time. During this period, periodically monitor the Central System to verify that during the times when there are expected SRM and SSM messages (i.e., peak periods when buses are traveling) they are received by the Central System. The AM peak will be used for Test Case 4-3 testing to enable analysis during each workday of the test.

4. Each day during the testing period, following the AM peak period, members of the testing team will:
 - a. Connect to five Signal Command Modules (SCMs) attached to RSUs at signalized intersections (SIs) where CIPT-equipped buses pass by.
 - b. The SCM logs for the period of 6:00 a.m.–9:00 a.m. will be downloaded and inspected to identify the number of SRMs received by the RSU/SCM as well as the number of SSMS generated by the SCM and broadcast by the RSU.
 - c. The test team will search the UDOT V2X MMS system database to determine if each SRM and SSM was transmitted to the V2X MMS and stored.
 - d. Before the end of each day of testing, preliminary results will be shared with the test team.
5. Generate a written report with information about the SRM and SSM messages received and broadcast by the five selected RSUs compared with whether these messages were stored at the V2X MMS.

Test Case 4-3 Test Data:

The test data will consist of the following:

1. SRM messages contained in the UDOT V2X MMS. Accessible through the UDOT V2X MMS UI.
2. SSM messages contained in the UDOT V2X MMS. Accessible through the UDOT V2X MMS UI.
3. SCM logs of SSMS broadcast and SRMs received at the five selected intersections.

Test Case 4-3 Measurement/Verification Method:

Inspection of SCM logs at the five selected intersections to identify the number of SRMs received and SSMS broadcast by the RSU and comparison with the SRMs and SSMS in the V2X MMS to verify that these messages were received and stored, within the 5% margin of error.

Documentation of the total number of SRM and SSM messages stored during the test period will be extrapolated to estimate the expectations of a year of data collection and estimate the storage needed. This will be compared to the UDOT cloud storage capacity for assessment of the storage capacity to retain these data.

Test Case 4-3 Pass/Fail Criteria:

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

The test passes if the following conditions are met:

- The SRM and SSMS identified in the SCM logs are all verified to have been received and stored in the V2X MMS using a comparison of timestamps and indications of the RSU that sent the messages to the V2X MMS. A margin of error of 5% will be allowed to account for potential manual errors in collecting data.

- Extrapolated estimates of the total SRM and SSM message for all Utah CIs for one year are within the UDOT storage capacity.

Fail Criteria:

The test is considered a failure if storage fails to retain all received SRM and SSMs from the selected RSUs that were monitored in this test case. Failure would also result if the extrapolated expected annual storage is not sufficient.

Test Case 4-3 Test Failure Remediation:

- Partial RSU failure:
 - o Investigate the manual process to determine if errors were involved in testing activities.
 - o Investigate forwarding configuration and network connectivity.
 - o Review performance metrics to ensure no systemic issues have occurred.
 - o Rerun the test for the affected RSU if necessary.
- Systemic failure:
 - o Investigate central ingestion pipelines or database performance.
 - o Identify root cause and restart the test once resolved.

2.3.1.4.1.4 Test Case 4-4: Validate Central System Data Storage of Persistent CI Message Data for Expanded CTW CIs (MAP, SPaT)

Summary of Test Case 4-4:

Test that the UDOT Central Systems can support the data storage of additional MAP, SPaT, and RTCM messages collected from CTW Program-added RSUs for standard UDOT V2X CI traffic. CDOT and WYDOT do not have to conduct this test as they have no expanded CI sites.

The large volume of data representing SPaT, MAP, and RTCM messages will provide sufficient data to execute this test in this timeframe. Over a data collection period:

- RSUs will forward all transmitted MAP, SPaT, and RTCM messages to the Central System (note that RTCM broadcasts are not expected at all the expansion sites during the time of testing and the final number of RTCM sites will be determined by test members looking for locations with RTCM and including them in this test case whenever possible, before this test is completed).
- The Central System will ingest and store forwarded MAP, SPaT, and RTCM messages based on CTW state policies
- The Central System's storage of messages will be monitored throughout the test.
- The deduplication of messages when stored in the UDOT V2X MMS will be understood and factored into calculations described below.

Assets to be used to complete Test Case 4-4 will include:

- UDOT Central System for MAP, SPaT, and RTCM message ingestion, storage, and querying.

- UDOT RSUs (including SCMs).

General description of roles:

- UDOT will execute this procedure.
- UDOT Central System operators will monitor performance metrics and perform storage validation.

Anticipated Results of Test Case 4-4:

The UDOT Central System successfully stores MAP, SPaT, and RTCM messages collected during the duration of the test from all newly deployed RSUs. Total volume of storage for the SPaT, MAP, and RTCM messages is extrapolated out to one year and compared to UDOT storage capacity.

Test Case 4-4 Test Procedures:

1. Complete the setup and configuration steps described in the “Prerequisite Test Setup and Configuration” writeup above. Confirm that RSUs are actively forwarding MAP and SPaT messages to the Central System and that these messages are being processed and stored within a database that can be queried.
2. Define and record a test start time to mark the beginning of the data collection period (e.g., 10:00 a.m.). Data may have been received by the Central System prior to the start time; however, only messages received after the defined start time will be included in the test analysis.
3. Allow data collection to proceed for the test period beginning at the designated start time. During this period, periodically monitor the Central System to verify that message ingestion and processing are functioning correctly. This will involve visual examination that there are regular additions of SPaT, MAP, and RTCM messages, with no observed periods when no messages are received for more than a 5-minute period.
4. After the data collection period has been concluded, begin the analysis phase to evaluate the test results, as follows:
 - a. The test team will determine the start time on day one and end time on the final day and determine the number of each message anticipated to be broadcast by the new CIs established in the CTW Program (note that the number of intersections will be determined at the time the test begins as Utah is adding additional intersection beyond the 250 originally planned).
 - b. SPaT messages are broadcast at a frequency of 10 per second, and MAP and RTCM messages are broadcast at one per second. Using these parameters, the test team will determine the number of each message anticipated to be broadcast by the new CIs established in the CTW Program.
 - c. Using a calculation of 86,400 seconds per day, the total number of anticipated SPaT, MAP, and RTCM messages will be determined for the test period. Analysis of the V2X MMS data logs will be compared against the total number of expected SPaT and MAP messages.
5. The volume of messages stored will be extrapolated to a 1-year period to estimate the storage capacity required to store messages for a year. This will be compared with the UDOT storage capacity to determine if capacity is sufficient.

6. Query the UDOT V2X MMS to review system monitoring and performance metrics to confirm that no system downtime occurred during the test period.
7. Generate a written report with the relevant data collected.

Test Case 4-4 Test Data:

The test data will consist of the following:

1. MAP, SPaT, and RTCM messages contained in the UDOT V2X MMS. Accessible through the UDOT V2X MMS UI.

Test Case 4-4 Measurement/Verification Method:

- Comparison of the expected number of messages received against the actual messages stored.
- Extrapolation of the storage used in the test to a full year of message storage will be compared against UDOT storage capacity.

Test Case 4-4 Pass/Fail Criteria:

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

The test passes if the following conditions are met:

- The Central System records of MAP, SPaT, and RTCM messages received and stored is within 10% of the anticipated records calculated by the expected frequency of broadcast over the test period.
- No unexplained gaps in messages received and stored are observed. SPaT and MAP messages should be regular at a frequency of 10 Hz and 1 Hz, respectively, for all CIs. RTCM messages should be regular at 1 Hz at intersections where it is broadcasting. Gaps would be identified if periods outside a margin of error were observed (i.e., there should be no observations of more than 2-second gaps between SPaT messages or 4-second gaps between MAP and RTCM messages).

Fail Criteria:

This test is considered a failure if the "pass" criteria defined above are not met.

Test Case 4-4 Test Failure Remediation:

- Partial RSU failure:
 - o Investigate forwarding configuration and network connectivity.
 - o Review performance metrics to ensure no systemic issues have occurred.
 - o Rerun the test for the affected RSU if necessary.
- Systemic failure:
 - o Investigate central ingestion pipelines or database performance.
 - o Identify root cause and restart the test once resolved.

2.3.1.4.1.5 Test Case 4-5: Validate UDOT Central System Data Storage of SDSM Data for Expanded CTW CIs with VRU Safety Systems

Summary of Test Case 4-5:

Test Case 4-5 will test that the UDOT Central Systems can support the data storage of additional SDSM messages broadcast at UDOT CI VRU Safety Systems. CDOT and WYDOT do not have to conduct this test as they have no expanded CI sites.

Over the observation period:

- VRU Safety Systems will generate SDSM data as designed. As pedestrians or other VRUs enter and move through crosswalks at VRU Safety System-equipped intersections, SDSMs will be generated describing the VRU location and movement.
- RSUs will forward all transmitted SDSM messages to the Central System.
- The Central System will ingest and store the forwarded SDSM messages based on CTW state policies
- A selected period will be used to connect to the RSU at one of the VRU Safety System intersections and monitor the generation of SDSMs. The number of SDSMs collected during the limited period will be compared to SDSMs stored in the UDOT V2X MMS during the same period.

Assets to be used to complete Test Case 4-5 will include:

- UDOT Central System for SDSM message ingestion, storage, and querying.
- UDOT Central System for performance metrics.
- UDOT RSUs.
- UDOT VRU Safety Systems.

General description of roles:

- UDOT will execute this procedure.
- UDOT Central System operators will monitor performance metrics and perform storage validation.

Anticipated Results of Test Case 4-5:

During the limited time of detailed testing, the number of SDSMs generated at the selected intersection will match the SDSMs stored in the V2X MMS. Additionally, visual examination of the data stored in the V2X MMS database during the entire data collection period will show records of SDSMs generated and stored in the V2X MMS.

Test Case 4-5 Test Procedures:

1. Complete the setup and configuration steps described in the “Prerequisite Test Setup and Configuration” writeup above that relate to SDSM message generation. Confirm that RSUs are actively forwarding SDSM messages to the Central System and that these messages are being processed and stored within a database that can be queried.

2. Define and record a test start time to mark the beginning of the data collection period (e.g., 10:00 a.m.). Data may have been received by the Central System prior to the start time; however, only messages received after the defined start time will be included in the test analysis.
3. Allow data collection to proceed for the test period beginning at the designated start time. During this period, periodically monitor the Central System to verify that message ingestion and processing are functioning correctly. This monitoring will consist of examining data received and confirming that some SDSM data are received and stored in the V2X MMS consistently. For example, if there was a period of more than 1 hour during the daytime when no SDSMs were stored, this would trigger the test team to investigate if there were, in fact, no VRUs crossing during this time or if data storage is not working properly.
4. For one of the VRU expansion sites, the test team will select one 1-hour period and connect to the RSU/SCM/Light Detection and Ranging (LiDAR) at the intersection to download the number of SDSMs generated during this period. The number of SDSMs generated at the intersection will be recorded. The test team will also examine the V2X MMS database storage for the period selected to compare with the SDSMs generated at the test site. These detailed comparisons of SDSMs generated vs. stored will be evaluated to determine if all SDSMs are being stored in the V2X MMS.
5. Based on the data stored during the test period, the number of messages and storage requirements will be extrapolated to estimate the storage capacity required for 1 year. This will be compared to UDOT storage capacity.
6. Generate a written report with the relevant data collected and results of analyses.

Test Case 4-5 Test Data:

The test data will consist of the following.

1. SDSM messages that are stored in the UDOT V2X MMS. Accessible through the UDOT V2X MMS UI.
2. SDSM messages generated by the intersection equipment (e.g., RSU, LiDAR, and SCM) and accessible through connections to the SCM or LiDAR at the intersection for the 1-hour time periods at the selected VRU Safety System expansion site.

Test Case 4-5 Measurement/Verification Method:

- Comparison of SDSMs stored in the V2X MMS vs. messages generated and broadcast at the intersection for the 1-hour period..
- Visual examination of V2X MMS logs for the test duration to determine if there are any unexpected gaps in SDSM messages stored during periods when pedestrians are expected.
- Extrapolation of data storage to estimate storage needs to store one year of data compared to UDOT storage capacity.

Test Case 4-5 Pass/Fail Criteria:

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

The test passes if the following conditions are met:

- The comparison of V2X MMS SDSMs stored against SDSMs generated at the site during the 1-hour data collection period are within 10%.
- No unexplained periods of time are observed where the V2X MMS does not store any SDSMs when pedestrians are expected.
- There is sufficient storage capacity to store all data.

Fail Criteria:

This test is considered a failure if the "pass" criteria defined above are not met.

Test Case 4-5 Test Failure Remediation:

- Partial failure of one or more VRU Safety Intersections:
 - o Investigate forwarding configuration and network connectivity.
 - o Review performance metrics to ensure no systemic issues have occurred.
 - o Rerun the test for the affected intersection if necessary.
- Systemic failure:
 - o Investigate central ingestion pipelines or database performance.
 - o Identify root cause and restart the test once resolved.

2.3.1.5 Test Plan STP-5: Central Systems Monitor Field Equipment Health

Brief Description:

STP-5 will evaluate the ability of the CTW Central Systems for UDOT and CDOT to monitor RSU health by analyzing V2X messages generated and transmitted by field devices. STP-5 consists of the following activities:

- **Central System Monitoring for CI RSUs (UDOT only).** Test activities will analyze the ingestion and storage of transmitted V2X messages from a random selection of different CI RSUs into the Central System over the span of a week and compare these to the messages broadcast by the RSU. In the Utah deployment, SPaT and MAP messages are generated and forwarded to the RSUs for broadcast. Both MAP and SPaT messages will be points of interest since they have standard, predictable rates of transmission that can be used to compare to the duration of the test. Received MAP and SPaT messages will not be considered for this test. This portion of the test will only be conducted for UDOT since there are no CTW CIs for CDOT.
- **Central System Monitoring for Connected Roadway RSUs (UDOT and CDOT).** Test activities will analyze the ingestion and storage of transmitted V2X messages from a random selection of different Connected Roadway RSUs into the Central System over the span of a week and compare these to the messages broadcast by the RSU. TIM messages will be the point of interest since they can be reliably configured to transmit for the duration of the test, unlike BSMs which are transmitted by

nearby vehicles and thus their rate is not predictable. This test will monitor transmitted TIMs. TIMs messages received by RSUs will not be considered for this test. The CDOT Central System deduplicates TIM messages for storage and, as such, received TIM counts will be preferred over stored TIM counts for CDOT analysis.

- **Central System monitoring for RSUs (UDOT and CDOT).** Test activities will evaluate the system's ability to detect and report RSU operational status changes. Test activities will involve inducing offline conditions for a selected set of RSUs by powering down devices or disabling V2X functionality and verifying that the Central System accurately reflects transitions between online and offline states. The test will focus on system awareness of RSU health through loss and restoration of connectivity (e.g., Internet Control Message Protocol (ICMP) response or V2X message transmission), rather than analysis of message content.

At the conclusion of the 1-week test period, the Central System will be used to validate observed message counts against expected values based on standard, theoretical transmission rates (1 Hz for MAP and TIM messages, and 10 Hz for SPaT messages). Any significant message gaps identified for individual RSUs will be investigated further. At this time, deduplication in the UDOT system is not planned during the test period, but references to deduplication remain such that it will be considered at the time of testing. For the CDOT system, TIMs are deduplicated before being stored in the central database such that any non-unique message is only saved once per hour, giving an expected stored quantity of 1 count per unique message per hour (2 unique TIMs = 2 counts per hour). Count metrics are collected for messages before and after deduplication occurs, enabling accurate analysis of received message counts.

Test Objective:

The objective of this test is to validate that UDOT and CDOT can scale their V2X deployment sites while maintaining the ability to monitor RSU (and Remote Processing Units [RPU] which are specific to Utah) health and functionality through their Central System. Detailed objectives are as follows:

- Verify that RSUs at deployment sites successfully forward the transmitted V2X messages to the Central System.
- Verify the Central System's ability to receive and count V2X messages.
- Verify Central System message counts for CI RSUs (with message ingestion originating from RSUs) match expected values.
- Verify that Central System message counts for Connected Roadway RSUs match with expected values.

Requirements to be Verified:

The CTW System Requirement to be verified by conducting STP-5 include:

- CS-12 Central Systems monitor expansion sites. Central Systems shall monitor health of additional Field Equipment deployed in each state, as documented in the Concept of Operations (ConOps) Sections 3.2.1.2, 3.2.2.2, 3.3.1.2, and 3.4.1.2.
- ConOps 3.2.1.2 – Utah Connected Intersections: Central Systems.
- ConOps 3.2.2.2 – Utah V2X Connected Roadways: Central Systems.
- ConOps 3.3.1.2 – Wyoming V2X Connected Roadways: Central Systems.

- ConOps 3.4.2.2 – Colorado V2X Connected Roadways: Central Systems.

Test Location(s):

UDOT will select 10% of the total number of new CIs and roadway RSUs deployed as part of the CTW site expansion. These devices must be online initially to ensure useful test data can be collected. CDOT will select 15 RSUs deployed as part of the CTW Program. This will ensure there is a good spread of devices selected to be tested relative to the size of the CTW Program deployment since UDOT and CDOT have largely different installation commitments.

Test Duration:

The duration of STP-5 is anticipated as follows:

- Test setup and configuration: Approximately 1 day per test case (can be performed simultaneously).
- Test data collection period: 7 consecutive calendar days per test case (can be performed simultaneously).
- Data analysis and results documentation: Approximately 2 days following completion of the data collection period (can be performed simultaneously).

Additional time may be required depending upon test failure remediation measures, estimated as follows:

- Additional 1–4 days if one or more minor issues are identified in the results of the original test case.
- Additional 4–7 days if significant issues are identified in the results of the original test case.

The duration of STP-5 is also described in Table 6 below. Note that data collection may span weekends.

Table 6: Estimated Duration to Conduct STP-5

Source: CTW Team, April 2026

Test Case	Setup	Data Generation/Collection	Analysis	Total Estimated Days	Reserved for Remediation and Retesting
Test Case 5-1	1 working day	7 calendar days	2 working days	10 calendar days	3-7 working days
Test Case 5-2	1 working day	7 calendar days	2 working days	10 calendar days	3-7 working days
Test Case 5-3	1 working day	1 calendar day	2 working days	4 calendar days	4 working days

Prerequisite Test Setup and Configuration:

The prerequisites needed to execute the test procedure are as follows:

- Central System configuration:

- o Confirm that each Central System is configured to ingest MAP, SPaT, and TIM messages to be stored in a searchable database. This is likely already an innate function of the Central System and may require no additional effort.
- RSU configuration:
 - o For CI RSUs, ensure the RSU is fully functional and transmitting relevant MAP and SPaT messages for its intersection.
 - o For Connected Roadways, create a TIM message that will be configured for the full duration of the 1-week test to deploy to the chosen RSUs. Verify that this TIM is being transmitted. The TIM deployment can happen manually over National Transportation Communications for Intelligent Transportation Systems Protocol (NTCIP)-1218 (Simple Network Management Protocol [SNMP]v3).
 - o In the UDOT deployment, MAP and SPaT messages are broadcast by the RSU. However, TIM messages are stored and forwarded by the RSUs and can be used for Central System ingestion and monitoring.
 - o For CDOT, configure V2X message forwarding on the RSUs to forward to the Central System's ingest endpoint.
 - o Transmitted TIM message forwarding on Connected Roadway RSUs.
- V2X message ingestion verification:
 - o For CDOT, verify that the Central System can identify which RSU a given ingested V2X message originated from.

2.3.1.5.1 Test Cases (Including Procedures, Data, Anticipated Results, and Test Failure Remediation Approach)

2.3.1.5.1.1 Test Case 5-1: Validate Central System Monitoring for Expanded CI Sites

Summary of Test Case 5-1:

UDOT will randomly select 10% of their new CI RSUs deployed as part of the CTW site expansion. UDOT will configure these RSUs to forward MAP and SPaT messages to the Central System for collection and counting.

The RSUs will generate and transmit V2X messages continuously over a 1-week test period, during which all forwarded messages will be ingested and stored by the Central System. At the conclusion of the test period, the observed message counts will be compared against the predicted message counts to assess system uptime and data completeness. Additionally, RSU health will be monitored through NTCIP 1218 mechanisms. Together those will be used to verify the Central System's ability to gauge each roadside system operational status. The Central System should also be able to track when each message was received over time to better graph out possible RSU downtime. The Central System shall be periodically checked over the course of the data collection period to ensure the data is received, as expected.

Assets to be used to complete Test Case 5-1 will include:

- UDOT Central System (i.e., UDOT V2X MMS).

- UDOT RSUs (approximately 10% of newly installed RSUs).

General description of roles:

- UDOT will be the only DOT executing this test procedure, as it is the only CTW Program participant with expanded CI deployment sites.
- UDOT Central System operators will compare the SPaT and MAP message counts in the Central System against the predicted number of messages (using the generation and broadcast frequencies of 10 Hz for SPaT and 1 Hz for MAP at the conclusion of the test period to determine system operational status).

Anticipated Results of Test Case 5-1:

The Central System successfully receives and records SPaT and MAP messages for each of the selected roadside systems, with total message counts reaching at least 95% of the expected values over the 1-week test period.

Test Case 5-1 Test Procedures:

1. Identify the RSU locations that will participate in this test. The sample should consist of approximately 10% of the newly deployed CI RSUs installed as part of the CTW site expansion.
2. Complete the setup and configuration steps described in the "Prerequisite Test Setup and Configuration" writeup above that relate to CIs. Confirm that the selected RSUs are actively forwarding MAP and SPaT messages to the Central System and that these messages are being processed and stored within a database that can be queried.
3. Define and record a test start time to mark the beginning of the data collection period (e.g., 10:00 a.m.). Data may have been received by the Central System prior to the start time; however, only messages received after the defined start time will be included in the test analysis.

Allow data collection to proceed for a 7-day period beginning at the designated start time. During this period, periodically monitor the Central System to verify that message ingestion and processing are functioning correctly and that no significant data gaps are occurring. Central System performance metrics and system logs may be used for this verification.
5. After the 7-day data collection period has concluded, begin the analysis phase to evaluate the test results.
6. Query the UDOT V2X MMS database to verify that the expected number of SPaT messages has been received from each RSU selected for testing.
 - a. Querying for SPaT message counts is recommended, as these messages are transmitted at a consistent and predictable rate of 10 Hz, allowing the expected number of messages to be calculated mathematically.
 - b. MAP messages may also be queried; since deduplication will not be operational in the UDOT Central System when testing is performed, MAP messages will provide a reliable indicator for verifying the Central System's ability to monitor RSU health and may be used as an additional (optional) testing parameter.
7. Generate a graph of the data queried to represent message volume over time. Accompany the graph with data representing the messages received.

Test Case 5-1 Test Data:

The test data will consist of SPaT and MAP messages received and stored by the Central System as well as a "control" data set to be used in comparison and analyses:

1. SPaT Message Counts contained in the UDOT V2X MMS database. Accessible through the V2X MMS UI.
2. Control for SPaT Message Counts. Test participants will determine the anticipated number of SPaT messages for the period selected, given that SPaT are generated/broadcast at 10 Hz.
3. MAP Message Counts. contained in the UDOT V2X MMS database. Accessible through the V2X MMS UI.
4. Control for MAP Message Counts. Test participants will determine the anticipated number of MAP messages for the period selected, given that MAP messages are broadcast at 1 Hz.
5. RSU aggregated health status as reported by the UDOT V2X MMS system over the course of the test observation period, based on RSU monitoring (e.g., NTCIP 1218 metrics).

Test Case 5-1 Measurement/Verification Method:

- The number of SPaT Messages stored in the UDOT V2X MMS database will be compared against the expected number of SPaT messages (identified as "Control" above) to determine any difference in the counts.
- The number of MAP messages stored in the UDOT V2X MMS database will be compared against the expected number of MAP messages (identified as "Control" above) to determine any difference in the counts.
- The RSU aggregated health status will be monitored and any identifications of system outages will be noted and factored into the test runs, which may cause interruption or repeating the tests.

Test Case 5-1 Pass/Fail Criteria.

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

The test case passes if the Central System for each CTW state successfully performs the following:

- The total number of SPaT messages received is at least 95% of the expected count per RSU, calculated at a 10 Hz transmission rate over the 1-week test period (6,048,000 SPaT messages per RSU).
- The total number of MAP messages received is at least 95% of the expected count per RSU over the 1-week test period. Since deduplication is not planned to be operational when testing occurs, this threshold should not need to be adjusted. The expected MAP messages will be 604,800 MAP messages per RSU.
- It is acceptable for RSUs to have less than 95% of their expected message count as long as the total number of RSUs this occurs for is not greater than 20% of the RSU test set. This is to allow for scenarios where RSUs have gone offline during the test. This is an acceptable normal occurrence and is even an opportunity to illustrate how the Central System can detect a device's health.

- Examination of the messages ingested over time does not show any unexplained gaps in the SPaT and MAP messages received and stored. SPaT and MAP messages should be regular at a frequency of 10 Hz and 1 Hz, respectively, for all CIs. Gaps would be identified if periods outside a margin of error were observed (i.e., there should be no observations of more than 2-second gaps between SPaT messages or 4-second gaps between MAP messages).
- RSU aggregated health status, as reported by the Central System, is consistent with observed message ingestion trends, including identification of periods of reduced performance or downtime.

Fail Criteria:

- The test is considered a failure if more than 20% of the total set of test RSUs fail to have 95% of expected transmitted MAP or SPaT messages forwarded to the Central System during the 1-week test period.
- The test is also considered a failure if RSU aggregated health status, as reported by the Central System is inconsistent with observed message ingestion trends.

Test Case 5-1 Test Failure Remediation.

Remediation of partial RSU failure (one or more RSUs affected): If one or more RSUs or RPU temporarily stop or fail to continuously transmit MAP and/or SPaT messages during the test period:

- Investigate the affected RSUs or RPUs to identify potential causes of the interruption.
- Review historical device and network connectivity data to determine whether the RSUs/RPUs were offline during the observed ingestion gaps.
- The test may be rerun for the affected RSUs/RPUs, or alternate roadside sites may be selected if any devices experienced extended or complete outages. Rerunning the test is optional, as the Central System's ability to detect and report RSU health issues is still demonstrated.

Systemic Failure (all RSUs/RPUs affected): If all RSUs temporarily stop or fail to transmit MAP and/or SPaT messages during the test period:

- Investigate the Central System for interruptions or failures in message ingestion.
- Identify and document the root cause of the system-wide data loss.
- The test will likely need to be restarted and executed in full once the issue has been identified and resolved.

2.3.1.5.1.2 Test Case 5-2: Validate Central System Monitoring for Expanded Connected Roadway Sites

Summary of Test Case 5-2:

UDOT and CDOT will randomly select 10% of their new Connected Roadway RSUs deployed as part of the CTW site expansion, or 15 RSUs, whichever is greater. These RSUs will be configured to forward TIM messages to the Central System for collection and counting. In the Utah deployment, TIM messages are transmitted and forwarded directly by RSUs. Additionally, UDOT and CDOT will create or generate a TIM message that will be deployed to each RSU that will be transmitted for the duration of the test to ensure there are always active TIM messages being transmitted.

The RSUs will generate and transmit TIM messages continuously over a 1-week test period, during which all forwarded messages will be ingested and stored by the Central System. At the conclusion of the test period, the observed message counts will be compared against the predicted message counts to assess system uptime and data completeness. This will be used to verify the Central System's ability to gauge each RSU's operational status. The Central System should also be able to track when each message was received over time to better graph out possible RSU downtime. The Central System shall be periodically checked over the course of the data collection period to ensure the data is being received, as expected. This should be checked at least once per day during the testing period.

Assets to be used to complete Test Case 5-2 will include:

- UDOT Central System (i.e., UDOT V2X MMS).
- UDOT RSUs on Connected Roadways (approximately 10% of newly installed RSUs).
- CDOT Central System (i.e., ODE).
- CDOT RSUs that are installed on Connected Roadways (15 of the RSUs).

General description of roles for Test Case 5-2:

- UDOT and CDOT will both be executing this test procedure, as they both have expanded Connected Roadway deployment sites as part of their CTW Program commitments.
- UDOT and CDOT Central System operators will compare the number of TIMs received by the Central System with the predicted number of TIMs based on the duration that the TIMs were broadcast at 1 Hz at the conclusion of the test period to determine system operational status.

Expected Results of Test Case 5-2:

The Central System successfully receives and records TIM messages for each of the selected RSUs, with total message counts reaching at least 95% of the expected values over the 1-week test period.

Test Case 5-2 Test Procedures:

1. Identify the RSUs that will participate in this test. The sample should consist of approximately 10% of the newly deployed Connected Roadway RSUs installed as part of the CTW site expansion. If 10% of the installed devices are less than 15 RSUs, then select 15 devices instead.
2. Complete the setup and configuration steps described in the "Prerequisite Test Setup and Configuration" writeup for Connected Roadways. Confirm that the selected RSUs are actively forwarding TIM messages to the Central System and that these messages are being processed and stored within a database that can be queried. The TIM messages will need to be configured to transmit for the full duration of the 7-day data collection period.
3. Define and record a test start time to mark the beginning of the data collection period (e.g., 10:00 a.m.). Data may have been received by the Central System prior to the start time; however, only messages received after the defined start time will be included in the test analysis.
4. Allow data collection to proceed for a 7-day period beginning at the designated start time. During this period, periodically monitor the Central System to verify that message ingestion and processing are functioning correctly and that no significant data gaps are occurring. Central System performance metrics and system logs may be used for this verification.

5. After the 7-day data collection period has concluded, begin the analysis phase to evaluate the test results.
6. Determine the number of TIM messages received from each RSU selected for testing and compare against the expected counts. For UDOT this may involve using either database counts or received message counts. For CDOT, this precise calculation will only involve received message counts.
8. Generate graph of the data queried to represent all messages over time.

Test Case 5-2 Test Data:

The test data will consist of TIM messages received and stored by the Central Systems, as well as a "control" data set to be used in comparison and analyses:

1. Utah Testing Data:
 - a. Utah TIM Message Counts contained in the UDOT V2X MMS database. Accessible through the V2X MMS UI.
 - b. Control for UT TIM Message Counts. TIMs sent by the UDOT V2X MMS to each RSU.
2. Colorado Testing Data:
 - a. Colorado TIM Message Counts contained in the CDOT ODE. Accessible through the Connected Vehicle (CV) Manager MongoDB database.
 - b. Control for CO TIM Message Counts. TIMs sent by the CDOT ODE to each RSU.

Test Case 5-2 Measurement/Verification Method:

Inspection and analysis of Central System logs and stored message counts to look for the TIM message sent to the RSU specifically for this test to verify that it is received by the Central System. This will indicate that the Central System is monitoring the health of RSU.

Test Case 5-2 Pass/Fail Criteria.

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

The test case passes if the Central System for each CTW state successfully performs the following:

- The total number of transmitted TIM messages received is at least 95% of the expected count per RSU over the 1-week test period. (86,400 TIM messages per RSU when no deduplication is applied).
- It is acceptable for RSUs to have less than 95% of their expected message count as long as the total number of RSUs this occurs for is not greater than 20% of the RSU test set. This is to allow for scenarios where RSUs have gone offline during the test. This is an acceptable normal occurrence and is even an opportunity to illustrate how the Central System can detect a device's health.
- A graph of the messages ingested over time does not show any clear signs of downtime, as described in the above bullet points.

Fail Criteria:

The test is considered a failure if more than 20% of the total set of test RSUs fail to have 95% of expected transmitted TIM messages forwarded to the Central System during the 1-week test period.

Test Case 5-2 Test Failure Remediation:

If a location fails, proceed with the following steps:

- Remediation of Partial RSU Failure (one or more RSUs affected): If one or more RSUs temporarily stop or fail to continuously transmit TIM messages during the test period:
 - o Investigate the affected RSUs to identify potential causes of the interruption (e.g., was the device offline for any time period?).
 - o Review historical device and network connectivity data to determine whether the RSUs were offline during the observed ingestion gaps (e.g., was there a communications loss? Was there a sensor fault?).
 - o The test may be rerun for the affected RSUs, or alternate RSUs may be selected if any devices experienced extended or complete outages. Rerunning the test is optional, as the Central System's ability to detect and report RSU health issues is still demonstrated.
- Systemic Failure (all RSUs affected): If all RSUs temporarily stop or fail to transmit TIM messages during the test period:
 - o Investigate the Central System for interruptions or failures in message ingestion.
 - o Identify and document the root cause of the system-wide data loss.
 - o The test will likely need to be restarted and executed in full once the issue has been identified and resolved.

2.3.1.5.1.3 Test Case 5-3: Validate Central System Monitoring Detects Offline RSU

Summary of Test Case 5-3:

UDOT and CDOT will select five RSUs from the CTW Program expansion that are actively monitored by the Central System via V2X message reception or ICMP ping responses. Prior to test initiation, each selected RSU will be verified as online. Testers will then power off the RSUs or, if power cycling is not feasible, disable their V2X stacks for the duration of the test case to be fully performed.

Loss of RSU connectivity will be confirmed via ICMP failure or cessation of V2X message transmission (SPaT or TIM, depending on installation location). Following this verification, the RSUs will be powered on or re-enabled. The Central System will subsequently be used to confirm restoration of normal operation and message transmission.

Assets to be used to complete Test Case 5-3 will include:

- UDOT Central System (i.e., UDOT V2X MMS).
- UDOT RSUs (5).
- CDOT Central System (i.e., ODE).

- CDOT RSUs (5).

General description of roles for Test Case 5-3:

- UDOT and CDOT will both be executing this test procedure, as they both have expanded deployment sites as part of their CTW Program commitments.
- UDOT and CDOT Central System operators will perform ICMP or Central System message ingestion inspections to determine the status of the selected RSUs.

Expected Results of Test Case 5-3:

The Central System detects when the five selected RSUs go offline due to device power-off or disabling of V2X functionality. It subsequently detects when the RSUs return to an operational state once they are restored.

Test Case 5-3 Test Procedures:

1. Identify and select five RSUs from the CTW deployment that are actively monitored by the Central System.
2. Verify each RSU is operational by confirming one of the following:
 - a. Successful ICMP ping responses.
 - b. Active transmission and receipt of V2X messages (e.g., SPaT or TIM, as applicable).
3. Ensure the Central System is actively displaying or logging RSU status by confirming that all five selected RSUs are reported as online/operational within the Central System.
4. Induce offline conditions for each RSU by powering off the device or disabling its V2X functionality.
 - a. This offline condition should be able to last for an extended period of time. (~1 day if necessary).
5. Verify the offline status of the RSUs through the Central System's detection capabilities by confirming one of the following:
 - a. Loss of ICMP response.
 - b. Cessation of V2X message forwarding (e.g., SPaT or TIM, as applicable).
6. Restore the five RSUs to operational status.
7. Verify the online status of the RSUs through the Central System's detection capabilities.

Test Case 5-3 Test Data:

Test data shall consist of RSU status records collected over the course of test execution. The control dataset shall be defined as the baseline online status of the five selected RSUs, established prior to inducing any offline state.

Test Case 5-3 Measurement/Verification Method:

Inspection and analysis of Central System logs and ICMP responses.

Test Case 5-3 Pass/Fail Criteria.

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

The test case passes if the Central System for each CTW state successfully performs the following:

- Detects and reports a transition to an offline/unavailable state for each of the five selected RSUs following device power-off or disabling of V2X functionality.
- Detects and reports a transition back to an online/operational state for each RSU after restoration of normal operation.
- Detection of both offline and restored states occurs within an acceptable time window of 1 hour.
- System logs, alerts, or dashboards provide clear and traceable evidence of each status transition event.

Fail Criteria:

The test is considered a failure if any of the following occur:

- The Central System fails to detect and report the offline state for one or more RSUs.
- The Central System fails to detect and report the return to an operational state for one or more RSUs.
- Status changes are not reflected within the acceptable detection time window of 1 hour.
- System outputs (logs, alerts, or dashboards) do not provide sufficient evidence of RSU status transitions.

Test Case 5-3 Test Failure Remediation.

Remediation of Partial RSU Failure (one or more RSUs affected):

- If one or more RSUs are not correctly detected as offline or restored during the test:
 - o Investigate the affected RSUs to confirm whether the offline condition was properly induced (e.g., device power state, V2X disablement).
 - o Review Central System logs, monitoring configurations, and data ingestion pathways to identify potential gaps in status detection.
 - o Verify network connectivity and ICMP behavior to determine whether the issue is device-side or system-side.
 - o The test may be rerun for the affected RSUs, or alternate RSUs may be selected if necessary.

Systemic Failure (all RSUs affected):

- If the Central System fails to detect status changes for all RSUs:
 - o Investigate the Central System for failures in monitoring, alerting, or data ingestion mechanisms.
 - o Identify and document the root cause of the system-wide detection failure.

- o Validate system configuration and dependencies before re-executing the test.

2.3.1.6 Test Plan STP-6: Field Equipment Compatibility

Brief Description:

Test plan STP-6 consists of three test cases to test various requirements related to Field Equipment interoperability:

- **Test Case 6-1** will verify that new Field Equipment (RSUs) can receive messages that are compliant with the SAE J2735 standards and with the CTI-4501 and SAE J3224 recommendations.
- **Test Case 6-2** will verify that new RSUs can send messages that are compliant with the J2735 standard and that OBUs can receive messages with SCMS credentials. This shall be observable by a vehicle driving through with OBU logging active.
- **Test Case 6-3** will verify that new RSUs are interoperable with the Central System by observing the Central System RSU health monitoring interface and sending TIM messages from the Central System to the RSUs.

Test Objective:

The objective of STP-6 is to confirm that RSUs deployed in the CTW Program can send and receive messages that comply with necessary standards and are interoperable with existing legacy systems.

Requirements to be Verified:

The CTW System Requirements to be verified by conducting STP-6 are:

- FE-1.1 Field Equipment receive messages in compatible SAE J2735 versions. All CTW Field Equipment added through this effort shall be capable of receiving and processing messages as defined in J2735 standards in all of the following versions: 2016, 2020, and 2024.
- FE-1.2 Field Equipment send messages in compatible SAE J2735 versions. CTW Field Equipment added through this effort that generate messages shall generate and send messages as defined in SAE J2735 according to one of the following versions: 2016, 2020, 2024.
- FE-4 CI expansion sites shall continue adherence to CTI 4501/1. CI expansion sites shall follow CTI 4501/1 to the extent possible considering legacy systems involved (e.g., traffic signal controllers) as of April 2025 and as determined in the design process.
- FE-6 Connected Roadway expansion sites interoperable with legacy Central Systems. RSUs deployed at Connected Roadway expansion sites shall be interoperable with legacy Central Systems deployed in Utah and Colorado as described in the CTW ConOps Sections 3.2.2 (Utah) and 3.4.2 (Colorado).
- FE-8 SCMS credentialing interoperability Connected Roadway expansions. SCMS credentialing on Connected Roadway and CI expansion sites shall be interoperable with credentialing performed for existing CTW systems, as defined in the CTW ConOps Sections 3.2 and 3.4.
- FE-10 SDSM messages interoperable to legacy systems. SDSM messages broadcast by VRU Safety Systems in expansion sites shall be as defined in SAE J3224.

- FE-11 Process SCMS certificates from external agency fleet vehicles. RSUs in CTW states shall have the capability to validate SCMS certificates that accompany messages broadcast by fleet vehicles owned by other CTW sites.

Test Duration:

The duration of STP-6 is shown in Table 7 below:

Table 7: Estimated Duration to Conduct STP-6

Source: CTW Team, April 2026

Test Case	Setup	Data Collection/ Perform Test	Analysis	Total Estimated Days	Reserved for Remediation and Retesting
Test Case 6-1	1 day	3 calendar days	1 week (5 days)	9 calendar days	1 – 2 weeks (10 days)
Test Case 6-2	1 day	1 day	1 week (5 days)	7 calendar days	1 – 2 weeks (10 days)
Test Case 6-3	1 day	1 day	1 week (5 days)	7 calendar days	1 – 2 weeks (10 days)

This timeline assumes that testing and coordination of RSUs with Central System was completed in advance of starting data collection/testing and therefore does not consider time associated with setup. Access to RSU and setup of vehicle equipped with OBU is also not considered in this estimated duration table.

Prerequisite Test Setup and Configuration:

The prerequisites needed to execute the following test cases are as follows:

- RSU configuration:
 - o Verify the operations of the RSUs and confirm that RSUs are installed in the field and functional.
 - o A series of RSUs shall be prepared with their SCMS enrolled with up-to-date certificates.
 - o The number of RSUs to be included in the test will be defined by the test team. This is the value that will be used to determine if 75% of the RSUs are operational (as outlined below).
- Test vehicle:
 - o A vehicle shall be equipped with an OBU with its SCMS enrolled with up-to-date certificates.
- Test tool:
 - o A non-standard, custom version of Wireshark to analyze the OBU log captures.
- Central Systems:
 - o Central Systems shall be functional and connected to the RSUs under test prior to beginning data collection.

- o For CIs (Utah only), confirm that the Connected Intersection Message Monitoring System (CIMMS) application or an equivalent application capable of performing basic CTI-4501 conformance checks on MAPs, SPATs, and RTCMs is configured within or in conjunction with the Central System.
- o Configure Central System to allow TMC Operator access.
- o The Central System is configured to deduplicate messages and testers are aware of this before test execution.

2.3.1.6.1 Test Cases (Including Procedures, Data, Anticipated Results, and Test Failure Remediation Approach)

2.3.1.6.1.1 Test Case 6-1: Field Equipment Compatibility – Receipt of J2735, CTI-4501, and SAE J3224 Compliant Messages with Interoperable SCMS Signatures

Summary of Test Case 6-1:

Test Case 6-1 will test that the RSU equipment is operational in the field and meets requirements. The plan is to test 10% of the new RSUs installed or a minimum of 15 RSUs. Therefore, Test Case 6-1 will involve:

- 48 RSUs at Utah intersections.
- 15 RSUs along Utah Connected Roadways.
- 15 RSUs along Colorado Connected Roadways.

The rationale for these numbers is as follows:

- The RSUs all undergo limited testing during installation (e.g, power and communications); therefore, there is not the need to verify that all RSUs are operational.
- Since RSUs within each CTW state are deployed with the similar approach to configurations, hardware, software (i.e., all Utah RSUs at intersections are similar, all Utah RSUs at Connected Roadways are similar, all Colorado RSUs are similar), there is not the need to expend resources testing each one.
- 10% will ensure that a representative sample is tested.
- Using a minimum of 15 RSUs (when 10% is less) allows enough of a sample size to represent the RSUs, while also enabling one or two errors to occur and still pass.

To accomplish this, activities will collect ASN.1 messages received by each new RSU being tested and forward these to a central database and decode them with an ASN.1 codec compiled from the standard. Standards conformance will be checked using CIMMS where possible and manual inspections will supplement the automated analysis, where necessary.

Requirements Verified:

The CTW System Requirements verified by Test Case 6-1 are:

- FE-1.1 Field Equipment receive messages in compatible SAE J2735 versions.

- FE-4 CI expansion sites shall continue adherence to CTI 4501/1.
- FE-6 Connected Roadway expansion sites interoperable with legacy Central Systems.
- FE-8 SCMS credentialing interoperability Connected Roadway expansions.
- FE-10 SDSM messages interoperable to legacy systems.

Assets to be used to complete Test Case 6-1 will include:

- UDOT and CDOT Central Systems for message ingestion, storage, and querying
- UDOT and CDOT RSUs.
- CIMMS connected to Utah CIs for analysis of CTI 4501 compliance of messages.

General description of roles:

- UDOT and CDOT will execute this test case.
- UDOT and CDOT Central System operators will monitor RSUs.
- CTW team members will conduct CIMMS analysis of messages.

Test Location:

Testing will be conducted in a location with access to the Central System that is receiving data from the RSUs.

Test Case 6-1 Test Procedures:

The steps and procedures that will be followed to complete the test procedure for Test Case 6-1 are:

1. Collect data in the Central System database forwarded from the selected new RSUs. This data is to be tested for 1 week to obtain a representative sample of all the message types of interest spanning various times of day, and days of the week. For CI data, the stored data may be deduplicated during testing.
2. Perform daily spot checks during data collection to verify that messages are being ingested into the Central System's database from at least 75% of the RSUs under test. The 75% is the percentage of RSUs tested during spot checking, not a pass or fail threshold. This is a number believed to be representative that testing should continue and that the system is operational to deliver the target results. Remediate by repairing RSUs and infrastructure as needed during this phase if there are a significant number of offline/erroring RSUs that could result in failure in step 3.
3. Query the database collections containing the raw ASN.1 messages with SCMS headers received from all of the new CTW RSUs over the collection period. Extract the raw UPER-encoded J2735 message frames. Examine the data set to identify if each message type of interest is in the dataset.

Step 3 Expected Result: A data set containing raw ASN.1 messages in UPER hex format with examples of each message type of interest: BSM, MAP, SPAT, SRM, SSM, SDSM, RTCM, TIM, and containing messages from each RSU of interest. Note that each RSU will not have all message types of interest; collectively, there will be examples of each message type.

Step 3 Pass/Fail:

Remarks: The collective presence of each message type across the sample of tested RSUs demonstrates that each RSU is capable of sending those messages to the Central System.

Expected message types vary with RSU location, and not all RSUs are expected to produce all message types, although they are capable of doing so.

The presence of BSMs indicates that the RSUs are receiving those messages from OBUs. Note that some RSUs may go offline or be in need of maintenance during the test period. Also, the RSUs that are expected to receive messages may have situations that prevent this (e.g., expected transit vehicles may not pass due to roadwork or schedule changes). For these reasons, a threshold of 75% has been identified to allow for these, and other, situations.

- a. PASS per RSU if examples of each message type that would be expected are found.
 - b. FAIL per RSU if there are no examples of message types present for each RSU that should have them, including:
 - i. FAIL RSUs at CI RSUs with no SPATs or MAPs
 - ii. FAIL RSUs at CIs that should be transmitting RTCMs and/or SDSMs if they are absent.
 - iii. FAIL RSUs at CIs that would be expected to have received BSMs from frequent public transit vehicle traffic if those are absent (note that there are some CIs not on transit routes and would only receive BSM if an emergency vehicle or snowplow was passing). An exception will be made for intersections with light V2X equipped vehicle traffic upon manual inspection of the data and knowledge of traffic patterns at the site.
 - iv. FAIL RSUs on highway corridors that should have TIMs if those are absent.
 - c. PASS this step if at least 75% of the new RSUs pass the above criteria regarding message types.
 - d. FAIL this step if fewer than 75% of the new RSUs pass. Proceed to the following steps if at least 25% of the RSUs passed and produced useful data before returning to this test case.
4. Query the database collections containing the decoded ASN.1 message types of interest for the RSUs of interest over the collection period.

Expected Result: A data set containing decoded messages in a textual, human-readable format (such as JSON), with examples of each message type of interest, and containing messages from each RSU of interest, and no decoding error messages.

Note that some RSUs may go offline or be in need of maintenance during the test period. Also, the RSUs that are expected to receive messages may have situations that prevent this (e.g., expected transit vehicles may not pass due to roadwork or schedule changes). For these reasons, a threshold of 75% has been identified to allow for these, and other, situations.

Step 4 Pass/Fail:

- a. PASS each RSU if successfully decoded examples of each message type are found for each selected RSU that produced messages in Step 2.
- b. FAIL each RSU if any raw message from Step 2 was not decoded or decoded with an error message.
- c. PASS this step if 75% or more of RSUs pass.
- d. FAIL this step if fewer than 75% of RSUs pass.

5. Basic CTI-4501 Message Validation (Utah only and only for RSUs at CIs, skip for highway corridor RSUs):

Query the database to obtain the processed messages output by the single-message CTI-4501 validation results of MAP, SPAT, and RTCM messages for the RSUs of interest over the selected period. CIMMS provides this information in the ProcessedMap, ProcessedSpat, and ProcessedRTCM collections. Examine the messages for validation errors.

Expected Result: A data set containing "ProcessedMap," "ProcessedSpat," and (if applicable to the state) "ProcessedRTCM" messages in JSON format.

Step 5 Pass/Fail:

- a. PASS per RSU if there are no messages with validation errors and the "is CTI-4501 compliant" flag is true.
 - b. FAIL per RSU if there are any validation errors, such as required CTI-4501 elements that are missing, or forbidden elements that are present, and the "is CTI-4501 compliant" flag is false for any messages.
 - c. PASS this step if 90% of RSUs with data available have no conformance issues. Note that 90% was selected to allow for possible errors due to routine issues.
 - d. FAIL this step if fewer than 90% of RSUs with data available have no conformance issues.
6. Additional CTI-4501 Validation Checks (Utah only and only for RSUs at CIs, skip for highway corridor RSUs). Expected Result: The dataset includes no events that contain conformance issues that cannot be explained (e.g., if situations arise where there is a reason why a non-conforming data was found).
 - a. Query the database to obtain any events indicating conformance issues produced by the CIMMS or equivalent for the new RSUs, including:
 - i. Broadcast Rate Events.
 - ii. Intersection and Signal Group Alignment Events.
 - iii. Message Count Progression Events
 - iv. Revocable/Enabled Lane Alignment Events
 - v. Signal Progression Events
 - vi. SPAT Time Change Details Events
 - vii. RTCM Events
 - viii. SSM/SRM Events
 - ix. RSU Broadcast Validation (near neighbor) Events
 - x. Direction of Travel Events
 1. This event is produced by BSM activity that requires manual confirmation.
 - xi. Connection of Travel Events
 1. This event is produced by BSM activity that requires manual confirmation.
 - xii. Stop Line Events
 1. This event is produced by BSM activity that requires manual confirmation.

b. Step 6 Pass/Fail:

Remarks: Note that some CIMMS events such as Stop Line Passage and Connection of Travel events rely on inference based on BSM behavior. If such events are observed, manual inspection of MAP messages may be necessary to confirm if their geometry and connections are CTI-4501 compliant. If there are such events, then perform manual spot checks using the Central System to visualize the MAP/SPAT and BSM messages that caused the conformance events, as needed to confirm or rule out a conformance issue.

- i. PASS per RSU if there are no CIMMS events indicating CTI-4501 non-compliance, or if manual verification of suggestive events rules out an issue.
 - ii. FAIL per RSU if there are CIMMS events that definitively indicate CTI-4501 non-compliance, or if there were any conformance issues confirmed by manual inspection of suggestive events.
 - iii. PASS this step if 90% of RSUs with data available have no conformance issues. Note that 90% was selected to allow for possible errors due to routine issues.
 - iv. FAIL this step if fewer than 90% of RSUs with data available have no conformance issues.
7. SAE J3224 Validation: For states where applicable (Utah only), extract the decoded SDSM messages from the dataset from Step 2. Examine them to verify that all required data in SAE J3224 (2022) Table 4 “Minimum criteria for SDSM transmission, detected VRU data” are present.

Expected Result: A data set containing decoded SDSM messages.

Step 7 Pass/Fail:

Remarks:

- a. PASS per RSU if all SDSM messages have all the required fields.
 - b. FAIL per RSU if any SDSM messages are missing required fields.
 - c. PASS this step if $\geq 90\%$ of RSUs pass.
 - d. FAIL this step if $\leq 90\%$ of RSUs pass.
8. Decode the SCMS Octet Encoding Rules (OER) headers collected in Step 1 with an IEEE 1609.2 codec compiled from the standard, for example by using a custom Wireshark build capable of decoding the messages or an online tool such as the ISS tool.

Expected Result: A set of decoded SCMS headers.

Step 8 Pass/Fail:

Remarks:

- a. PASS per RSU if the 1609.2 headers can be decoded.
- b. FAIL per RSU if the 1609.2 headers have decoding errors.
- c. PASS this step if $\geq 90\%$ of RSUs pass.
- d. FAIL this step if $\leq 90\%$ of RSUs pass.

Test Case 6-1 Test Data:

The test data will consist of ASN.1 messages in UPER hex format that include the message types of interest: BSM, MAP, SPAT, SRM, SSM, SDSM, RTCM, TIM and containing messages from each RSU of interest.

CIMMS output describing 4501 compliance will be data that is also analyzed as part of this test. See Appendix A to this ORP document describing the fields produced by CIMMS evaluation.

Test Case 6-1 Measurement/Verification Method:

Analysis and inspection, primarily of the CIMMS outputs. With manual inspection of data where required.

Test Case 6-1 Pass/Fail Criteria:

Individual pass/fail criteria for each step in Test Case 6-1 were identified in the steps above. An overall “pass” requires all applicable test steps to have passed.

Test Case 6-1 Failure Remediation:

Daily spot check shall be conducted to ensure at least 75% of the RSUs identified for this test are online and providing data during the test, to ensure success of subsequent steps. If it is not possible to have the Central System online with at least 75% of the RSUs to test, the testing may be postponed until such a time as this is possible, or the validation tests may be performed with a smaller subset of RSUs.

If any of the validation steps fail for significant numbers of functional RSUs, remediation steps could include:

- Editing MAP messages to conform with CTI-4501 if any deficiencies are found.
- Consult with hardware vendors if any systemic issues with SPAT, RTCM, or SDSM conformance are found produced by hardware.
- Consult with SCMS vendors to remediate any SCMS issues.
- Repair or replace hardware if any RSUs produce invalid messages due to malfunctioning or idiosyncratic issues with an individual RSU.
- Repair telecommunication and computer systems if issues result in a significant number of messages being corrupted during transmission or storage.

2.3.1.6.1.2 Test Case 6-2: Field Equipment Compatibility – Sending J2735 Compliant Messages with Interoperable SCMS Signatures

Summary of Test Case 6-2:

Test Case 6-2 will test and verify that the new RSUs can send messages to be received by OBUs and also receive messages sent by the OBUs. A test-drive through a designated corridor in an OBU-equipped vehicle while actively collecting OBU logs will verify that RSUs are sending correct messages. Note that the purpose of this drive-through is to test the functionality of the RSUs sending, not to test the OBUs themselves, although an OBU is used as a tool to do the test. Specifically, TIMs and SDSM messages will be tested.

Assets to be used to complete Test Case 6-2 will include:

- UDOT and CDOT Central Systems for TIM message creation and sending to RSUs.
- Five UDOT and five CDOT RSUs to broadcast messages to be received by OBUs. All RSUs will broadcast TIMs (i.e., both Colorado and Utah), and one RSU in Utah will also broadcast SDSMs. The RSUs will also receive messages broadcast by OBUs (BSMs).
- VRU Safety Systems installed at selected Utah intersections to generate SDSM messages.
- OBUs with ability to capture and retain OBU logs of the messages received.
- Wireshark to view/examine OBU data logs.

General description of roles:

- UDOT and CDOT will execute this test case.
- UDOT and CDOT Central System operators will monitor RSUs to ensure messages are broadcast and received.
- CTW team members will conduct CIMMS analysis of messages received by OBUs.

Requirements Verified:

The CTW System Requirements verified by Test Case 6-2 are:

- FE-1.2 Field Equipment send messages in compatible SAE J2735 versions.
- FE-10 SDSM messages interoperable to legacy systems.
- FE-11 Process SCMS certificates from external agency fleet vehicles.

Test Location:

The location of data collection/test-drive will be within the test-vehicle driving through the corridor, and data analysis will be conducted in office. The corridor will include an RSU(s) broadcasting TIMs and SDSMs.

Test Case 6-2 Test Procedures:

The steps and procedures that will be followed to complete the test procedure for Test Case 6-2 are:

1. Drive along a route to pass the five RSUs identified above while the RSUs are transmitting TIM messages and SDSMs. Collect OBU log data. Expected Result: A collection of OBU logs.
2. Analyze the OBU log captures using a tool such as a custom version of Wireshark to extract the ASN.1 messages. Expected Result: A collection of raw ASN.1 data.
3. Extract the J2735 messages of interest from the logs, including TIM, SDSMs and other messages, and verify that they are compliant with J2735 by decoding them with a J2735 codec compiled from the 2024 standard. Expected Result: A collection of decoded J2735 message frames.

Test Case 6-2 Test Data:

The test data will consist of messages received and logged by the OBUs. Messages shall be decoded with Wireshark or a J2735 codec to verify that their compliance.

Test Case 6-2 Measurement/Verification Method:

Analysis and inspection.

Test Case 6-2 Pass/Fail Criteria:

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

The test case passes if the RSUs can successfully send and receive messages between the OBUs in the correct format and in compliance with necessary standards. The test case is considered passed if the following requirements are met:

- PASS individual RSUs if valid TIM and SDSM (where appropriate) are logged on the OBU and can be decoded by a conforming codec.
- PASS individual RSUs if BSMs from passing OBUs are received and logged by RSUs.

Fail Criteria:

- The test case is considered failed if OBU log data cannot be extracted and decoded for every RSU, specifically the minimum of TIM and SDSM messages, indicating that the messages were not successfully received from the RSUs.

Test Case 6-2 Failure Remediation:

If valid data cannot be collected for any reason during the drive-through, attempt the drive-through again. Troubleshoot the RSUs to ensure that messages are being generated and broadcast. Troubleshoot any issues related to SCMS.

2.3.1.6.1.3 Test Case 6-3: Field Equipment Compatibility – Expanded Connected Roadway Sites Interoperable with Legacy Central Systems

Summary of Test Case 6-3:

Test Case 6-3 will test that the Central Systems in Utah and Colorado are interoperable with expanded Connected Roadway site RSUs by examining two directions of data exchanges, as follows:

- Test Case 6-3 will test that Central Systems can monitor the health of expanded RSUs demonstrating the ability to request and receive status from the RSU.
- Test Case 6-3 will test that Central Systems can send TIM messages to the expanded RSUs, demonstrating the ability to send messages to the RSUs.

To test this, a member of the test team will use the Central System to view the status of at least 75% of the RSUs that were added through the CTW Program. 75% is selected because of the desire to test

enough RSUs for there to be a variety of status reports (e.g., different messages displayed, different status of devices, etc.) and to have confidence they are interoperable with the Central System, but also 100% is not needed because this testing is not a substitute for the initial testing for communications and power that accompanied installation.

To support the other aspect of this test case described above, operators will also create TIMs and send the TIM messages to the new RSUs for broadcast. To demonstrate this, operators will create five TIMs in Utah and five TIMs in Colorado and send the TIMs to appropriate RSUs.

Assets to be used to complete Test Case 6-3 will include:

- UDOT and CDOT Central Systems for monitoring RSU health and to support TIM message creation and sending to RSUs.
- UDOT and CDOT RSUs to support testing if the Central System is monitoring the RSU health.

General description of roles:

- UDOT and CDOT will execute this test case.
- UDOT and CDOT Central System operators will use the Central System to access the RSUs installed through the CTW Program to view the status and overall health of each RSU.
- CTW team members will document outcomes.

Requirements Verified:

The CTW System Requirements verified by Test Case 6-3 are:

- FE-6 Connected Roadway expansion sites interoperable with legacy Central Systems.

Test Location:

- Utah Testing: UDOT Central System and selected RSUs added by the CTW Program.
- Colorado Testing: CDOT Central System and selected RSUs added by the CTW Program.

Anticipated Results of Test Case 6-3:

Test participants using the Central Systems in Utah and Colorado can use the Central Systems to view the new RSUs with monitoring information. All RSUs requested return monitoring information.

Operators using the Central Systems in Utah and Colorado successfully create five TIMs and send the TIMs to at least five of the new RSUs.

Test Case 6-3 Test Procedures:

The steps and procedures that will be followed to complete the test procedure for Test Case 6-3 are:

1. Examine the UI provided by the Central Systems to verify whether the new RSUs are visible and provide active health monitoring.

Expected Result: The Central System displays the new RSUs with monitoring information.

Pass/Fail:

2. TMC personnel create a test TIM message using the Central System. Expected Result: A TIM message is created.
3. After a time, use the Central System to observe the status of the RSUs and verify that the TIMs are being broadcast. Expected Result: Visual confirmation that the TIM is being broadcast and/or data logs generated by the Central System confirming the TIM is broadcasting.

Test Case 6-3 Test Data:

The test data will consist of monitoring the health of RSUs and assessing whether information can be displayed and observed in the Central System interface.

Test Case 6-3 Measurement/Verification Method:

Selection of RSUs along Interstates and Rural Corridors and visual inspection in the Central System UI to verify that these RSUs are reporting data and confirmation that the TIMs broadcast by the RSUs match the TIMs originally sent by the Central Systems. Note that other test cases are examining RSUs at CIs.

Test Case 6-3 Pass/Fail Criteria:

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

The test case is considered passed if the following requirements are met:

- PASS if at least 75% of the new RSUs are observed to be providing active status monitoring information. The RSU status need not be healthy, but the status must be able to be accurately monitored whether it is healthy or in an error state.
- PASS if a TIM message can be created.
- PASS if the TIM message was distributed to RSUs as evidenced by the Central System.

Fail Criteria:

- The test case is considered failed if RSU health monitoring is not functional or if TIM messages cannot be created.

Test Case 6-3 Test Failure Remediation:

If an insufficient number of RSUs are able to be monitored by the Central System, repair the RSUs or address network or other issues preventing communicating with the RSUs to meet the criterion.

If a TIM message cannot be created and sent to the RSU, work with the Central System vendor to troubleshoot.

2.3.1.7 Test Plan STP-7: Field Equipment Deployment Locations

Brief Description:

Test Plan STP-7 outlines the desktop-based verification procedures that will be executed to ensure that expansion sites for connected vehicle Field Equipment, such as RSUs, are strategically located to meet specific operational requirements.

Test participants will use mapping tools and visual inspection to evaluate a random 75% sample of deployment sites across participating states to conduct two types of analyses, performed separately for RSUs deployed at intersections and along rural and Interstate roadways and summarized as follows:

- **CIIs Site Analysis:** Test activities will confirm that selected intersection sites have existing power/communications and sit along active routes for V2X-equipped transit buses, snowplows, or emergency vehicles. It also checks that required coordination with local transit agencies is underway.
- **Connected Roadways Site Analysis:** Test activities will confirm that equipment meant to broadcast TIMs and gather vehicle safety data is deployed along major traffic corridors, specifically interstates, U.S. numbered routes, or state highways (such as I-70 in Colorado).

To align with CTW deployments, STP-7 tests are assigned by state as follows:

- UDOT: Executes both test cases (1 and 2).
- CDOT: Executes Test Case 2 only.
- WYDOT: Exempt from this test plan.

Test Objective:

This test will verify that CTW Program expansion locations are appropriate for V2X equipment. Specific objectives are as follows:

- Verify that the Field Equipment deployment locations adhere to earlier qualifications and that they support the use of transit, snowplows and emergency vehicles.
- Verify that CIPT and roadway expansion sites are in locations where existing or planned vehicular traffic can be supported according to each need/use case.

Requirements to be Verified:

The CTW System Requirements to be verified by conducting STP-7 include:

- FE-2.1 Expansion sites support transit use. Expansion sites for CIPT shall include intersections along core transit routes that would benefit from improved schedule adherence.
- FE-2.2 Expansion sites support snowplow use. Expansion sites for CIPT shall include intersections along UDOT snowplow routes and where snowplows are (or planned to be) equipped to send CIPT requests.
- FE-2.3 Expansion sites support emergency vehicle use. Expansion sites for CIPT shall include intersections used by emergency vehicles that are (or planned to be) equipped to send CIPT requests.

- FE-3 CI expansion sites to address needs. CI expansion sites supporting CIPT shall be in locations where there is existing or planned vehicular traffic that will be equipped to submit priority requests.
- FE-5 Connected Roadway expansion sites to address needs. RSUs deployed at Connected Roadway expansion sites shall be in locations where there is current or planned vehicular traffic that will be equipped to receive messages.
- FE-7 Connected Roadway expansion sites to address needs. Connected Roadway expansion sites that receive BSMs broadcast by passing vehicles shall be in locations where existing or planned equipped vehicles travel.

Test Location(s):

Test Case 1 will be conducted at UDOT offices. Test Case 2 will be conducted at UDOT offices (for Utah deployments) and CDOT offices (for Colorado deployments).

Test Duration:

The duration of STP-7 is described as follows:

- Test setup: Approximately 1 day per test case.
- Conduct tests (i.e., collect data, analyze data, write summary report): 7 working days total (need not be consecutive) and will not require full-time commitment to the testing.

Additional time may be required depending upon test failure remediation measures, estimated as follows:

- Additional 1–4 days if one or more minor issues are identified in the results of the original test case.

The duration of STP-7 is also described in Table 8 below.

Table 8: Estimated Duration to Conduct STP-7

Source: CTW Team, April 2026

Test Case	Setup	Data Assembly and Analysis	Total Estimated Days	Reserved for Remediation and Retesting
Test Case 7-1	1 working day	3 working days	4 working days	2 working days
Test Case 7-2	1 working day	2 working days	3 working days	2 working days
Total All Test Cases	2 working days	5 working days	7 working days	4 working days

Prerequisite Test Setup and Configuration:

No prerequisites are needed to execute STP 7. Randomly select 75% of expanded CIPT and Connected Roadway sites to be evaluated. Create data collection tables based on the examples below to track the results of each step.

2.3.1.7.1 Test Cases (Including Procedures, Data, Anticipated Results, and Test Failure Remediation Approach)

2.3.1.7.1.1 Test Case 7-1: Field Equipment Deployment Locations – Expansion Sites Support Transit, Snowplow, and Emergency Vehicle Use

Summary of Test Case 7-1:

UDOT will verify that CIPT expansion sites include the ability to support transit, snowplow, and emergency vehicle use by confirming that one or more of these vehicle types use the intersections where V2X systems are expanded in the CTW Program.

The CTW System Requirements verified by the test procedure are:

- FE-2.1 Expansion sites support transit use.
- FE-2.2 Expansion sites support snowplow use.
- FE-2.3 Expansion sites support emergency vehicle use.
- FE-3 CI expansion sites to address needs.

Assets to be Used to complete Test Case 5-1 will include:

- List of CIPT locations.
- Online maps of transit and snowplow routes, as well as emergency response coverage areas.

General description of roles:

- The UDOT test observer(s) will review each location and track the results in each procedure.

Anticipated Results of Test Case 7-1:

- All proposed expanded CIPT locations should be capable of accommodating Roadside Equipment (RSE) installations.
- Not all the CIPT locations will be where there are core bus routes.
- All intersections with RSE are at intersections used by snowplows and emergency vehicles and can be configured to accommodate snowplow preemption and emergency vehicle preemption.
- Transit buses, snowplows, and emergency vehicles may not use every selected intersection, but each of these vehicle types use at least some of the selected locations.
- When in a transit service area, outreach, coordination, or agreements have been planned or executed with Utah Transit Authority (UTA) or other transit agencies to deploy OBE on buses that serve each selected CIPT location.

Test Case 7-1 Test Procedures:

1. Obtain the following data/information to be used in subsequent steps:
 - a. Maps or documents that show or describe the locations of power hookups and existing UDOT communications connections (i.e., fiber connections) in vicinity of CTW Program expansion sites.

- b. Data or maps describing snowplow routes.
 - c. Coverage areas of emergency response vehicles.
 - d. Maps or documents describing transit routes of vehicles equipped with V2X technology or planned through current or future expansions.
2. Examine the location of each selected RSU site to assess if the selected sites for expanding CIPT are locations where existing power hookups and communications are present and the proposed sites are locations where V2X RSE has not been previously deployed.
3. Confirm that selected sites are along corridors that meet at least one of the following:
 - a. Coincide with core transit bus routes.
 - b. Are where snowplows can send CIPT requests.
 - c. Are where emergency vehicles can send CIPT requests.
4. Collectively, confirm that selected sites are along corridors that collectively are used by at least one vehicle type (i.e., transit buses, snowplows, and emergency vehicles). See Figure 1 for a sample data recording table.
5. Verify that, in locations served by a transit service, outreach, coordination, or agreements have been either planned or executed with UTA or other transit agencies at selected CIPT locations to deploy OBE on their buses. In the final report, include a summary of the current status of agreements with all applicable transit agencies.
6. Prepare a report summarizing the findings.

Test Case 7-1 Test Data:

The test data will consist of the sources referenced by UDOT when completing the test case. Figure 1 illustrates the data collection form/spreadsheet that will be used by UDOT when capturing the data.

Signal or Cabinet ID	Step 1: Does the site have existing infrastructure?	Step 2: Does the CIPT location cover core transit bus routes, is used by snowplows, or is used by emergency vehicles?	Step 3: Does at least one vehicle type (transit buses, snowplows, and emergency vehicles) use at least one of the selected locations?	Step 4: Has outreach, coordination, or agreements been planned or executed with a transit agency to deploy OBE on buses that serve each selected CIPT location that is in a transit service area?	Notes	Overall Pass/Fail
Location ID	Pass/Fail	Pass/Fail	Pass/Fail	Pass/Fail		Pass/Fail

Figure 1: Test Case 7-1 Data Collection and Recording Format

Source: CTW Team, April 2026

Test Case 7-1 Measurement/Verification Method:

Visual inspection of the assembled data resources that describe the sites selected for CTW Program expansion.

Test Case 7-1 Pass/Fail Criteria:

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

The test passes if the selected locations for each state successfully perform the following:

- 100% of selected locations had existing infrastructure for new RSE.
- 100% of proposed CIPT locations serve transit bus routes or snowplows routes or emergency vehicle corridors.
- 100% of the CIPT location is outside a transit service area, or if it is within one and outreach, coordination, or agreements are planned or executed to deploy OBE on serving transit buses.

Fail Criteria:

Test fails when any of the following occur:

- If a location does not have existing infrastructure to accommodate new RSE.

- If there are CIPT locations that do not serve transit bus routes, nor snowplows routes, nor emergency vehicles corridors.
- If no outreach, coordination, or agreements have been planned or executed with a transit agency to deploy OBE on buses that serve each selected CIPT location that is in a transit service area.

Test Case 7-1 Test Failure Remediation:

If a location fails, proceed with the following steps:

- Check for upcoming changes to transit routes or state plowing routes to see if they resolve the failure.
- If the failure persists, reevaluate the CIPT RSU location and document any extenuating factors that justify keeping the RSU in its current position.
- Barring extenuating factors, relocate the CIPT RSU to a passing location by evaluating nearby Intelligent Transportation System (ITS) sites to maintain optimal RSU spacing.

2.3.1.7.1.2 Test Case 7-2: Field Equipment Deployment Locations – Connected Roadway Sites to Address Needs

Summary of Test Case 7-2:

The selection of Interstates, U.S. numbered routes, and state highways as the primary metrics for roadway V2X deployment is rooted in their role as the backbone of regional mobility and economic throughput. UDOT and CDOT will verify that Connected Roadway locations are positioned in areas with existing or high-potential V2X-enabled traffic, prioritizing corridors where the immediate or anticipated utility of the technology is most pronounced. As V2X technology matures, major freight arteries and primary tourist routes are expected to be the earliest adopters.

For freight operators, the ability to receive timely and effective TIMs enables informed routing decisions, allowing them to efficiently traverse the region, especially during severe weather events. High-volume transit paths—particularly Interstates and U.S. numbered highways in Colorado and Utah—represent the highest density of long-haul commercial vehicles. Consequently, these routes provide the most robust locations for early-stage BSM data collection and performance validation. A core component of the CTW Program activities involves addressing travelers' critical need for real-time situational awareness. The CTW Program will prioritize the creation of TIMs specifically for Interstates, U.S. numbered routes, and state highways. Furthermore, focusing on heavy tourist routes will enhance safety in the future by delivering TIMs to drivers who may be less familiar with local road conditions and seasonal hazards.

By focusing on these high-capacity freight and tourist routes, the departments ensure that V2X infrastructure is deployed where the "network effect" is most likely to be triggered. Therefore, the physical presence of an Interstate, U.S. numbered route, or state highway in Utah—or I-70 in Colorado—serves as the primary metric for evaluating the viability and anticipated success of V2X-enabled traffic initiatives for Connected Roadway locations. This approach ensures that the limited initial RSU footprint is optimized for maximum impact on freight reliability, economic efficiency, and general traveler safety.

The CTW System Requirements verified by the test procedure are:

- FE-5 Connected Roadway expansion sites to address needs. RSUs deployed at Connected Roadway expansion sites shall be in locations where there is current or planned vehicular traffic that will be equipped to receive messages.
- FE-7 Connected Roadway expansion sites to address needs. Connected Roadway expansion sites that receive BSMs broadcast by passing vehicles shall be in locations where existing or planned equipped vehicles travel.

Assets to be used to complete Test Case 7-2 will include:

- List of Roadway RSU expansion locations.
- Online maps of transit and snowplow routes.

General description of roles:

- Test observer will review each location and track the results in each procedure.

Anticipated Results of Test Case 7-2:

- Each roadway RSU location is on an interstate, U.S. numbered route, or state highway.

Test Case 7-2 Test Procedures:

1. Compile the list of RSU locations for CTW RSU deployments along Connected Roadways in Utah and Colorado. Using the route identifier (e.g., I-70, US-6, US-191, SR-10), verify that each roadway RSU location is on an Interstate or along a U.S. or state numbered highway.
2. Complete a table verifying whether each location is along one of the selected route types.
3. (Optional): Import the location of CTW Program expansion RSUs into a map display to visually show the location of RSUs with highway identifiers.
4. Prepare a report summarizing the findings.

Test Case 7-2 Test Data:

The test data will consist of the sources referenced by UDOT and CDOT when completing the test case. Figure 2 illustrates the data collection form/spreadsheet that will be used by UDOT and CDOT when capturing the data.

Signal or Cabinet ID	Step 1: Is the RSU location along an Interstate, U.S. numbered route, or state highway?	Step 2: Does the CIPT location cover core transit bus routes, is used by snowplows, or is used by emergency vehicles?	Notes	Overall Pass/Fail
Location ID	Pass/Fail	Pass/Fail		Pass/Fail

Figure 2: Test Case 7-2 Data Collection and Recording Format

Source: CTW Team, April 2026

Test Case 7-2 Measurement/Verification Method:

Visual inspection of the assembled data resources that describe the sites selected for CTW Program expansion

Test Case 7-2 Pass/Fail Criteria:

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

The test passes if the selected locations for each state successfully perform the following:

- The test passes if 100% of the roadway RSU locations are serving an Interstate, U.S. numbered route, or state highway.

Fail Criteria:

Test fails when any of the following occur:

- The test fails if any of the roadway RSU locations are not serving an Interstate, U.S. numbered route, or state highway

Test Case 7-2 Test Failure Remediation:

If a location fails, proceed with the following steps:

- Check for upcoming changes to state routes to see if they resolve the failure.
- If the failure persists, reevaluate the roadway RSU location and document any extenuating factors that justify keeping the RSU in its current position.
- Barring extenuating factors, relocate the Roadway RSU to a passing location by evaluating nearby ITS sites to maintain optimal RSU spacing.

2.3.1.8 Test Plan STP-8: SCMS Top-Off Without Cellular Communications

Brief Description:

Test plan STP-8 consists of two parts. Part 1 will verify that Vehicle Systems without cellular communications can receive SCMS top-offs using Wi-Fi connections at selected DOT facilities or fleet depots. Part 2 will then confirm post-top-off secure C-V2X operation. STP-8 consists of the following test cases:

- **Test Case 8-1: SCMS Top-Off Without Cellular Communications.** Test activities will validate the Wi-Fi-based top-off process and certificate installation.
- **Test Case 8-2: Verify RSU Receipt and Security Validation of Post-Top-Off Signed Messages.** Test activities will validate post-top-off secure message transmission by confirming RSU receipt and security validation of signed messages.

Test Objective:

The objective of STP-8 is to validate that fleet vehicles equipped with C-V2X OBUs can securely connect to Wi-Fi, reach the contracted SCMS provider, complete a top-off certificate, and resume secure V2X communications without relying on a cellular modem. To confirm this, the following objectives will be examined:

- Verify that available Wi-Fi networks can provide internet connectivity to vehicles without cellular service.
- Verify that OBUs successfully establish Wi-Fi connections and initiate SCMS certificate top-offs through approved secure channels.
- Verify that certificates are downloaded, validated, and stored in the OBU without corruption or timing errors.
- Verify that, after top-off, the OBU can resume secure V2X operation using the newly installed certificates, using a field-validation and log-analysis approach consistent with STP-6-1/ STP-6-2.

Requirements to be Verified:

The CTW System Requirements to be verified by the STP-8 test procedures include:

- FE-1.1 Field Equipment receive messages in compatible SAE J2735 versions. All CTW Field Equipment added through this effort shall be capable of receiving and processing messages as defined in J2735 standards in all of the following versions: 2016, 2020, and 2024.
- FE-12 Enable fleet vehicles to receive SCMS top-offs without cellular connection. Selected sites shall include the capability to enable C-V2X-equipped fleet vehicles without cellular connectivity to connect to the Internet through Wi-Fi to enable the fleet vehicles to download SCMS top-offs from the contracted SCMS provider.
- VS-4 Receive Wi-Fi top-offs of SCMS certificates. Vehicle Systems without cellular communications shall include the capability to establish internet connection through Wi-Fi to receive top-offs of SCMS certificates directly from contracted SCMS providers.

Test Location(s):

- Utah Testing: Four test sites, each consisting of a DOT facility (e.g., DOT fleet yard or maintenance depot) that are equipped with the necessary Wi-Fi for SCMS top-off and an associated CI for post-top-off RSU validation.
- Four CIs located within or around Salt Lake City with RSUs capable of receiving and logging signed messages. One test OBU will be assigned to each site/location pair. Across the four OBUs, two will be configured for the pseudonym certificate profile and two will be configured for the identity certificate profile.

Test Duration:

The duration and phases of the two test cases that make up STP-8 are shown in Table 9. The duration may vary slightly by location of the test but is estimated to take approximately 30–60 minutes at each location under normal operating conditions. The duration is as follows:

- Less than 1 hour for test setup, baseline checks, and OBU preparation.
- Less than 1 hour for execution of the Wi-Fi top-off procedure and verification of secure V2X operation.
- Field execution to operate within RSU coverage, transmit one signed BSM and capture RSU logs/Packet Capture (PCAP).
- Log/PCAP review, SCMS/security validation confirmation, and documentation of results.
- Additional time for mitigation, troubleshooting, and retest activities, if needed.
- Additional time may be needed for log review, documentation of results, and mitigation of any issues discovered during testing, if needed.

Table 9: Estimated Duration to Conduct STP-8

Source: CTW Team, April 2026

Test Case	Setup	Data Generation/Collection	Analysis	Total Estimated Days	Reserved for Remediation and Retesting
Test Case 8-1	<1 hour	1 day (30–60 minutes per location, four locations)	1 day	2 calendar days	1–2 weeks (10 days)
Test Case 8-2	<1 hour	1 day (30–60 minutes per location, four locations)	1 day	2 calendar days	1–2 weeks (10 days)

Prerequisite Test Setup and Configuration:

The prerequisites needed to execute the test procedures are as follows. First, identify four test site/location pairs, each consisting of one DOT facility for Wi-Fi top-off and one associated CI for RSU

validation. Confirm RSU logging and/or packet capture capability at each CI. The subsequent prerequisites for test setup include:

- DOT configuration:
 - o Verify that the Wi-Fi network provides secure internet access for parked fleet vehicles.
 - o Ensure outbound HTTPS traffic to the contracted SCMS provider endpoint is allowed through the facility network. Note that only one UDOT-contracted SCMS provider to participate in this STP.
 - o Enable detailed logging for Wi-Fi connection events, SCMS transactions, certificate download activity, and certificate validation processes.
- OBU configuration:
 - o Configure the test OBU Wi-Fi as a client using the Service Set Identifier (SSID) and password required to connect to the facility hotspot or depot network.
 - o Prepare tools and access needed for OBU log review and SCMS portal verification.
 - o Ensure the OBU software is configured to initiate SCMS top-off automatically upon Wi-Fi connection.
 - o Configure two OBUs for the pseudonym certificate profile and two OBUs for the identity certificate profile.
 - o Load or retain the OBU enrollment information and ensure the test OBU begins with expired SCMS certificates, while enrollment information remains present and valid.
- RSU configuration:
 - o Ensure tools are available to collect and retain RSU logs and packet captures (e.g., tcpdump/PCAP), and that timestamps are synchronized for correlation.
 - o Confirm the test vehicle can safely operate within RSU coverage at each test location and that message transmission can be triggered.

2.3.1.8.1 Test Cases (Including Procedures, Data, Anticipated Results, and Test Failure Remediation Approach)

2.3.1.8.1.1 Test Case 8-1: SCMS Top-Off Without Cellular Communications

Summary of Test Case 8-1:

Test Case 8-1 will validate an alternate method for SCMS top-offs using Wi-Fi at a DOT facility, fleet yard, or maintenance depot. Vehicles typically perform SCMS top-offs via cellular backhaul, but Test Case 8-1 aims to accomplish this without cellular communications. The test OBU begins without active SCMS certificates but retains its enrollment information. Upon startup, the OBU automatically connects to Wi-Fi, performs the SCMS top-off, installs new certificates, and is then checked to verify that it can resume secure V2X message signing. Post-top-off secure C-V2X operation will be verified using a field-validation approach consistent with STP-6-1/STP-6-2, preferably by transmitting an BSM at a CI and reviewing RSU logs for receipt and security validation. Baseline fleet snowplows already configured for Wi-Fi-based SCMS top-off may be used as reference vehicles, if needed, to confirm expected system behavior and connectivity.

Assets to be used to complete Test Case 8-1 will include:

- Four UDOT facilities with Wi-Fi connection.
- Four UDOT OBUs with SCMS enrollment completed and cellular connection disabled. Two will be configured for the pseudonym certificate profile, and two will be configured for the identity certificate profile.
- SCMS certificate subscription enabled.

General description of roles:

- UDOT will be the only DOT executing this test procedure, as it is the only CTW Program participant with expanded OBUs deployed in the CTW Program.
- UDOT staff and contractors will perform the process of moving the vehicles with OBUs into the UDOT facilities with Wi-Fi connections, then drive past the selected RSUs.
- UDOT staff or contractors will analyze the data packets from the RSUs to determine if SCMS certificate loading was successful.

Anticipated Results of Test Case 8-1:

- The OBUs successfully receive SCMS certificate updates without using cellular communications.

Pre-Test Conditions:

- Wi-Fi coverage is verified at the selected depot or facility location.
- The SCMS server endpoint is reachable from the facility network.
- The vehicle is powered and the OBU is operational.
- The OBU clock and system time are correct enough to support Transport Layer Security (TLS) and certificate validation.

Test Case 8-1 Test Procedures:

The steps and procedures that will be followed to complete the test procedure for Test Case 8-1 are:

1. Position the test vehicle or test OBU outside the coverage range of the facility Wi-Fi network and confirm that the test OBU is provisioned with expired SCMS application certificates with enrollment information remaining present and valid.
 - a. Expected Result: The OBU is in a state where secure message signing using existing application certificates is no longer valid, but the device remains capable of requesting SCMS top-off using its enrollment credentials.
 - b. Remarks: This step establishes the pre-top-off condition needed to demonstrate that the subsequent certificates were received through the Wi-Fi top-off process.
2. With the test vehicle or test OBU remaining outside the coverage range of the facility Wi-Fi network, power off the OBU or Vehicle System to simulate normal vehicle shutdown before the test startup sequence.
 - a. Expected Result: The OBU powers down safely and cleanly.

3. Restore power to the OBU to simulate vehicle startup and allow the device to complete its normal boot sequence.
 - a. Expected Result: The OBU reboots and initializes normal startup services, including the SCMS client or related certificate management processes.
4. Observe whether the OBU automatically connects to the depot or facility Wi-Fi network upon boot.
 - a. Expected Result: A successful Wi-Fi connection is established, the SSID is detected, and the OBU receives network parameters such as an Internet Protocol (IP) address.
5. Confirm that the OBU initiates an SCMS top-off through Wi-Fi within a reasonable time after connecting to the network and completes the certificate download process.
 - a. Expected Result: The OBU contacts the contracted SCMS provider, downloads new certificates, and installs them successfully.
 - b. Remarks: A successful result demonstrates that Wi-Fi can provide the necessary Internet path for SCMS top-offs without cellular connectivity.
6. Verify the SCMS connection and certificate issuance by reviewing the SCMS provider portal, ISS portal, or equivalent SCMS transaction logs.
 - a. Expected Result: The SCMS transaction record confirms that the OBU contacted the SCMS and that certificate issuance or download activity occurred for the test device.
7. Confirm that the OBU successfully validates and stores the newly obtained certificates in its local key store.
 - a. Expected Result: The new certificates are valid, trusted, and available for use by the OBU.
 - b. Measurement/Verification Method: Inspection and analysis of OBU certificate validation logs or key store status.

Test Case 8-1 Test Data:

- OBU certificate validation logs or key store status.
- OBU status and logs.
- Dynamic Host Configuration Protocol (DHCP) lease records.
- Network activity.
- SCMS logs or key store status.

Test Case 8-1 Measurement/Verification Method:

The verification method will consist of evaluating the performance of the OBU and the ability to initiate SCMS top-off procedures through Wi-Fi as follows:

- SCMS connections and associated certificates should be verified.
- Inspection and analysis of OBU certificate validation logs or key store status.
- Inspection and analysis of OBU status and logs, DHCP lease records, network activity, SCMS logs, or key store status.

Test Case 8-1 Pass/Fail Criteria:

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

The test case passes if the OBU shows all necessary information, connects to the Wi-Fi network, and does not encounter issues during the power on/off process. Also, SCMS records must be retained. Test Case 8-1 will be considered a pass if all of the criteria in the following bullets are successful:

- PASS if the OBU shows expired SCMS application certificates and retained enrollment information.
- PASS if the OBU shuts down cleanly and is ready for the restart sequence.
- PASS if the OBU completes boot successfully and the SCMS-related processes start normally.
- PASS if the OBU connects to the intended Wi-Fi network and receives usable network connectivity.
- PASS if the OBU reaches the SCMS provider through Wi-Fi and completes certificate download and installation without errors.
- PASS if the SCMS records confirm successful contact and issuance for the test OBU.
- PASS if the new certificates are accepted by the OBU and stored for operational use.

Fail Criteria:

This test case is considered failed if any of the following occur:

- Any of the above PASS criteria for Test Case 8-1 are not met.
- If SCMS certificates are not valid, enrollment information is missing, or the device is otherwise unable to attempt top-off.
- The OBU does not shut down cleanly, enters a boot loop, or fails to preserve the necessary certificate/enrollment state.
- There is a Transport Layer Security (TLS) handshake failure.
- SCMS endpoint is unreachable.
- Download data fails or times out.
- The SCMS shows issuance/authorization/rate-limit errors.

Test Case 8-1 Failure Remediation:

- If the OBU cannot connect to Wi-Fi, verify SSID configuration, credentials, signal coverage, DHCP behavior, and any MAC filtering at the facility.
- If the OBU reaches Wi-Fi but cannot reach the SCMS provider, review outbound firewall rules, Domain Name System (DNS) resolution, routing, proxy settings, and TLS certificate trust configuration.
- If the SCMS transaction fails due to authorization, rate-limit, or provider-side issues, coordinate with the SCMS provider to review logs and confirm the OBU configuration and enrollment status.

- If certificates download but are not accepted by the OBU, review OBU clock synchronization, certificate validation logic, key store capacity, and certificate installation procedures.

2.3.1.8.1.2 Test Case 8-2: Verify RSU Receipt and Security Validation of Post-Top-Off Signed Messages

Summary of Test Case 8-2:

Test Case 8-2 will validate post-top-off secure C-V2X operation by confirming that RSUs can receive and security-validate signed messages transmitted by OBUs using topped-off SCMS certificates. Following successful completion of STP-8-1, each test OBU will transmit at least one signed BSM at a CI. RSU logs and/or packet captures will be reviewed to confirm message receipt and security validation. This test is similar in approach to the RSU message receipt and evidence collection activities in STP-6-1.

Assets to be used to complete Test Case 8-2 will include:

- Four UDOT OBUs with SCMS certificates that have been successfully updated in Test Case 8-1. One OBU will be assigned to each test site/location pair; two OBUs will use the pseudonym certificate profile, and two OBUs will use the identity certificate profile.
- Four RSUs at the associated CIs that the OBU-equipped vehicles will pass while broadcasting signed BSMs.
- Tools to collect and retain RSU logs and packet captures.

General description of roles:

- UDOT staff and contractors will drive the four OBUs that received certificates in Test Case 8-1 past the selected RSUs, with one OBU tested at each site/location pair.
- UDOT staff or contractors will analyze the data packets from the RSUs to determine if SCMS certificate loading was successful.

Anticipated Results of Test Case 8-2:

- The OBUs that successfully received SCMS certificate in Test Case 8-1 send signed BSMs to the assigned RSUs, and the RSUs validates that the SCMS certificates are valid and store or log the received messages.

Pre-Test Conditions:

- CI RSUs are operational and within coverage of the planned test path.
- RSU logging and security-validation logging are enabled, and access is available for evidence collection.
- OBUs have completed SCMS top-off (per STP-8-1) and are configured for the assigned certificate profile.
- Time synchronization is sufficient to support certificate validation and log correlation.

Test Case 8-2 Test Procedures:

The steps and procedures that will be followed to complete the test procedure for Test Case 8-2 are:

1. At the selected test location, operate the test vehicle within range of the CI RSU and confirm the OBU is in normal operating state with topped-off certificates available for signing.
 - a. Expected Result: The test vehicle is within RSU coverage and the OBU is ready to transmit signed messages.
 - b. Remarks: This step establishes the post-top-off condition for message transmission testing.
2. Transmit one or more signed BSMs using the topped-off certificates and collect RSU-side evidence of receipt and security validation (logs and/or PCAP).
 - a. Expected Result: The RSU receives at least one signed BSM and evidence indicates the message is accepted as a valid secure message.
3. Repeat Steps 1 through 2 for each of the four test OBUs across the four site/location pairs, capturing evidence for each OBU and associated RSU.
 - a. Expected Result: Each OBU successfully transmits at least one signed BSM that is received and security-validated by the corresponding RSU.

Test Case 8-2 Test Data:

- OBU logs.
- RSU logs.
- Security validation logs.
- Packet captures.

Test Case 8-2 Measurement/Verification Method:

Measurement and validation will consist of evaluating OBU operations and confirming that RSUs can receive topped-off SCMS certificates transmitted by OBUs. Confirming that a signed BSM will be transmitted at each location, and RSU logs or packet captures will be reviewed as a method of confirmation. Members of the test team will:

- Observe and review OBU logs, RSU logs, and security-validation logs.
- Review packet captures demonstrating signed BSM receipt and validation.

Test Case 8-2 Pass/Fail Criteria:

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

The test case passes if each OBU that completed the Wi-Fi SCMS top-off in Test Case 8-1 is able to operate normally, transmit signed BSMs using the newly installed certificates, and have those messages received and security-validated by the assigned RSU. Also, RSU logs, security-validation logs, and/or packet captures must be retained. Test Case 8-2 will be considered a pass if all of the criteria in the following bullets are successful:

- PASS if the OBU is operational and ready to transmit signed messages using the topped-off certificates.

- PASS if at least one signed BSM is transmitted by the OBU at the assigned test location.
- PASS if the corresponding RSU receives the signed BSM.
- PASS if RSU logs, security-validation logs, and/or packet captures show that the received message was successfully security validated.
- PASS if all four OBUs demonstrate successful message receipt and security validation at their assigned locations.

Fail Criteria:

This test case is considered failed if any of the following occur:

- Any of the above PASS criteria for Test Case 8-2 are not met.
- The OBU is not operable or cannot enter a transmit-ready state.
- The signed BSM is not received by the corresponding RSU, or RSU indicates security-validation failure.

Test Case 8-2 Failure Remediation:

- If the OBU is not transmitting BSMs as expected; verify V2X applications are running; confirm message transmission triggers are enabled; and review OBU application logs for signing, key selection, or service restart issues after top-off.
- If RSU receives the message but indicates security-validation failure, confirm the OBU is signing with the topped-off certificates, confirm time synchronization, and confirm the correct certificate profile (pseudonym vs. identity) and PSIDs are configured for the transmitted message types.
- If the RSU does not receive messages or evidence collection is incomplete, refer to STP-6-1 and STP-6-2 for RSU remediation steps related to reception, logging, packet capture configuration, and field connectivity.
- If failures are suspected to be unrelated to signing/security, treat the issue as an RSU reception problem and apply STP-6-1/STP-6-2 troubleshooting guidance for the receiving infrastructure.

2.3.1.9 Test Plan STP-9: Vehicle System Compatibility

Brief Description:

STP-9 will test that Vehicle Systems added through the CTW Program are interoperable with legacy equipment and are able to receive and validate SCMS certificates from other CTW states outside of Utah. For the purposes of STP-9, "Vehicle Systems added through the CTW Program" refer specifically to transit vehicles in Utah and the GM Test Vehicle. Transit vehicles added through the CTW Program will form the basis for testing Vehicle System compatibility and the GM test vehicle will test cross-border SCMS compatibility. While the CTW Program is adding Vehicle Systems to snowplows, these vehicles will not be part of STP-9 due to the lack of snowplows operating for snow removal during the period of testing.

Test Objective:

Test objectives include:

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- Test that select Vehicle Systems added through the CTW Program can correctly receive and process messages across all SAE J2735 versions that they may encounter. This includes J2735 2016 (for SPaT and MAP messages) in Utah and J2735 2024 for TIMs in Utah, Colorado, and Wyoming. No RSUs in CTW states are broadcasting messages in J2735 2020; therefore, this cannot be tested.
- Test that the Vehicle Systems added through the CTW Program generate and transmit messages, based on vehicle type (e.g., BSM and SRM for transit vehicles, BSMs for the GM vehicle) using one supported SAE J2735 version.
- Test that transit vehicles equipped with connectivity through the CTW Program are interoperable with legacy CIPT Field Equipment and able to receive SPaT/MAP messages and broadcast SRMs when appropriate.
- Test that the GM test Vehicle System is able to recognize and validate SCMS certificates attached to messages from RSUs operated by Colorado and Wyoming (i.e., external, partner CTW agencies).
- Test, to the extent possible, that the Vehicle Systems added through the CTW Program correctly reject corrupted messages.

Requirements to be Verified:

The CTW System Requirements to be verified by STP-9 are:

- VS-1.1 Vehicle Systems receive in compatible SAE J2735 versions. All CTW Vehicle Systems added through this effort shall be capable of receiving and processing messages as defined in J2735 standards in all of the following versions: 2016, 2020, and 2024.
 - o VS-1.1 will be tested in Test Case 9-1 and 9-2, as follows:
 - VS-1.1 with regard to J2735 version 2016 will be field tested in Test Cases 9-1 and 9-1.
 - VS-1.1 with regard to J2735 version 2024 will be field tested in Test Cases 9-1 and 9-2.
 - VS-1.1 with regard to J2735 version 2020 is not field testable in current CTW Program operations.
- VS-1.2 Vehicle Systems send in compatible SAE J2735 versions. All CTW Vehicle Systems added through this effort shall generate and send messages as defined in SAE J2735 according to one of the following versions: 2016, 2020, or 2024.
 - o VS-1.2 will be tested in Test Case 9-2.
- VS-2 SRM messages interoperable to legacy systems. SRM messages broadcast by Vehicle Systems deployed in the CTW project that are CIPT-participating vehicles shall be interoperable with legacy CIPT Field Equipment.
 - o VS-2 will be tested in Test Case 9-2.
- VS-3 Process SCMS certificates from external agency RSUs. Vehicle Systems operated by CTW agencies shall have the capability to validate SCMS certificates that accompany messages broadcast from RSUs operated by other CTW sites.
 - o VS-3 will be tested in Test Case 9-3.

Test Locations:

- Utah CIPT-equipped intersection locations.
- RSUs in Wyoming and Colorado that are broadcasting TIMs.

Test Duration:

The duration of STP-9 is shown in Table 10 below. Note that data collection may span weekends.

Table 10: Estimated Duration to Conduct STP-9

Source: CTW Team, April 2026

Test Case	Setup	Data Generation/Collection	Analysis	Total Estimated Days	Reserved for Remediation and Retesting
Test Case 9-1	1 working day	2 calendar days	2 working days	5 calendar days	3-7 working days
Test Case 9-2	1 working day	1 calendar days	2 working days	4 calendar days	3-7 working days
Test Case 9-3	1 working day	2 calendar days	2 working days	5 calendar days	3-7 working days

Prerequisite Test Setup and Configuration:

The prerequisites needed to execute STP-9 are as follows:

- Vehicle System configuration:
 - o A limited number of transit vehicles (i.e., three vehicles) that were equipped through the CTW Program will be used for testing in STP-9. In addition, the GM test vehicle will be used. These vehicles will be operated as they exist, without additional configuration, as follows:
 - Transit vehicles will broadcast BSMs and SRMs encoding the messages using J2735 Version 2016;
 - The GM test vehicle will broadcast BSMs encoding messages using J2735 Version 2024 and is equipped with an Human Machine Interface (HMI) to display received TIMs.
 - SCMS certificate validation is operational on all vehicles.
 - o Field observation tools will be used in the GM test vehicle. These may include cameras operated by observers in the vehicle as well as the GM vehicle video recording capabilities that are expected but have not yet been confirmed.
 - o Vehicle System logs will be available and accessed, as needed.
- RSU and Infrastructure Setup
 - o Select RSUs in Utah along one or more transit corridors supporting CIPT that were added through the CTW Program. Note that these RSUs will be broadcasting J2735 SPaT and MAP messages in version 2016.

- o RSUs in Utah that receive TIMs from the UDOT V2X MMS and broadcast J2735 TIMs in version 2024.
- o Legacy RSU and CIPT Field Equipment in Utah that was deployed before the CTW Program will remain operational.
- o RSUs in Colorado and Wyoming that broadcast J2735 TIMs in version 2024.
- o Central System (Utah and Colorado) message storage and access will be operational to support inspection of messages received and sent by Central Systems.
- o RSU logs will be available, as needed.

2.3.1.9.1 Test Cases (Including Procedures, Data, Anticipated Results, and Test Failure Remediation Approach)

2.3.1.9.1.1 Test Case 9-1: Vehicle Systems Receive and Process Messages in SAE J2735 Versions

Summary of Test Case 9-1:

This test case will verify that CTW Vehicle Systems can receive and correctly process incoming messages in all SAE J2735 versions that are possible using existing and added CTW infrastructure. Currently, all RSUs operating in Utah that are broadcasting J2735 SPaT and MAP messages are encoded using J2735 Version 2016. The TIMs that are sent to the RSUs for broadcast in Utah are encoded using J2735 Version 2024. There are no opportunities to test J2735 Version 2020 in any CTW state.

Since only Utah is adding OBUs through the CTW Program, this test case is limited to vehicles added in Utah.

Assets to be used to complete Test Case 9-1 will include:

- GM Test Vehicle. The GM test vehicle will either have a separate observer (beyond the driver) or will utilize the on-board capabilities to record video inside the vehicle of equipment displays).
- Transit vehicle OBU(s).
- UDOT V2X MMS.
- RSUs operating in Utah along CIPT routes.
- RSUs operating in Utah broadcasting TIMs.

General description of roles:

- Transit buses will be operating in normal operations and will be receiving SPaT and MAP messages that are broadcast from RSUs.
- CTW team member will access logs of the on-board processors and OBUs on the transit buses selected to inspect and confirm that the SPaT, MAP, and SSMs (J2735 Version 2016) are received successfully.
- CTW team member will drive the GM test vehicle to pass a minimum of three RSUs that are broadcasting TIMs in Utah, and the in-vehicle HMI will be observed to determine if the TIMs (J2735 Version 2024) were received and displayed properly.

- CTW team member will drive the GM test vehicle on a Utah CIPT-equipped corridor, and the OBU logs will be inspected to identify if the vehicle received SPaT and MAP messages (J2735 Version 2016) successfully.
- CTW team members will attempt to create a limited number (less than five) of corrupted J2735 messages (i.e., the messages will be malformed) and upload the messages to RSUs for broadcast. Testing will assess if the transit vehicle(s) and GM vehicle reject the malformed message. This will not be a test of invalid or incorrect data in the message, but rather a corrupt message. Note that this is identified as “will attempt to...” because the CTW team has not performed this before. Also, note that this is not intended and will not be an exhaustive test of all possible malformed approaches.

Anticipated Results of Test Case 9-1:

The transit Vehicle Systems tested in Utah receive and processes messages in J2735 version 2016 successfully (i.e., no crashes, parsing failures, or unexpected rejection due to version mismatch).

The GM test vehicle while tested in Utah receives and processes SPaT and MAP messages in J2735 version 2016 and TIMs in J2725 version 2024 successfully (i.e., no crashes, parsing failures, or unexpected rejection due to version mismatch).

Inspection shows that the malformed/corrupted J2735 messages that are broadcast by the RSU are rejected by the Vehicle Systems.

Test Case 9-1 Test Procedures:

The steps and procedures that will be followed to complete Test Case 9-1 include:

1. Select a test day and drive the GM test vehicle along a route that is equipped with CIs added through the CTW Program. Additionally, drive the GM test vehicle past a minimum of three RSUs broadcasting TIMs using J2735 version 2024.
 - a. Visually inspect that the TIMs are received successfully and displayed on the HMI of the GM test vehicle.
 - b. Access the logs of the GM test vehicle to confirm if the SPaT and MAP messages broadcast by the CIs were received and processed successfully.
2. Select a total of at least three transit vehicles for which the Vehicle Systems have been added through the CTW Program (i.e., not legacy systems) and that are operating along CIPT-equipped routes.
3. Select any time when transit buses are operating during normal weekday routes:
 - a. Download the messages from the OBU of the buses that were monitored and conduct visual examination against the J2735 standards to confirm that transit vehicle added through the CTW Program successfully received J2735 Version 2016. The OBUs provide UIs that allow verification of received messages through both map and text displays. Also, message logs are available for review. Also, as current J2735 standards do not include explicit version information within transmitted messages, version verification will not be performed. However, given that the messages are created by UDOT systems using J2735 Version 2016, the version is known. Since no CI RSUs in Utah broadcast other versions of J2735, this meets all possible options for CIPT-equipped vehicles.

- b. Snowplows will not be tested. However, these are equipped with the same OBP/OBU as the transit vehicles.

Test Case 9-1 Test Data:

- OBU logs from selected transit vehicles.
- Visual displays of TIMs on the GM test vehicle.
- GM Test Vehicle OBU logs.

Test Case 9-1 Measurement/Verification Method:

- Visual demonstration (HMI).
- Inspection of OBU logs.
- Packet capture decode confirming message version and content.

Test Case 9-1 Pass/Fail Criteria:

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

The test passes if:

- Participating transit Vehicle Systems are observed successfully receiving and processing SPaT and MAP messages broadcast in J2735 version 2016. Logs show correct parsing/handling and no version-related errors.
- The GM test vehicle receives and displays TIMs that were broadcast in J2735 version 2024.
- The OBU rejects or ignores every malformed message, if a malformed message can be created and if it is able to be broadcast by the RSU.

Fail Criteria:

Test fails when:

- Any version's messages are not received, cannot be parsed, or are rejected due to version mismatch.
- HMI does not display messages when expected (if display is required for that message type).
- The OBU processes a malformed message, if a malformed message can be created and if it is able to be broadcast by the RSU.

Test Case 9-1 Test Failure Remediation:

- Confirm vehicle firmware supports all required J2735 versions.
- Verify configuration for version negotiation/parsing libraries.
- Validate RSU message encoding for each version with analyzer output.
- Apply configuration updates or firmware patches and repeat procedure.

- After identifying and resolving issues, repeat testing as indicated above.

2.3.1.9.1.2 Test Case 9-2: Vehicle Systems Generate and Transmit Messages in a Supported J2735 Version and are Interoperable to Legacy Systems

Summary of Test Case 9-2:

This test case will verify that Vehicle Systems added through the CTW Program can generate and transmit messages (at minimum, BSM for all vehicles tested and SRM for transit vehicles). As noted above, transit vehicles will be broadcasting J2735 Version 2016, and the GM vehicle will be broadcasting messages in J2735 Version 2024. The BSM and SRM messages that are broadcast by a selection of two Utah transit buses as well as the BSMs broadcast by the GM test vehicle will be collected and assessed to determine that they are broadcasting J2735 compliant messages.

This test case will also test that Vehicle Systems added through the CTW Program are compatible with legacy systems (i.e., RSUs and SCMs in operation in Utah).

Since only Utah is adding Vehicle Systems through the CTW Program, this test case will be limited to Utah. Wyoming and Colorado will not run this test case.

Assets to be used to complete Test Case 9-2 will include:

- CTW transit buses (2).
- CTW GM test vehicle.
- CIPT-equipped intersection (legacy Field Equipment included).
- RSU(s) and/or message decoder(s).
- Message analyzer/packet capture tools.

General description of roles:

- Transit buses will be operated in normal operations and will be broadcasting BSMs continuously and will broadcast SRM message broadcasts when appropriate.
- CTW team member will drive the GM test vehicle, broadcasting BSMs.
- CTW team member will use the UDOT V2X MMS to analyze if BSMs and SRMs are received by appropriate RSUs and will examine a minimum of 10 BSM and 10 SRM messages received against J2735 standards.
- CTW team members will use the UDOT V2X MMS to inspect whether the SRMs received by the RSUs are processed and result in transit signal priority requests (i.e., are compatible with legacy systems).

Anticipated Results of Test Case 9-2:

- SRM and BSM messages are generated and transmitted correctly, as determined by examining the UDOT V2X MMS logs of messages received by RSUs in the vicinity of the vehicles.

- CIPT-equipped Vehicle Systems added through the CTW Program successfully perform CIPT functions (i.e., receive SPaT/MAP, broadcast SRM when appropriate) when passing legacy CIs in Utah, confirming they are compatible with legacy CIs.

Test Case 9-2 Test Procedures:

The steps and procedures that will be followed to complete Test Case 9-2 include:

1. Operate CIPT-equipped transit vehicles according to the regular schedules without any changes for this test case.
2. Select a test day and drive the GM test vehicle along a route that is also used by CIPT-equipped Utah transit vehicles for approximately 30 minutes. The day selected should be a weekday when transit vehicles are operating and expected to broadcast SRMs to request priority. Note that this time period would be extended in the unlikely event that 10 SRM messages are not observed.
3. Using the UDOT V2X MMS, examine the messages received by RSUs during the period when the transit vehicles and GM test vehicle were operating.
4. Download the messages from the V2X MMS and conduct visual examination against the J2735 standards to assess compliance.
5. If needed to supplement visual inspection, use a message analyzer to confirm encoding and version correctness.
6. Access the logs of SCMs along the route selected to determine if the SCM successfully received the SRM messages and submitted priority requests as appropriate.
7. Repeat data collection of transit vehicle data if no SRMs are broadcast during the period of observation.

Test Case 9-2 Test Data:

- Message logs from the V2X MMS of BSMs and SRMs received by RSUs in the selected corridor.
- Logs from the SCMs located at the intersections along the selected corridor.

Test Case 9-2 Measurement/Verification Method:

- Inspection of V2X MMS logs describing messages received by the RSUs.
- Observed interoperability outcome as follows:
 - o All BSM and SRM messages received by the RSU are forwarded to the SCM.
 - o Interoperability will be verified by confirming that the SCM successfully receives and processes the messages.
 - o If the SCM cannot decode or process a message, an error is generated and the message will not be visible in the SCM interface or logs.
 - o Additionally, interoperability will be verified by observing the on-board processor (OBP) and SCM UIs simultaneously. Messages and priority requests displayed on the OBP will be compared with messages received and processed by the SCM to confirm that the messages are being transmitted, received, and acted upon successfully.

Test Case 9-2 Pass/Fail Criteria.

Pass Criteria: The test passes if:

- Messages received by the RSUs are correctly encoded in the configured J2735 version, confirming the transit vehicles and the GM test vehicle broadcast messages in one J2735 version.
- SRMs are broadcast by transit vehicles and received by RSUs that result in signal priority when appropriate, confirming that transit vehicles added through the CTW Program are interoperable with legacy Field Equipment in Utah.
- Messages are readable/decodable by existing systems operated in Utah.

Fail Criteria:

The test is considered a failure if:

- Messages are malformed, encoded in wrong version, or cannot be decoded by receiving systems.
- Transit vehicles equipped through the CTW Program are not compatible and are unable to broadcast or successfully process priority requests.

Test Case 9-2 Test Failure Remediation:

- Verify vehicle message generation settings and version configuration.
- Validate message schema/fields against J2735 requirements.
- Update encoder library or vehicle firmware and retest.
- After identifying and resolving issues, repeat testing as indicated above.

2.3.1.9.1.3 Test Case 9-3: Cross-State Message Handling

Summary of Test Case 9-3:

This test case will verify that messages broadcast from RSUs in other CTW states are received, validated (including SCMS), and handled correctly by Vehicle Systems.

Assets to be used to complete Test Case 9-6 will include:

- GM Test Vehicle
- RSU(s) operating in Wyoming
- RSU(s) operating in Colorado
- Vehicle and RSU logs (as available)

General description of roles:

- Vehicle test operator drives the GM test vehicle to Colorado and Wyoming to pass at least one RSU broadcasting TIMs.
- Vehicle test operator observed TIMs displayed in the vehicle, recording the displays using internal cameras to the extent possible.

- Test team member reviews logs and messages from the RSU.

Anticipated Results of Test Case 9-3:

- Messages broadcast by CTW states other than Utah are received and processed correctly by the GM test vehicle.
- SCMS validation succeeds for valid external RSUs (i.e., in partner CTW states).
- HMI and logs reflect accurate receipt and trust.

Test Case 9-3 Test Procedures:

The steps and procedures that will be followed to complete Test Case 9-3 include:

1. Identify cross-border corridors in Wyoming and Colorado where RSU messages from the other CTW states are being broadcast.
2. Verify that TIMs are actively being broadcast by the RSUs identified. Work with CTW team members to arrange for test TIMs to be broadcast, if required.
3. Clear any cached TIMs in the vehicle OBU application prior to testing (note that this may be accomplished by restarting the vehicle application) to ensure that any TIM displayed during the test is newly received and verified as part of this test rather than being retained from an earlier test.
4. Drive the test vehicle through the corridor and capture received messages.
5. Confirm messages are validated and displayed/logged correctly.
6. Confirm no incorrect rejection occurs due to state origin.

Test Case 9-3 Test Data:

- Visual display of TIM content observed by driver and recorded as much as possible.
- OBU logs.

Test Case 9-3 Measurement/Verification Method:

- HMI observation.
- OBU log inspection.

Test Case 9-3 Pass/Fail Criteria:

The following definitions will be used to determine pass/fail outcomes of this test case.

Pass Criteria:

The test passes if:

- Messages are received, validated, and handled correctly across state lines.

Fail Criteria:

Test fails when:

- Messages are not received, rejected incorrectly, or mishandled due to origin.

Test Case 9-3 Test Failure Remediation:

- Verify RSU broadcast and certificate chain.
- Confirm vehicle trust store includes external CTW Program anchors.
- After identifying and resolving issues, repeat testing as indicated above.

2.3.2 Test Results

2.3.2.1 System Test Results Summary

System Test Results will be tracked in the System Test Results Summary (STRS) document (spreadsheet), stored on CTW Google Drive.

Each entry in the STRS document will have the following fields:

- System Test Plan Test Identifier (ex: STP-X or STP-X-Y).
- Date/Time of the Start of Test (ex: 2026-02-15 14:00).
- System Test Plan Manager (name of person executing the STP or coordinating a team to execute the STP).
- Test Result (PASS/FAIL).
- Comments.

2.3.2.2 System Test Results Data

All data and any associated test analysis documentation for a given STP will be stored on the CTW Program Google Drive using the following directory structure:

../STP-X-Y/2026-MM-DD-HH-mm/

Meaningful sub-directories will be created based on the needs of the given STP.

2.3.3 Test Failure Remediation

In the event of a failed test, the CTW team will troubleshoot to identify the cause of failure and make any updates or changes needed to correct the issue. A subsequent test will then be conducted. This process will be repeated, as needed, until the issue has been resolved and the test is successful.

2.3.4 Other Inspections

There was one inspection that did not require a full STP and is addressed in this section as inspection to be conducted. Specifically, UDOT will compare the selected intersections for VRU Safety System expansions with pedestrian crash statistics compiled by an authoritative source to verify the CTW System Requirement:

- FE-9.1 VRU Safety System Expansion sites at sites with consistent pedestrian traffic.

UDOT staff will review each VRU expansion location and track the results and confirm that each selected VRU expansion site has a greater than average pedestrian crash total over the last 10 years.

Authoritative crash data will be obtained from the state and/or local authorities for the region of interest over the 10-year period between 2015 and 2025. Pedestrian crash statistics and VRU Safety System expansion sites will be visualized and visually inspected together on a map to confirm that the number of pedestrian related crashes at each location is greater than 3.2 over the 10-year period.

3 Operational Demonstration Readiness Plan (ORDP)

This ORDP portion of the ORP provides details about the demonstrations the CTW team developed to exhibit that the CTW system performs as expected in key use cases. The demonstrations complement the tests described in the STP portion of this ORP.

3.1 ORDP Introduction

Demonstrations in Phase 1 are focused on interoperability (intra-site) among the multiple devices, applications, and technologies that are planned for deployment alongside existing ITS field devices and Central Systems amongst the three CTW states of Utah, Colorado, and Wyoming. These demonstrations lay the groundwork for approval to advance to Phase 2 activities. These tests and demonstrations will also prepare the CTW Program to participate in interoperable demonstrations during Phase 2 involving the other two V2X Accelerator program sites, Texas Transforming Roads: Unleashing Smart Technologies (TRUST) and Maricopa County Arizona Connected Vehicle Acceleration Zone (CVAZ), and the USDOT.

The CTW team designed seven demonstration concepts and presented them to the Federal Highway Administration (FHWA) at an Operational Readiness Concept Briefing on August 12, 2025, which was held virtually. Feedback from that briefing has been incorporated into Section 3.2.3. The seven demonstrations that will be completed and are described in greater detail in Section 3.2.3, are:

- Demonstration 1: CIs Issuing Preferential Treatment for Transit Vehicles
- Demonstration 2: Vehicle Equipped with OEM Red Light Violation Warning (RLVW) Application Approaching Red Light
- Demonstration 3: C-V2X Equipped Vehicle at VRU Safety Intersection
- Demonstration 4: Vehicle That is Not C-V2X Equipped at VRU Safety Intersection
- Demonstration 5: Generation and Delivery of TIMs to C-V2X Equipped Vehicle
- Demonstration 6: Generation and Delivery of TIMs to Non-V2X Equipped Vehicles
- Demonstration 7: C-V2X Equipped Vehicle driving in Utah, Wyoming, Colorado receiving TIMs (Interoperability)

3.1.1 Objectives

The seven demonstrations have been designed to show that the deployed CTW system performs as designed and expected in key use cases, providing evidence of successful and secure communications as well as the effective operation of ITS applications among various roadside equipment, in-vehicle devices, and mobile devices.

As per the requirements, demonstrations must cover certain criteria. The following list includes these criteria and a high-level overview of which demonstrations address each:

- Key use cases illustrating the capability of the system to perform in accordance with the CTW ConOps:
 - o *For the CTW Program:* The six use cases in the ConOps are the following:
 1. CI Issuing Preferential Treatment: **Demonstration 1.**
 2. Vehicle Equipped with OEM RLVW Application: **Demonstration 2.**
 3. SWIW TIM: **Demonstration 5 or Demonstration 7.**
 4. Adjacent State Coordination: **Demonstration 6 and Demonstration 7.**
 5. Variable Speed Limits (VSLs): **Not included in the demonstrations.** The CTW team decided not to simulate VSLs and risk dissemination; VSLs are hard to predict when they could be observed and the capabilities for VSLs are similar to those in other use cases, such as SWIW TIM.
 6. Driver Warning of VRU Conflict at a CI: **Demonstration 3 and Demonstration 4.**
- Safety-focused demonstration elements:
 - o *For the CTW Program:* The applications that will be included in the demonstrations to meet this are VRU safety, RLVW, and SWIW.
- Security-focused demonstration elements:
 - o *For the CTW Program:* All demonstrations will utilize SCMS.
- Privacy-focused demonstration elements:
 - o *For the CTW Program:* No identifiable information beyond BSMs from public agency vehicles and the GM vehicle.
- Intra-site interoperability-focused demonstration elements:
 - o *For the CTW Program:* Wyoming, Colorado, and Utah interoperability, as described in the Adjacent State Use Case, will be demonstrated through **Demonstrations 6 and 7.**

3.1.2 Background

The tests and demonstrations build on the user needs, challenges addressed, use cases, operational concepts, and scenarios included in Sections 4, 5, and 6 of the CTW ConOps and the requirements in Section 3 of the CTW SyRS. UDOT, CDOT, and WYDOT aim to improve safety, improve traveler mobility, and reduce fuel costs. To achieve these goals, several new or expanded capabilities, interfaces, and other changes are needed to respond to the challenges and address the user needs.

Each state in the CTW Program already has operational systems partially supporting the user needs, and therefore the anticipated changes primarily reflect expansion or enhancement, and the extent of these will differ by each state. One essential change that all CTW members must accomplish is the interoperability and consistency aspects of the messages exchanged across jurisdictional borders. A second top priority is adding the data exchange between CTW states.

3.2 Approach

The seven demonstrations were designed to build on the six use case scenarios provided in Section 6 of the ConOps.

3.2.1 Overall Demonstration Strategy

Each of the seven demonstrations developed for the CTW system will:

- Include on-board test equipment to log messaging data and conduct visual monitoring in the vehicle and recording for later reviews.
- Include data storage at the Central System(s) about the event (e.g., TIMs, SPaT, and MAP messages broadcast and BSMs received).
- Involve a state DOT staff member as the vehicle driver with no additional responsibilities beyond driving the designated route (e.g., not monitoring or controlling any devices).
- Include SCMS certificates for all messages broadcast by OBUs and RSUs.
- Omit any personally identifiable information in accordance with the CTW Data Plan. Only BSMs and SRMs from the vehicles used in the demonstrations will be exchanged.

The CTW team understands that situations may arise that require a change of plans. If this occurs, the CTW team will advise FHWA and other participants and observers as far in advance as possible. All invited participants in the bi-weekly CTW FHWA Coordination Meeting, as well as any additional demonstration observers and participants, will be sent emails about demonstration information and announcements, and any changes will be communicated promptly.

Section 3.2.2 includes the overall schedule describing the sequence of events and days when demonstrations will occur, as agreed with the FHWA team. Some organizational and circumstantial constraints that have and will continue to impact the timing and scheduling of demonstrations include:

- Equipped vehicles needed in the demonstrations, such as transit vehicles, snowplows, and emergency vehicles, will also be needed for day-to-day operations, which could limit some of their availability (multiple demonstrations).
- The RLVW can only be safely demonstrated on a closed course (i.e., without also potentially affecting other travelers) and will take place at the Utah Department of Motor Vehicles (DMV) test track (Demonstration 2).
- Uncertainty about when the GM vehicle will be available for the CTW team (Demonstrations 2, 3, 5, and 7).
- Coordination needed for the TIMs (Demonstrations 5, 6, and 7) and intra-site operability demonstration (Demonstration 7) around an event such as inclement weather or roadwork.
- Having all systems operational per the configuration management and integration plan, as described in the system design documentation.
- The successful execution of CTW system test plans will be a prerequisite to conducting the demonstrations to ensure functionality of deployed systems and set the stage for successful demonstrations. Any challenges with the deployed systems passing any of the tests that could delay

one or more demonstrations will be communicated with the FHWA team to assess the feasibility and timing of the demonstrations. There is now ample time between the planned STPs and the demonstrations to discuss the plans for demonstrations, in the event any STPs do not pass successfully.

3.2.2 Demonstration Events

Invitees and participants for the demonstrations include FHWA staff and supporting contractors, CTW team members, and personnel who will be part of the demonstration activities. Some demonstrations will be planned in advance and held as a live event, and others are more difficult to plan in advance, as they are subject to variables such as weather, and will be attended remotely (see the demonstration schedule in Table 11).

Demonstrations 1–6 are planned to be in-person demonstrations in Utah. Observations may occur at the roadside, in a vehicle, at the UDOT TOC, or a combination of these locations for various demonstrations. Specific dates and times for these demonstrations are described below and will occur over a consecutive 2-day period.

- Demonstration 1: CIs Issuing Preferential Treatment for Transit Vehicles
- Demonstration 2: Vehicle Equipped with OEM RLVW Application Approaching Red Light
- Demonstration 3: C-V2X Equipped Vehicle at VRU Safety Intersection
- Demonstration 4: Vehicle That is Not C-V2X Equipped at VRU Safety Intersection
- Demonstration 5: Generation and Delivery of TIMs to C-V2X Equipped Vehicle
- Demonstration 6: Generation and Delivery of TIMs to non-V2X Equipped Vehicles

Demonstration 7 (C-V2X Equipped Vehicle driving in Utah, Wyoming, Colorado receiving TIMs [Interoperability]) will be remotely observed and recorded. This demonstration will be more effective if the CTW team plans it as weather conditions or roadwork activities occur to demonstrate key features in actual conditions. However, as this demonstration involves considerable driving time (e.g., to reach locations in Wyoming and Colorado where RSUs are broadcasting TIMs), staff time and schedule availability will be factors in selecting final dates to perform the demonstration. Observers may join webinars or attend in-person, depending upon their location and travel availability. Recordings will be shared during debriefs. Proposed dates for this demonstration avoid conflicts with the following meetings, but may be adjusted as needed:

- Connected Vehicle Pooled Fund Study (CV PFS) Meeting in Salt Lake City, Utah: May 11-17, 2026
- ITS America Annual Meeting: June 8-14, 2026

The results of each demonstration will be documented as they occur, including any aspects of the deployed CTW system that do not function as anticipated and any feedback from demonstration participants so the CTW team can make any needed changes to the deployed system. These findings, as well as any subsequent changes to the deployed system that occur after the demonstrations, will be formally summarized in a final Operational Readiness Demonstration Report.

Table 11: Demonstration Schedule*Source: CTW Team, April 2026*

Demonstration Number and Name	Time Needed	May 11-17	June 1-7	June 15-21	June 22-28
Demonstration 1: CIs Issuing Preferential Treatment for Transit Vehicles	1 p.m. peak period	Potential dry runs as demonstrations for CV PFS – demos to be selected closer to event (suggestion is Demonstration 2)	None	None	Tuesday, PM peak period
Demonstration 2: Vehicle Equipped with OEM RLVW Application Approaching Red Light	1–2-hour period any time (not impacted by peak periods)	Potential dry runs as demonstrations for CV PFS – demos to be selected closer to event (suggestion is Demonstration 2)	None	None	Wednesday, 3–5 p.m.
Demonstration 3: C-V2X Equipped Vehicle at VRU Safety Intersection	4-hour period, off-peak	Potential dry runs as demonstrations for CV PFS – demos to be selected closer to event (suggestion is Demonstration 2)	None	None	Wednesday, 10 a.m.–2 p.m.
Demonstration 4: Vehicle That is Not C-V2X Equipped at VRU Safety Intersection	Concurrent to Demonstration 3	Potential dry runs as demonstrations for CV PFS – demos to be selected closer to event (suggestion is Demonstration 2)	None	None	Wednesday, 10 a.m.–2 p.m.

Demonstration Number and Name	Time Needed	May 11-17	June 1-7	June 15-21	June 22-28
Demonstration 5: Generation and Delivery of TIMs to C-V2X Equipped Vehicle	30-minute loop drive; six runs (to include all observers); 4 hours total, off-peak	Potential dry runs as demonstrations for CV PFS – demos to be selected closer to event (suggestion is Demonstration 2)	None	None	Tuesday, 10 a.m.–2 p.m.
Demonstration 6: Generation and Delivery of TIMs to non-V2X Equipped Vehicles	Concurrent to Demonstration 5	Potential dry runs as demonstrations for CV PFS – demos to be selected closer to event (suggestion is Demonstration 2)	None	None	Tuesday, 10 a.m.–2 p.m.
Demonstration 7: C-V2X Equipped Vehicle Driving in Utah, Wyoming, Colorado Receiving TIMs (Interoperability)	No live observations, remotely observed or recorded and presented later	Potential dry runs as demonstrations for CV PFS – demos to be selected closer to event (suggestion is Demonstration 2)	Goal is to conduct this week (FHWA need not be on site)	Backup week for Demo 7	None

3.2.3 Demonstrations

This section describes the seven demonstrations that are planned, including the anticipated preparations and procedures for each of them.

3.2.3.1 Demonstration 1: CIs Issuing Preferential Treatment for Transit Vehicles

3.2.3.1.1 Demonstration 1 Description

Demonstration 1 Objective and Performance Expectation:

The objective of Demonstration 1 is that observers experience an “end-to-end” process where a transit vehicle requests priority and the system grants priority at one or more SIs. The performance expectations are as follows:

- The transit vehicle(s) is observed to be behind schedule.
- The vehicle automatically issues a CIPT request.
- The request is received and passed to the intersection.
- The intersection adjusts the timing parameters to extend the green time on the approach the transit vehicle is using.
- Finally, it will demonstrate that the priority is removed after the vehicle passes the intersection.

Demonstration 1 will show that Use Case 1, a CI Issuing Preferential Treatment, is successfully supported along a corridor that includes CIs added through the CTW Program.

Demonstration 1 Brief Description:

The CTW team has defined both a primary (mandatory) demonstration as well as an optional demonstration, described as follows:

- The primary (mandatory) demonstration will be a demonstration where in-service transit vehicles operating their scheduled routes will be monitored by observers who are located at the UDOT TOC during an evening peak period. Access to live data feeds from both the SCMs at the CIs and transit schedule status will enable observers to:
 - o Identify transit vehicles that are behind schedule (estimated 2–4 vehicles will be identified).
 - o Access and view data from the SCM identifying that SRMs were received by the RSU and that priority requests were submitted to the signal controller.
 - o Access and view signal controller output (through the SCM) that indicates that the signal is operating in priority status.
 - o Access and view signal controller output (through the SCM) that indicates when the signal controller is no longer operating in priority status (after the vehicle has passed the intersection).

A benefit to this approach of monitoring multiple vehicles along multiple corridors is that it is much more likely to observe the CIPT request modifying the green phase at the signal controller.

An optional approach to Demonstration 1 would be to use an off-duty transit vehicle to allow observers to ride in a vehicle. This vehicle could be configured to broadcast priority requests (either by following behind an operational transit vehicle that is also broadcasting requests or by simulating the need for priority). This approach to the demonstration has been used in the past when UDOT conducted a demonstration for the CV PFS meeting. It is less preferred because there is less for observers to see while on the transit vehicle, and the ability to access multiple systems from the TOC provides a better understanding of all the actions being performed.

Note that UDOT has requested the option to use an off-duty transit bus for this purpose but has not yet received approval. One option being considered is to use the off-duty transit bus as the transportation to/from the locations for Demonstrations 2 and 3 (i.e., travel to the VRU Safety System equipped intersection and travel to the Utah test track). UDOT is exploring the opportunity for this to be an off-duty transit bus that could also be used to demonstrate CIPT requests. This will be finalized as UDOT learns more about the status of the request for use of the vehicle and plans the logistics of transportation to/from the demonstrations.

Demonstration 1 Location:

Demonstration 1 will be conducted in person in Utah. There will not be one route selected in advance as would be the situation with a ride-along demonstration. Using a conference room to monitor the peak period conditions, the demonstration team will seek out as many transit vehicles as possible (representing both on schedule and behind schedule). Therefore, the location will include the entire area equipped with CIs where transit vehicles are operating CIPT. The bus routes that are monitored and observed (including those behind schedule and requesting CIPT) will be illustrated on a map in the demonstration report.

Demonstration 1 Equipment:

The equipment that will be used is as follows:

- Multiple computers and monitors located in a UDOT TOC conference room to conduct visualization remotely of the following:
 - o SCM UI (bus location breadcrumb trail).
 - o Signal controller (whether a Transit Signal Priority [TSP] call is received and the signal is responding).
 - o OBP (to indicate receipt of MAP and SPaT).
- Optional: Equipment to record a video of the visualization/demonstration.
- Optional Approach: One UTA transit bus (off duty but operating as if it is on a scheduled route for testing purposes).

Demonstration 1 Participants:

The participants are expected to include:

- UDOT.
- CTW team members (i.e., Narwhal as a minimum, others to be determined).
- UTA representative (optional at their preference).

- FHWA observers.
- UTA bus driver (only needed if optional approach of operating an off-duty vehicle is executed).

3.2.3.1.2 *Demonstration 1 Schedule*

The schedule for when Demonstration 1 will be conducted is included in Section 5.

The duration of Demonstration 1 is expected to be a total of three non-consecutive days as follows:

- **Demonstration Preparations:** Approximately 1 day to assemble all computers, provide access to systems, and verify they work successfully from the UDOT TOC.
- **Active Demonstration:** A 3.5-hour period is planned with observers and participants arriving at the TOC conference room at 3:00 p.m. for briefing and familiarization with the systems and transit routes to be monitored. The 3-hour peak period (3:30–6:30 p.m.) will be the duration of the active demonstration, but participants may decide that enough observations have occurred or the peak period has reduced the opportunities to observe transit vehicles requesting priority and terminate the demonstration early.
- **Demonstration Summary Preparation:** Approximately 1 day will be dedicated to preparing the summary of the demonstration, including data summary tables, image captures of observations, and an overall summary of the demonstration findings that also indicate whether the observers determined that the demonstration was a success.

3.2.3.1.3 *Demonstration 1 Procedure*

Preparations for Demonstration 1:

The CTW team preparations needed to activate, operate, and terminate the demonstration are:

- Select the corridors and transit routes to be the focus for the demonstration. Since observations will be remote, this could include multiple routes to increase the number of CIPT requests observed.
- Ensure that the installation and testing of CIs and the OBU applications are completed.
- Assemble the computers with software and connection capabilities to monitor RSUs, OBUs, and transit schedule status from the UDOT TOC conference room.

Procedures for Demonstration 1:

The procedures that will be used to complete this demonstration are as follows:

1. Assemble in the UDOT TOC conference room and connect to RSU, OBU, and transit status resources.
2. Activate data logging or visualization/monitoring test equipment.
3. By accessing transit status, identify a route where the vehicle is operating behind schedule.
4. Access the resources to enable observers to view the following:
 - a. Indications that the OBU is broadcasting SRM messages.
 - b. Indications that the RSU has received and validated the SCMS certificate on the SRM messages.

- c. Indications that a priority request for the approach the transit vehicle is following has been submitted to the signal controller.
 - d. Indications that the signal controller operates in priority mode.
 - e. Indications that the signal controller transitions back out of priority mode.
 - f. Indications that the OBU stops broadcasting SRMs after passing the intersection (unless it is already within range of a downstream OBU and broadcasting requests for priority at that intersection).
5. Repeat steps 3-4 with additional routes/buses.
 6. By accessing transit status, identify a route where the vehicle is **not** operating behind schedule.
 7. Access the resources to enable observers to view the following:
 - a. Indications that the OBU is not broadcasting SRM messages.
 - b. Indications that the RSU has **not** received any SRM messages for the approach the vehicle is traveling.
 - c. Indications that a priority request for the approach the transit vehicle is following has **not** been submitted to the signal controller.
 - d. Indications that the signal controller is **not** operating in priority mode (unless priority has been requested from another approach).
 8. Repeat Steps 6-7 for additional routes/buses.
 9. Conduct back-office data collection for presentation of demonstration results.

Other Items to support the procedures:

- Additional training or safety protocols:
 - o None are required.
- Approval and feedback:
 - o Members of the FHWA observation team will provide reactions to the demonstration, indicating when they feel enough transit vehicles have been observed (both requesting and not requesting priority).
 - o The FHWA observation team will provide feedback on the demonstration provided, including whether they consider the demonstration 'approved and completed successfully'.

3.2.3.1.4 Demonstration 1 Data

In Demonstration 1, the data will include data displayed to observers that is also collected and summarized in the report. This data includes:

- SRMs broadcast by the transit vehicle.
- SRMs received by the CIs.
- SSMS broadcast by the CIs.
- SCM data documenting the communication of priority requests delivered to the signal controller.

- Signal controller data describing the priority status of the intersection before, during, and after priority requests were delivered.

3.2.3.1.5 Demonstration 1 Expected Results

The observable validation criteria associated with the demonstration's overall purpose include:

- Confirm the two-way exchange of SAE J2735 messages between an equipped transit fleet vehicle and CIs in a corridor.
- Confirm the ability of an equipped transit fleet vehicle to accurately determine when to request preferential treatment.
- Confirm the ability of the CI to receive and adapt signal timing as intended.

Expected Results of Demonstration 1:

- For the observations where the transit bus is on schedule:
 - o Observe the two-way exchange of SAE J2735 messages between an equipped transit fleet vehicle and CIs in a corridor.
 - o The equipment on the transit bus compares the current bus location with the scheduled location, determines the bus to be on schedule, and does not broadcast SRM message(s).
 - o The OBU on the vehicle observed does not broadcast an SRM.
 - o The RSU at the traffic signal that the vehicle is approaching does not receive an SRM.
 - o The traffic signal at the intersection does not adjust timing to give the transit bus priority.
 - o The bus stops at any red lights.
- For the observations when the transit bus is behind schedule:
 - o Observe the two-way exchange of SAE J2735 messages between an equipped transit fleet vehicle and CIs in a corridor.
 - o The equipment on the transit bus compares the current bus location with the scheduled location and determines the bus to be behind schedule.
 - o The OBU on the vehicle observed broadcasts SRMs.
 - o The RSU at the traffic signal that the vehicle is approaching receives SRMs.
 - o The SCM at the intersection sends a priority request to the signal controller.
 - o The traffic signal at the intersection adjusts timing to give the transit bus priority or does not adjust timing but the priority request was received (e.g., if the signal is already green no adjustment to the timing is needed).
 - o The traffic signals remain green and the bus continues through each intersection.

3.2.3.1.6 Demonstration 1 Remediation Plans

If the demonstrations are not identified as "approved and completed successfully," the following approach will be taken:

- The CTW team conducting the demonstration will identify whether the issue is isolated to one or more CIs or one or more OBUs on vehicles:
 - o If the issue is isolated to limited OBUs and RSUs, it will continue with demonstrations using other RSUs and OBUs.
 - o The CTW team will then determine if actions can be taken during the demonstration to address issues with the troubled RSUs and/or OBUs (e.g., remote restarts, downloading updated files, etc.) and repeat the demonstration if successful.
- If the issue is not isolated to limited OBUs or RSUs, the demonstration will pause. The CTW team will resolve the issues and repeat the demonstration as soon as possible:
 - o If this repeated demonstration can be conducted while the FHWA team is still in Utah, it will be conducted in person at the UDOT TOC.
 - o If this repeated demonstration is not possible while the FHWA team is in Utah, remote access to computers and a webinar approach will be used to demonstrate the successful functionalities.

3.2.3.2 Demonstration 2: Vehicle Equipped with OEM RLVW Application Approaching Red Light

3.2.3.2.1 Demonstration 2 Description

Demonstration 2 Objective and Performance Expectation:

The objective of Demonstration 2 is to demonstrate that a vehicle equipped with an RLVW application successfully receives SPaT and MAP messages from a CI and alerts the driver appropriately to avoid entering the intersection during the red phase. The performance expectation is that this demonstration will show that CTW Use Case 2, Vehicle Equipped with OEM RLVW Application, is successfully supported by providing the driver an alert about a red light when it is warranted.

Demonstration 2 Brief Description:

Demonstration 2 will utilize a private test track that is owned by the State of Utah and includes an SI. An RSU will be equipped at the intersection to broadcast SPaT and MAP messages. The GM vehicle that is equipped with an RLVW application will be driven multiple times to approach the intersection and encounter green, yellow, and red phases. The demonstration will show that the RLVW application warns the driver, when appropriate. The GM vehicle is expected to have video recording capabilities and additional cameras in the vehicle that will capture the driver displays. No other vehicles will be on the test track, thus allowing entry to the intersection during yellow and red phases to demonstrate the warnings issued.

Demonstration 2 Location:

State of Utah test track facility. This facility will be reserved for this demonstration, and no additional traffic will be operating at the intersection tested.

Demonstration 2 Equipment:

The equipment that will be used is:

- One equipped GM vehicle.
- Test track intersection signal controller (existing).
- RSU connected to the test track intersection signal controller (existing and will be updated as needed to support this demonstration).
- Test equipment to log messaging data and conduct visualization/monitoring remotely or in the vehicle.

Demonstration 2 Participants:

The participants are expected to include:

- UDOT, including one UDOT staff to drive the vehicle and other UDOT staff to participate in recording video and observing the demonstration.
- CTW team members.
- FHWA observers, including those that will have authority to accept the demonstration as successful or identify the demonstration as not successful.

3.2.3.2.2 Demonstration 2 Schedule

The schedule for when Demonstration 2 will be conducted is included in Section 5. The duration of Demonstration 2 is expected to be a total of 4 non-consecutive days as follows:

- Demonstration setup and preparation of the RSU in the test track facility: approximately 2 days.
- Demonstration setup of the GM vehicle: No additional setup is expected (more will be known as the GM vehicle arrives); however, observers with cameras are expected in the vehicle.
- Demonstration activity: One 2-hour period will be enough time to drive through the intersection under various scenarios that include the following: green phase, green to yellow phase transition, yellow phase, yellow phase to red transition, red phase, and red phase to green transition.
- Data analysis and results documentation: 1 day to summarize the demonstration results and to link to posted video that was recorded.

3.2.3.2.3 Demonstration 2 Procedure

Preparations for Demonstration 2:

The CTW team preparations needed to activate, operate, and terminate the demonstration are:

- Reserve the State of Utah test track facility.
- Ensure the test track CI is equipped with an RSU configured in the same way as other UDOT CIs are.
- Ensure the RLVW application is operational in the GM vehicle and that the GM vehicle capabilities for recording video inside and outside the vehicle is functional to help document what occurs during the demonstration. Supplement with riders and observers recording video as well.
- Assemble the test equipment to log messaging data on board and conduct visualization/monitoring remotely or in the vehicle with an observer in the vehicle recording the on-screen display.
- Arrange travel to/from the test track for FHWA and CTW team member observers.

Procedures for Demonstration 2:

The procedures that will be used to complete this demonstration are as follows:

1. Prepare remote visualization/monitoring equipment at the test track or in the vehicle.
2. Ensure the intersection signal and RSU are operational at the test track.
3. Load data logging or monitoring test equipment in the GM vehicle.
4. Conduct test track runs with the GM vehicle to confirm RLVW application functionality in the following scenarios:
 - a. Conduct one or more drives approaching the intersection during the green phase.
 - b. Conduct one or more drives approaching the intersection during the green to yellow transition.
 - c. Conduct one or more drives approaching the intersection during the yellow to red transition.
 - d. Conduct one or more drives approaching the intersection during the red phase.
 - e. Conduct one or more drives approaching the intersection during yellow or red phases where the driver does not stop.

Other items to support the procedures:

Items to support the procedures and success of the demonstration are as follows:

- Additional training or safety protocols:
 - o The driver should be aware of how to conduct maneuvers that simulate the vehicle stopping at the red light, stopping in advance of a yellow light, and not stopping in a situation where the red phase is imminent.
- Approval and feedback:
 - o Members of the FHWA observation team will provide reactions to the demonstration, indicating when they feel enough drives through the intersection have been completed to adequately demonstrate the functionality.
 - o The FHWA observation team will provide feedback on the demonstration provided, including whether they consider the demonstration “approved and completed successfully.”

3.2.3.2.4 Demonstration 2 Data

In Demonstration 2, the data will include the following:

- SPaT and MAP messages that are broadcast by the RSU and received by the vehicle OBU.
- BSMS broadcast by the vehicle OBU and received by the RSU.
- Displays of driver warnings in the vehicle (recorded with video and images).

3.2.3.2.5 Demonstration 2 Expected Results

The observable validation criteria associated with the demonstration’s overall purpose include:

- Confirm receipt of SAE J2735 messages from a UDOT CI by an equipped OEM vehicle.
- Confirm receipt of BSMS from an equipped OEM vehicle by a UDOT CI.
- Confirm the ability of an equipped OEM vehicle to issue an appropriate in-vehicle RLVW message, as designed.
 - o Note: This will demonstrate SPaT/MAP message accuracy and timeliness. The RLVW application is on the GM vehicle, and its functionality is outside of the CTW Program's scope.

Expected Results of Demonstration 2:

- For the one or more drives approaching the intersection during the green phase:
 - o The driver times the drive to approach the intersection in the green phase.
 - o No RLVW message appears.
 - o The driver continues through the intersection.
- For the one or more drives approaching the intersection during the green to yellow transition:
 - o The driver times the drive to approach the intersection as the green to yellow transition is happening.
 - o An RLVW message appears.
 - o The driver slows down and stops for the eventual red light.
- For the one or more drives approaching the intersection during the yellow to red transition:
 - o The driver times the drive to approach the intersection as the yellow to red transition is happening.
 - o An RLVW message appears.
 - o The driver slows down and stops for the eventual red light.
- For the one or more drives approaching the intersection during the red phase:
 - o The driver times the drive to approach the intersection a red phase.
 - o An RLVW message appears.
 - o The driver slows down and stops for the eventual red light.
- For the one or more drives approaching the intersection during yellow or red phases:
 - o The driver times the drive to approach the intersection as the yellow or red phase are occurring.
 - o An RLVW message appears.
 - o The driver does not slow or stop and proceeds through the intersection.
 - o The messages and displays are recorded to demonstrate how the warning messages would be delivered when the driver does not stop.

3.2.3.2.6 Demonstration 2 Remediation Plans

If the demonstrations are not identified as "approved and completed successfully," the following approach will be taken:

- The CTW team conducting the demonstration will identify if the issue is related to the SPaT and MAP message generation and/or broadcast. If this is identified as a cause, the CTW team will troubleshoot the signal controller, RSU, and SCM at the intersection to restore operations.
- If the issue is not isolated to the messages broadcast by the RSU, the next step is to ensure that the SCMS certificates are properly attached to the messages and that the vehicle OBU is able to process the SCMS certificates. This will confirm if the OBU in the vehicle is receiving the messages.
- If there is still no resolution, the CTW team will work with GM to troubleshoot the RLVW application on the vehicle. Note that the application on the GM vehicle is outside of the CTW Program, as that is the proprietary property of GM.

3.2.3.3 Demonstration 3: C-V2X Equipped Vehicle at Vulnerable Road User (VRU) Safety Intersection

3.2.3.3.1 Demonstration 3 Description

Demonstration 3 Objective and Performance Expectation:

The objective of Demonstration 3 is to demonstrate that the equipment at a VRU Safety System equipped intersection can support delivery of messages to drivers of C-V2X equipped vehicles that alert them to VRUs potentially in their path of travel. The performance expectation is that this demonstration will show that Use Case 6, Driver Warning of VRU Conflict at a CI, is successfully supported for C-V2X equipped vehicles by providing an in-vehicle alert to the driver of a C-V2X equipped vehicle when one or more VRUs are present and will cause a conflict with their travel path. Note that this demonstration will be conducted in conjunction with Demonstration 4, Vehicle That is Not C-V2X Equipped at VRU Safety Intersection.

Demonstration 3 Brief Description:

At intersections that are equipped with VRU Safety Systems, drivers of vehicles approaching the intersection that are equipped with OBUs are expected to receive two possible messages related to VRU safety:

- TIMs describing pedestrians in crosswalks around corners. When VRUs are crossing crosswalks that the vehicle would pass through if making a right turn, the VRU Safety System will generate a TIM that identifies a warning to watch for VRUs. The valid region for this TIM will be the right turn lane. Therefore, only OBUs in vehicles in the right turn lane will display these warnings to the drivers.
- SDSMs. VRU Safety Systems will continuously broadcast SDSMs describing the location, trajectory, and speed of VRUs. Vehicle OBUs equipped with safety systems will process these SDSMs. When the current trajectory of the vehicle is such that it is expected to conflict with a VRU reported by the SDSMs, the OBU in the vehicle will generate a warning message to the driver.

Demonstration 3 will demonstrate the use of TIMs to warn drivers of pedestrians in crosswalks around the right-turn corner. This demonstration will involve test participants performing standard crosswalk crossings when the walk sign is illuminated and V2X-equipped vehicles approaching the intersection in the right-turn lane.

The use of on-board applications to process and use the SDSMs will not be demonstrated as part of this demonstration. Nonetheless, SDSMs are generated by the LiDAR devices and sent to the external systems that generate the TIMs for broadcast by the RSUs.

The CTW team has no control over the commercial OBUs use of SDSM messages or where and when the alerts will be displayed.

Demonstration 3 Location:

Demonstration 3 will be conducted in person in Utah. One of the VRU Safety System locations will be selected based on the ability to park vehicles nearby and establish safe viewing areas. The exact site is still to be determined.

Demonstration 3 Equipment:

The equipment that will be used is:

- One operational VRU Safety System functioning properly at the intersection.
- One equipped UDOT vehicle with a Commsignia OBU.
- Test equipment to log message data and conduct visualization/monitoring in the vehicle.
- A camera to record displays in each vehicle.
- Mobile devices (e.g., radios or cell phones) for the drivers to communicate with the other demonstration participants.
- Blank-out sign operational at the intersection in the approach(es) being used for the demonstration that displays a message that alerts drivers to pedestrians in the crosswalk. (Note: This is for the concurrent Demonstration 4).
- Optional: One OEM-equipped GM vehicle with the Denso device will be driven through the intersection to observe how messages are displayed and to understand if the SDSMs broadcast by the RSU are received and used by the vehicle.

Demonstration 3 Participants:

The participants are expected to include:

- One UDOT driver of the UDOT vehicle with the Commsignia device.
- One UDOT driver of the OEM-equipped GM vehicle with the Denso device (optional).
- One UDOT driver of a vehicle with no C-V2X equipment (or equipment turned off) to support concurrent Demonstration 4.
- An observer in each vehicle to monitor displays.
- An on-site roadside coordinator with communication to the vehicles.
- One or more VRUs (which will include one or more pedestrians and optional bicyclists) who will cross the intersection within the crosswalk and only during periods of time when the “Walk” indicator is illuminated.

- CTW team members and other observers.
- FHWA team members with responsibility to observe and advise whether the demonstration is successful or not successful.

3.2.3.3.2 *Demonstration 3 Schedule*

The schedule for when Demonstration 3 will be conducted is included in Section 5.

The duration of Demonstration 3 is expected to be a total of 4 non-consecutive days as follows:

- **Demonstration Preparations:** Approximately 2 days to assemble all equipment to be used to record the activities. Additional time to verify that the VRU Safety System is fully operational and that the OBUs are configured properly for TIM display. Time will also be dedicated to developing a detailed timeline of what will happen at the demonstration site to ensure the safety of all involved, including acquiring and issuing reflective vests and other safety equipment that is needed per UDOT policies.
- **Active Demonstration:** A 4-hour timeframe is identified and blocked out to conduct Demonstration 3 in conjunction with Demonstration 4. The actual time to conduct demonstrations will likely require a maximum of 1 hour, but additional time is allowed for staging and communication and coordination with observers.
- **Demonstration Summary Preparation:** Approximately 1 day will be dedicated to preparing the summary of the demonstration, including data summary tables, image captures of observations, and an overall summary of the demonstration findings that indicate whether the observers determined that the demonstration was a success.

3.2.3.3.3 *Demonstration 3 Procedure*

Preparations for Demonstration 3:

The CTW team preparations needed to activate, operate, and terminate the demonstration are:

- Select the intersection with the installed VRU safety equipment (i.e., LiDAR, RSU).
- Identify the UDOT vehicle with the OBU and HMI and confirm availability of it and the GM vehicle.
- Confirm the availability of the drivers and observers to monitor the displays.
- Arrange the staging area near the intersection for roadside observers. Arrange for transportation of FHWA and CTW team observers to/from the intersection.
- Assemble the test equipment to log messaging data on board and conduct visualization/monitoring.
- Have the coordinator in a safe location (with other attendees for loading/unloading) to help confirm maneuvers with the drivers and VRU(s) to safely conduct all passes of the intersection.
- Distribute safety vests and ensure that all participants and observers are aware of safety protocols.

Procedures for Demonstration 3:

The procedures that will be used to complete this demonstration are as follows:

1. Prepare and load remote visualization/monitoring and testing equipment in the vehicles at a staged area near the test intersection.

2. Activate data logging and monitoring test equipment on each equipped vehicle.
3. Stage observers and participants at a safe location near the test intersection for loading/unloading.
4. Stage the VRUs (i.e., one or more pedestrians and one or more [optional] bicyclists) at the intersection and communicate with them about when to cross.
5. Instruct the drivers to drive the route that passes the intersection multiple times to incorporate both turning right and proceeding straight.
6. Have on-board observers monitor output and record video as appropriate.
7. Conduct intersection runs with the equipped vehicles as follows:
 - a. Conduct two or more drives by each vehicle approaching the intersection and traveling straight while a VRU crosses the side street (no conflict).
 - b. Conduct two or more drives by each vehicle approaching the intersection and turning right as a VRU is crossing the side street (conflict).
 - c. Conduct two or more drives by each vehicle approaching the intersection and turning right while no VRU crosses the side street (no conflict).

Other items to support the procedures:

Items to support the procedures and success of the demonstration are as follows:

- Additional training or safety protocols:
 - o Reflective safety vests will be available for demonstration participants and VRUs to help with visibility, as needed.
 - o A CTW team member will be designated to stand next to the active intersection with a reflective safety vest and flag to coordinate with VRU participants and intervene, if necessary, to prevent any possible collisions.
- Approval and feedback:
 - o Members of the FHWA observation team will provide reactions to the demonstration, indicating when they feel enough drives through the intersection have been completed to adequately demonstrate the functionality of the VRU Safety System.
 - o The FHWA observation team will provide feedback on the demonstration provided, including whether they consider the demonstration "approved and completed successfully."

3.2.3.3.4 Demonstration 3 Data

In Demonstration 3, the data will include the following:

- SDSMs generated at the roadside devices indicating pedestrians in crosswalks.
- TIMs generated at the roadside devices.
- TIMs received by the vehicle OBUs and visually displayed at appropriate times.

3.2.3.3.5 Demonstration 3 Expected Results

Observable validation criteria associated with the demonstration's overall purpose include:

- Confirm LiDAR capabilities to successfully identify VRUs in crosswalks.
- Confirm the system's capability to generate SDSMs with VRU locations.
- Confirm the broadcast of SDSMs from RSUs.
- Confirm the ability of OBUs on equipped vehicles to receive SDSMs.
- Confirm the ability of the roadside systems to generate TIMs and broadcast TIMs.
- Confirm the ability of vehicle application(s) to accurately determine when to display TIMs (i.e., alerts are only delivered to drivers who are in the right-turn lane when there is a VRU in the crosswalk that the right turn crosses, creating a potential conflict with the VRU).
- Confirm the vehicle application alert ends when a VRU leaves the crosswalk or the path is no longer obstructed.

Expected Results of Demonstration 3:

- For the drives by each vehicle approaching the intersection and traveling straight while a VRU crosses the side street (no conflict):
 - o The driver times the drive to approach the intersection in the thru lane as a VRU is crossing in parallel.
 - o No VRU conflict message appears.
 - o The driver continues straight through the intersection.
- For the drives by each vehicle approaching the intersection and turning right as a VRU is crossing the side street (conflict):
 - o The driver times the drive to approach the intersection in the right-turn lane as a VRU begins to cross.
 - o A VRU conflict message appears in the vehicle.
 - o The driver slows down and waits for the VRU to cross the intersection before proceeding and turning right.
- For the drives by each vehicle approaching the intersection and turning right while no VRU crosses the side street (no conflict):
 - o The driver times the drive to approach the intersection in the right lane when no VRU is crossing.
 - o No VRU conflict message appears.
 - o The driver continues and makes a right turn at the intersection.

3.2.3.3.6 Demonstration 3 Remediation Plans

If Demonstration 3 is not identified as "approved and completed successfully," the following approach will be taken:

- The CTW team conducting the demonstration will isolate each step in the process to determine where an issue is occurring, such as:
 - o Examining the data moving from the LiDAR detection system to the OBU to determine if the LiDAR system is not generating appropriate SDSM messages and/or not sending them to the

RSU that generates the TIMs. If this is the situation, the CTW team will explore whether other VRU Safety Systems at nearby intersections are working properly or attempt to resolve the issues with this intersection.

- o Examining the messages generated and broadcast by the RSU to determine if TIMs are being generated when VRUs are crossing the intersections. If they are not, the CTW team may swap the RSU or troubleshoot the existing RSU.
- o Examining whether the OBU is receiving the TIMs and, if so, try to understand why it is not displaying (e.g., is the security credential check passing?). UDOT may use an alternate vehicle (or alternate mobile OBU) to conduct more testing.
- If there is still no resolution, the CTW team will work with the LiDAR vendor and Commsignia to troubleshoot the components.

3.2.3.4 Demonstration 4: Vehicle That is Not C-V2X Equipped at VRU Safety Intersection

3.2.3.4.1 Demonstration 4 Description

Demonstration 4 Objective and Performance Expectation:

The objective of Demonstration 4 is to demonstrate that the equipment at a VRU Safety System-equipped intersection can support delivery of messages to all drivers in order to alert them to VRUs potentially in their path of travel. The performance expectation is that this demonstration will show that Use Case 6, Driver Warning of VRU Conflict at a CI, is successfully supported for non-C-V2X equipped vehicles by providing a roadside alert for turning drivers when one or more VRUs are present.

Demonstration 4 Brief Description:

Demonstration 4 will be one additional data collection process added to Demonstration 3. This will not be conducted as a separate demonstration, but rather as an add-on to Demonstration 3. During Demonstration 3, a UDOT participant in a non-C-V2X equipped vehicle will drive through the intersections and view the blank-out signs that illuminate to warn them of pedestrians in the crosswalk. Note that this may be the same vehicles used in Demonstration 3 with the OBUs turned off.

Alternately, no additional vehicles would be driven, and drivers of the vehicles would just be asked to verify whether they observed the blank-out signs illuminated.

Demonstration 4 Location:

Same as Demonstration 3.

Demonstration 4 Equipment:

Same as Demonstration 3, with the following adjustments:

- Blank-out sign operational at the intersection in the approach(es) being used for the demonstration that displays a message that alerts drivers to pedestrians in the crosswalk. (Note: This is for the concurrent Demonstration 4).

- One UDOT vehicle that is not C-V2X equipped (or use of a C-V2X equipped vehicle with the OBU turned off).

Demonstration 4 Participants:

Same as Demonstration 3, with the following adjustments:

- Driver of the UDOT vehicle that is not C-V2X equipped (or use of a C-V2X equipped vehicle with the OBU turned off).

3.2.3.4.2 Demonstration 4 Schedule

Same as Demonstration 3.

3.2.3.4.3 Demonstration 4 Procedure

Demonstration 4 will be conducted with Demonstration 3. The only change to the procedure is to record whether the blank-out sign illuminated when pedestrians were in the crosswalk and did not illuminate when pedestrians were not in the crosswalk.

Approval and Feedback:

Members of the FHWA observation team will provide reactions to the demonstration, indicating when they feel enough drives through the intersection have been completed to adequately demonstrate the functionality. The FHWA observation team will provide feedback on the demonstration provided, including whether they consider the demonstration "approved and completed successfully."

3.2.3.4.4 Demonstration 4 Data

- Manual observations of whether the blank-out sign illuminates when pedestrians are in the crosswalk.

3.2.3.4.5 Demonstration 4 Expected Results

Expected Results of Demonstration 4:

- For the drives by each vehicle approaching the intersection and traveling straight while a VRU crosses the side street (no conflict):
 - o The driver times the drive to approach the intersection in the thru lane as a VRU is crossing in parallel.
 - o The blank-out sign illuminates (i.e., it activates whenever pedestrians are crossing, not limited only to vehicles in the right turn lane).
 - o The driver continues straight through the intersection.
- For the drives by each vehicle approaching the intersection and turning right as a VRU is crossing the side street (conflict):
 - o The blank-out sign illuminates (i.e., it activates whenever pedestrians are crossing, not limited only to vehicles in the right-turn lane).
 - o The driver slows down and waits for the VRU to cross the intersection before proceeding and turning right.

- For the drives by each vehicle approaching the intersection and turning right while no VRU crosses the side street (no conflict):
 - o The driver times the drive to approach the intersection in the right lane when no VRU is crossing.
 - o No blank-out sign message appears.
 - o The driver continues and makes a right turn at the intersection.

3.2.3.4.6 Demonstration 4 Remediation Plan

If the Demonstration 4 is not identified as "approved and completed successfully," the following approach will be taken:

- The CTW team conducting the demonstration will isolate each step in the process to determine where an issue is occurring, such as:
 - o Examining the data moving from the LiDAR detection system to the controller of the blank-out sign to determine if the data is reaching the controller or if the issue is with the LiDAR system or the controller not activating the blank-out sign.
- If there is still no resolution, the CTW team will work with the LiDAR vendor and Narwhal to troubleshoot the components.

3.2.3.5 Demonstration 5: Generation and Delivery of TIMs to C-V2X Equipped Vehicle

3.2.3.5.1 Demonstration 5 Description

Demonstration 5 Objective and Performance Expectation:

The objective of Demonstration 5 is to demonstrate that the UDOT portion of the CTW systems generates and delivers TIMs to C-V2X-equipped vehicles and the vehicles begin to display the TIMs when the vehicle enters the valid region and terminates the display as the vehicle exits the valid region. The performance expectation is that this demonstration will show that Use Case 3, SWIW, is successfully supported and will also demonstrate successful use of additional TIMs by providing an in-vehicle alert to the driver of a C-V2X equipped vehicle about inclement weather conditions. Note that this demonstration leverages a SWIW TIM that will be created manually (instead of automatically generated based on BSM feedback from vehicles).

Demonstration 5 Brief Description:

In Demonstration 5, observers will experience the manual creation of TIMs from within the UDOT TOC building and then ride in the GM test vehicle to observe that the TIMs are displayed at appropriate locations and removed from display when appropriate. On the day of the demonstration, all observers will gather in the UDOT TOC conference room for a demonstration of the use of the UDOT V2X MMS. A UDOT operator will use the V2X MMS to create a number of TIMs at previously selected locations. Then, the observers will break into groups of two to three participants who will join the UDOT driver and additional CTW team member who will describe the conditions and expected displays from the in-vehicle OBU display.

A driving route of approximately 15–25 minutes will be driven, with time for orientation and questions. Each group will return to the UDOT TOC parking lot, and the next group will depart.

Demonstration 5 Location:

Demonstration 5 will depart from the UDOT TOC parking lot. The route followed will include the following:

- The vehicle will turn right out of the UDOT TOC (on West 2100 South); there is an existing RSU near this location that will have received the TIMs from the controller at the UDOT TOC. All TIMs will be received by the OBU at this time.
- The vehicle will turn north onto West 3230 West and drive on this road until it turns on to eastbound California Avenue where an “Icy Road” or “High Wind Warning” TIM will be active for display to the observers.
- The vehicle will travel on California Avenue to Interstate 215 (I-215, where a Work Zone TIM will be displayed.
- The vehicle will then exit from I-215 to Highway 210, where the curvature of the exit ramp will result in a CSW TIM to be displayed.
- The vehicle will then return to the UDOT TOC.
- When completed, the route taken for the demonstration, together with indications of TIM messages received, will be presented on a map as part of the description of the demonstration and outcome.

Demonstration 5 Equipment:

The equipment that will be used includes:

- One deployed and operational RSU.
- UDOT V2X MMS TIM generation capabilities.
- OEM vehicle currently planned as the GM vehicle (a UDOT maintenance vehicle with an OBU and HMI could be used as a back-up or to demonstrate the functionality from an additional [different vendor] OBU).
- Test equipment to log event messaging and TIM data and to conduct visualization/monitoring for demonstration purposes.

Demonstration 5 Participants:

The participants are expected to include:

- One driver (UDOT staff).
- One UDOT staff to explain the expected TIMs.
- CTW team members to plan and create TIMs.
- CTW team members to arrange video recording in the vehicles. Note that one approach might be to conduct a run with only CTW team members to record video of the TIM displays and outside views.
- Other observers.

3.2.3.5.2 Demonstration 5 Schedule

The schedule for when Demonstration 5 will be conducted is included in Section 5.

The duration of Demonstration 5 is expected to be a total of three non-consecutive days as follows:

- Demonstration Preparations: Approximately 1-2 days to determine the details of TIMs to be used to demonstrate as many features of the UDOT V2X MMS as possible within the planned driving route. Verification that the RSU is functioning and that the GM vehicle is prepared to display all TIMs.
- Active Demonstration: A 4-hour period is planned, with observers and participants arriving at the TOC conference room by 9:30 a.m. for an overview of the demonstration and to observe the TIMs being created in the V2X MMS. Approximately 2 hours are planned to ensure that all observers have the opportunity to ride in the vehicle for the pre-planned route. Ideally, observers could ride in both the GM vehicle and a UDOT vehicle with OBU and HMI.
- Demonstration Summary Preparation: Approximately 1 day will be dedicated to preparing the summary of the demonstration, including data summary tables, image captures of observations, and an overall summary of the demonstration findings that also indicate whether the observers determined that the demonstration was "approved and completed successfully."

3.2.3.5.3 Demonstration 5 Procedure

Preparations for Demonstration 5:

The CTW team preparations needed to activate, operate, and terminate the demonstration are:

- Complete the installation and testing of RSUs.
- Test that the GM vehicle is equipped to receive and display the TIMs planned for Demonstration 5.
- Identify a UDOT vehicle with OBU and HMI (optional) and test that the OBU and HMI are configured for the TIMs planned.
- Determine if any TIMs planned for Demonstration 5 are already active and/or assemble the information needed to create the planned TIMs (i.e., descriptions of valid region, selected ITIS codes, etc.).
- Verify an operational OBU with HMI at the planned site.

Procedures for Demonstration 5:

The procedures that will be used to complete this demonstration are as follows:

1. Assemble all observers at the agreed location/time.
2. Create the TIMs using the UDOT V2X MMS, allowing all observers to view the creation process and TIMs that are created, and send the TIMs to the RSU.
3. Assemble observers in the parking lots in groups that fit in the test vehicle(s).
4. Drive the route and describe the anticipated TIMs to be displayed as the vehicle approaches the valid region.

5. As the TIMs are displayed, a CTW team member will capture the display of TIMs and observers will view the TIM.
6. After all demonstration rides are complete, meet in the UDOT TOC conference room to see the process of closing/ending the TIMs and confirm that they are no longer broadcast by the RSUs. Note that some TIMs created for actual work zone activities may be left active.
7. Note: An optional drive through the route could be conducted to show that any TIMs that were discontinued are no longer broadcast.

Other Items to support the procedures:

Items to support the procedures and success of the demonstration are as follows:

- Additional training or safety protocols:
 - o None are deemed necessary.
- Approval and feedback:
 - o Members of the FHWA observation team will provide reactions to the demonstration, indicating when they feel the vehicle OBU has received and displayed the appropriate TIM (based on the explanation of what TIM should be received and the briefing prior to the road demonstration).
 - o The FHWA observation team will provide feedback on the demonstration provided, including whether they consider the demonstration "approved and completed successfully."

3.2.3.5.4 Demonstration 5 Data

In Demonstration 5, the data will include content entered into the V2X MMS, data reported by the RSU describing messages received and broadcasts, and the in-vehicle display of TIMs. This data includes:

- Content entered in the V2X MMS (i.e., ITIS codes, valid region for each TIM).
- RSU reports of TIMs received from the V2X MMS and broadcast.
- Manual notes (or observers' spoken confirmation that they see) of TIMs displayed in the vehicle (as observed by participants).

3.2.3.5.5 Demonstration 5 Expected Results

Expected Results of Demonstration 5:

- On the demonstration drive, all observers view the TIM message content as follows:
 - o TIMs are displayed only after the vehicle enters the valid region.
 - o TIMs include the expected messages.
 - o TIMs are no longer displayed as the vehicle exits the valid region.

3.2.3.5.6 Demonstration 5 Remediation Plans

If the demonstrations are not identified as "approved and completed successfully," the following approach will be taken:

- The CTW team conducting the demonstration will identify the source of the issue. Possible sources to explore will be:
 - o If the V2X MMS did not successfully deliver the TIMs to the appropriate RSU (check of logs will identify this).
 - o If TIMs broadcast by the RSU were not received by the OBU (or if only partial TIMs were received).
 - o If one or more of the RSUs were not broadcasting TIMs at 1Hz.
 - o If the OBU was not able to receive, validate the SCMS messaging, or display the TIMs.
- Once the source of the issue is identified, the CTW team will determine if a quick solution is possible. If so, they will correct the issue and perform the demonstration again. If there is a larger-scale issue, the CTW team will seek to define a time to conduct the demonstration again, preferably while the FHWA team is still available.

3.2.3.6 Demonstration 6: Generation and Delivery of TIMs to Non-V2X-Equipped Vehicles

3.2.3.6.1 Demonstration 6 Description

Demonstration 6 Objective and Performance Expectation:

The objective of Demonstration 6 is to demonstrate that the CTW systems generate and deliver TIMs to non-C-V2X equipped vehicles through the use of the SDX. The performance expectation is that this demonstration will show that Use Case 3, SWIW, is successfully supported and will also demonstrate successful use of the SDX to deliver information to vehicles that are not C-V2X equipped and to systems and users accessing information through third-party information providers.

Demonstration 6 Brief Description:

Demonstration 6 involves one additional data collection and monitoring process added to Demonstration 5. This will not be conducted as a separate demonstration, but rather as an add-on to Demonstration 5. During Demonstration 5, a representative from Trihydro (i.e., the operator of the SDX) will participate in the demonstration (preferably from the UDOT TOC) to demonstrate to users that the TIMs created by the UDOT V2X MMS are being sent to the SDX and received by the SDX. Furthermore, the demonstration will share screen views with observers to show how the TIMs are available on the SDX and potentially what consumers are pulling the TIMs in.

Demonstration 6 Location:

Same as Demonstration 5. The display of accessibility to the SDX could also be shared on a webinar to others not physically at the UDOT TOC.

Demonstration 6 Equipment:

Same as Demonstration 5, with the following adjustments:

- A laptop with connectivity to the internet and the ability to share the screen with observers will be used to demonstrate the sharing to the SDX and to consumers of the SDX data feed.

Demonstration 6 Participants:

Same as Demonstration 5, with the following adjustments:

- Trihydro will be the specific CTW team member conducting the portions related to Demonstration 6 and will be able to answer questions about the message communications to other parties.

3.2.3.6.2 Demonstration 6 Schedule

Same as Demonstration 5.

3.2.3.6.3 Demonstration 6 Procedure

Demonstration 6 will be conducted with Demonstration 5, with the only change to the procedure to provide visual information to the observers who are not in the vehicles (or in between vehicle rides) is visual verification of the sharing of TIMs through the SDX in a way that enables operators of non-C-V2X vehicles to receive the messages.

Approval and feedback:

- Members of the FHWA observation team will provide reactions to the demonstration, indicating when they feel the demonstration has shown that TIMs are shared through the SDX.
- The FHWA observation team will provide feedback on the demonstration provided, including whether they consider the demonstration “approved and completed successfully.”

3.2.3.6.4 Demonstration 6 Data

- Manual observations of whether the SDX receives the TIMs and makes the TIMs available to subscribers.

3.2.3.6.5 Demonstration 6 Expected Results

Expected Results of Demonstration 6:

- Each time a TIM is sent by the UDOT V2X MMS to an RSU, the same TIM will also be sent to the SDX.
- The SDX will make the TIM available to consumers. This will be demonstrated by sharing the feed and creating a geographic query in the SDX to show that the TIMs are all available.
- At the close of the demonstration, the TIMs will be cancelled in the UDOT V2X MMS, and observers will be able to observe the TIMs no longer available on the SDX.

3.2.3.6.6 Demonstration 6 Remediation Plans

If Demonstration 6 is not identified as “approved and completed successfully,” the following approach will be taken:

- The CTW team conducting the demonstration will check to determine if the connection to the SDX is no longer functioning.
- Trihydro will check the status of the SDX to determine if anything is preventing these TIMs from being accepted and/or shared with subscribers to the SDX.

3.2.3.7 Demonstration 7: C-V2X Equipped Vehicle Driving in Utah, Wyoming, and Colorado Receiving TIMs (Interoperability)

3.2.3.7.1 Demonstration 7 Description

Demonstration 7 Objective and Performance Expectation:

The objective of Demonstration 7 is to drive the CTW GM vehicle to pass by RSUs in Utah, Wyoming, and Colorado and to have the vehicle receive TIMs from each state and display the TIM consistently to the driver, regardless of the state DOT that is operating the RSU. The performance expectation is that Demonstration 7 will show that Use Case 3, SWIW, and Use Case 4, Adjacent State Coordination, are successfully supported by providing in-vehicle alerts to the driver of a C-V2X equipped vehicle about events that may impact travel. However, if inclement weather is not happening during the demonstration, the TIMs may not include SWIW TIMs.

Demonstration 7 Brief Description:

During this demonstration, a UDOT employee will drive the CTW GM vehicle on two separate round-trip drives. One drive will be to Evanston, Wyoming, and the vehicle will encounter several UDOT- and WYDOT-operated RSUs on this drive. A second drive will be to Grand Junction, Colorado, and the vehicle will encounter several UDOT- and CDOT-operated RSUs on this drive. The demonstration will record the in-vehicle OBU display of the TIMs received from RSU broadcasts. In addition to the video capture, additional information will be provided to describe the existing TIMs that are broadcast by each RSU. This demonstration will be a demonstration of interoperability as each CTW state will be generating TIMs consistently and in accordance with the TIM Guidance document being developed by FHWA.

There will be no live observations of this demonstration. The encounters with the RSUs will be recorded and a compilation of video will be assembled. A "post-drive" webinar will be conducted to share the results of the demonstration with FHWA observers. During this webinar, logs of the TIMs that were created and sent by the Central Systems in Utah, Wyoming, and Colorado will also be shown as the baseline of what TIMs should have been received by the vehicle.

Demonstration 7 Location:

During this demonstration, a UDOT employee will drive the CTW GM vehicle on two separate round-trip drives, as follows:

- Salt Lake City, Utah, to Evanston, Wyoming (approximately 80 miles along I-80).
- Salt Lake City, Utah, to Grand Junction, Colorado (approximately 283 miles along I-15, US 191, and I-70).

Demonstration 7 Equipment:

The equipment that will be used is:

- The GM vehicle and deployed RSUs.
- Test equipment to record video of the TIMs received by the vehicle and displayed to drivers.
- Central System logs or on-screen displays of the TIMs sent to RSUs (from Central Systems in all three CTW states).

Demonstration 7 Participants:

- One driver (UDOT staff).
- One observer/recorder in the vehicle (UDOT staff or CTW team member).
- WYDOT staff, CDOT staff, UDOT staff to create TIMs (if not already existing).
- CTW team members to participate in post-drive webinar.
- FHWA (to identify the demonstration as successful or not successful) .
- Other observers.

3.2.3.7.2 Demonstration 7 Schedule

The schedule for when Demonstration 7 will be conducted as included in Section 5.

The duration of Demonstration 7 is expected to be a total of eight non-consecutive days as follows:

- *Demonstration Preparations:* Approximately 1 day to plan the route and ensure that TIMs are operational to support the demonstration.
- *Active Demonstration:* The drive to/from Evanston, Wyoming, will be completed in 1 day, with time allowed to potentially pass the same RSU multiple times, if needed. The drive to/from Grand Junction, Colorado, will either be completed in 1 day or spread over 2 days.
- *Demonstration Summary Preparation:* Approximately 1 day will be dedicated to preparing the webinar content and video captures to present to observers during the webinar summary event.
- *Webinar Summary Event:* The webinar will be approximately 2 hours to explain the drive and show video and/or images of the TIMs received as well as screen captures of the Central Systems that sent the TIMs to the RSUs.

3.2.3.7.3 Demonstration 7 Procedure

Preparations for Demonstration 7:

The CTW team preparations needed to activate, operate, and terminate the demonstration are:

- Complete and implement TIM generation in the format defined by the CTW team.
- Identify a time during an identified “window of possible dates” when active events are resulting in a variety of TIMs being broadcast in each CTW state. Create additional TIMs to supplement, if needed.

- Plan each drive and arrange for the driver and supporting recorder (if needed).
- Identify workstation devices needed in the vehicle to monitor RSU broadcasts and/or record TIMs displayed while passing RSUs.

Procedures for Demonstration 7:

1. Identify planned roadwork or other events that would trigger TIMs. (Note that simulated TIMs or “benign” TIMs could be used if actual events are not possible but this practice is discouraged.)
2. Identify dates where TIMs are active in at least two CTW states (preference is all three), which may include an event that warrants a TIM in an adjacent CTW state. The TIM may include a SWIIV message about a weather event.
3. Identify the dates of the demonstration and mobilize the driver and equipped GM vehicle.
4. Activate TIM data logging and ensure the equipped GM vehicle and HMI are working properly.
5. Observe receipt of TIMs on the designated RSUs via querying the RSU.
6. Observe the availability of TIMs on the RSUs.
7. Drive the equipped GM vehicle on the corridor with RSUs broadcasting TIMs.
8. Observe that the OBU successfully received TIMs from the RSU.

Other Items to support the procedures:

Items to support the procedures and success of the demonstration are as follows:

- Additional training or safety protocols:
 - o None are deemed necessary.
- Approval and feedback:
 - o Members of the FHWA observation team will provide reactions to the demonstration, although as the demonstration will not be observed live, it will not be possible for comments during the execution of the demonstration.
 - o The FHWA observation team will provide feedback on the demonstration provided, including whether they consider the demonstration “approved and completed successfully.”

3.2.3.7.4 Demonstration 7 Data

In Demonstration 7, the data will include data displayed that is recorded to share with observers participating in the demonstration webinar. This data includes:

- TIMs created by UDOT (displayed through screenshots of the V2X MMS).
- TIMs created by WYDOT (displayed through screenshots of the Operational Data Environment [ODE]).
- TIMs created by CDOT (displayed through screenshots of the ODE).
- TIMs received by the GM vehicle and displayed through the HMI (in Utah, Wyoming, and Colorado).

3.2.3.7.5 *Demonstration 7 Expected Results*

The observable validation criteria associated with the demonstration's overall purpose include:

- The driver starts driving on designated corridors from Utah to Colorado and Utah to Wyoming.
- As the driver approaches locations in Utah, Colorado, or Wyoming as the vehicle is in the valid region of a TIM (e.g., upstream of where there are events), a TIM appears. The driver continues on the roadway and eventually the TIM is no longer displayed.
- As the driver approaches a state line, TIMs may appear about events that are occurring in the adjacent state that the driver is approaching. A second TIM may appear describing the event when the driver crosses into the state where the event is occurring. The driver continues on the roadway and eventually the TIM is no longer displayed.

3.2.3.7.6 *Demonstration 7 Remediation Plans*

If the demonstrations are not identified as "approved and completed successfully," the following approach will be taken:

- While performing the drives, the driver and/or passenger will communicate by phone with team members in each partner state. This will enable confirmation after viewing TIMs that the expected message was received in the expected format. If the TIMs are not received and/or displayed as expected, there will be a decision as to whether corrective actions can be taken and the vehicle will be driven past the RSU again.
- If immediate remediation is not possible, the CTW team will troubleshoot, resolve the issues, and repeat the drive to demonstrate successful receipt of the TIMs.

4 Responsibilities

Table 12 identifies the organizational entities that have a role in each of the tests or demonstrations. Details about the roles of each of the entities are provided in Table 13. Note that no additional staffing or training needs are required beyond those already provided by members of the CTW team.

Table 12: ORP Responsibilities per Test or Demonstration*Source: CTW Team, April 2026*

STP or Demonstration	UDOT	CDOT	WYDOT	Narwhal	Neaera	Trihydro	Athey Creek	Crest	WSP	SCMS	X-Factor
STP-1: Central System Create and Exchange Event Reports	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
STP-2: Central Systems Support TIM Exchanges	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
STP-3: Central Systems Create and Disseminate TIMs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
STP-4: Central Systems Support Data Storage	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
STP-5: Central Systems Monitor Field Equipment Health	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	No	No
STP-6: Field Equipment Compatibility	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
STP-7: Field Equipment Deployment Locations	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	No	No
STP-8: SCMS Top Off Without Cellular Communications	Yes	No	No	Yes	No	No	Yes	No	No	Yes	No
STP-9: Vehicle System Compatibility	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
2.1: Demonstration 1: CIs Issuing Preferential Treatment for Transit Vehicles	Yes	No	No	Yes	No	No	Yes	Yes	No	No	Yes
2.2: Demonstration 2: Vehicle Equipped with OEM RLVW Application Approaching Red Light	Yes	No	No	Yes	No	No	Yes	Yes	No	No	Yes
2.3: Demonstration 3: C-V2X Equipped Vehicle at VRU Safety Intersection	Yes	No	No	Yes	No	No	Yes	Yes	No	No	Yes

STP or Demonstration	UDOT	CDOT	WYDOT	Narwhal	Neaera	Trihydro	Athey Creek	Crest	WSP	SCMS	X-Factor
2.4: Demonstration 4: Vehicle That is Not C-V2X Equipped at VRU Safety Intersection	Yes	No	No	Yes	No	No	Yes	Yes	No	No	Yes
2.5: Demonstration 5: Generation and Delivery of TIMs to C-V2X Equipped Vehicle	Yes	No	No	Yes	No	No	Yes	Yes	No	No	Yes
2.6: Demonstration 6: Generation and Delivery of TIMs to non-V2X Equipped Vehicles	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes
2.7: Demonstration 7: C-V2X Equipped Vehicle driving in Utah, Wyoming, Colorado receiving TIMs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes

Table 13: ORP Responsibilities per Entity*Source: CTW Team, April 2026*

Name	Responsibility
UDOT (includes UDOT staff and V2X Maintenance and Management System Contractor)	• Oversee all testing and demonstrations • Coordinate demonstration sites and logistics • Operate vehicles and related equipment • Verify Field Equipment locations and compatibility • Monitor Central Systems, generate TIMs, collect data • Manage data gathering and analysis, creation of test reports, and final test summaries
CDOT	• Coordinate tests and demos held in Colorado • Verify Field Equipment locations and compatibility • Monitor Central Systems, generate TIMs, collect and review data
WYDOT	• Coordinate tests involving WYDOT systems • Monitor Central Systems, manage and monitor the SDX, generate TIMs, collect and review data
Narwhal	• Prepare equipment and systems for testing • Equip test sites, including buses, with equipment for monitoring messages and activities • Execute system tests • Equip and test locations for Wi-Fi-based SCMS certificate top-off • Analyze test results • Prepare test summaries
Neaera	• Prepare equipment and systems for testing • Support generation of TIMs messages • Support Field Equipment deployment and compatibility assessment • Gather and analyze CIMMS data • Analyze test results • Prepare test summaries

Name	Responsibility
Trihydro	• Prepare equipment and systems for testing • Support generation of TIMs messages • Operate the SDX system, gather and analyze data from SDX operations • Analyze test results • Prepare test summaries
Athey Creek	• Support UDOT efforts for planning and execution of tests and demonstrations • Assist in preparation of test reports
Crest Solutions	• Data collection and analysis • Analysis of CTI4501 compliance • Verification that objectives were met
WSP	• Support field testing of Field Equipment • Analysis of CTI4501 compliance
SCMS Providers	• Support SCMS certificate compatibility tests
X-Factor	• Assist UDOT in coordinating each of the live demonstrations, including providing support at the demonstration staging areas • Coordination with stakeholders • Coordination with UDOT leadership and press
Horrocks	• No direct involvement in tests or demonstrations • Provide branding support • Review and editing of test reports

5 Schedule

Draft start and end dates for conducting the System Testing and Demonstrations described above are presented in Table 14 and Table 15, along with dependencies on project deliveries and other testing activities. Dependencies will be monitored throughout the execution of the CTW Program and alterations made, as needed, for any changes in schedule.

Table 14: ORP Schedule for System Testing

Source: CTW Team, April 2026

System Test Plan (STP) Number and Name	Dependencies	Completed by June 15	Completed by June 30	Completed by July 15
STP-1 Central System Create and Exchange Event Reports	Utah V2X MMS	None	- Wyoming, Colorado, and Utah 5 days total	n/a
STP-2 Central Systems Support TIM Exchanges	Utah V2X MMS	None	- Wyoming, Colorado, and Utah - All Test Cases 5 days total	n/a
STP-3 Central Systems Create and Disseminate TIMS	Utah V2X MMS GM Test Vehicle	None	- Wyoming, Colorado, and Utah 10 days total	n/a
STP-4 Central Systems Support Data Storage	Utah V2X MMS	None	None	- Wyoming, Colorado, and Utah - All Test Cases 10 days total
STP-5 Central Systems Monitor Field Equipment Health	Utah V2X MMS Utah CIMMS	None	None	- Colorado and Utah 15 days total

System Test Plan (STP) Number and Name	Dependencies	Completed by June 15	Completed by June 30	Completed by July 15
STP-6 Field Equipment Compatibility	Utah V2X MMS Utah CIMMS GM Test Vehicle	None	None	- Wyoming, Colorado, and Utah - All Test Cases 3 weeks total
STP-7 Field Equipment Deployment Locations	None	- Colorado and Utah - All Test Cases 5 days total	n/a	n/a
STP-8 SCMS Top-Off Without Cellular Communications	None	- Utah 5 days total	n/a	n/a
STP-9 Vehicle System Compatibility	Utah V2X MMS GM Test Vehicle	None	None	- Wyoming, Colorado, and Utah - Test Case 6 5 days total

Table 15: ORP Schedule for Demonstrations*Source: CTW Team, April 2026*

Demo Number and Name	August 1–7 (Saturday–Friday)	August 11 (Tuesday)	August 12 (Wednesday)	August 13 (Thursday)
Demo-1: CIs Issuing Preferential Treatment for Transit Vehicles	None	Tuesday, PM peak period	None	If needed
Demo-2: Vehicle Equipped with OEM RLVW Application Approaching Red	None	None	Wednesday, 3–5 p.m.	If needed
Demo-3: C-V2X Equipped Vehicle at VRU Safety Intersection	None	None	Wednesday, 10 a.m.–2 p.m.	If needed

Demo Number and Name	August 1–7 (Saturday–Friday)	August 11 (Tuesday)	August 12 (Wednesday)	August 13 (Thursday)
Demo-4: Vehicle That is Not C-V2X Equipped at VRU Safety Intersection	None	None	Wednesday, 10 a.m.–2 p.m.	If needed
Demo-5: Generation and Delivery of TIMs to C-V2X Equipped Vehicle	None	Tuesday 10 a.m.–2 p.m.	None	If needed
Demo-6: Generation and Delivery of TIMs to non-V2X Equipped Vehicles	None	Tuesday, 10 a.m.–2 p.m.	None	If needed
Demo-7: C-V2X Equipped Vehicle Driving in UT, WY, CO Receiving TIMs (Interoperability)	Plan to conduct this week (FHWA need not be on site)	None	None	None

6 Approvals

Figure 3 depicts a typical table that will be used to record and indicate approval of each ORP test or demonstration. These approvals will indicate that the project may proceed to the next stage.

Program Manager:	Date:
Testing Manager:	Date:
Data Analyst:	Date:
Tester:	Date:

Figure 3: ORP Approvals
Source: FHWA, October 2025

7 Risks and Contingencies

Table 16 lists all risks and contingency plans that have been identified at this time, with emphasis on both the system testing and operational readiness demonstrations.

Table 16: ORP Risks
Source: CTW Team, April 2026

ID	Risk	Contingency
1	Delivery of GM Vehicle and Understanding of Applications	The CTW team will schedule a meeting to be briefed on the installed applications and their functionality prior to the GM vehicle being delivered in order to minimize any possible delays to testing depending on when the GM vehicle is able to be delivered.
2	Timely Installation and Testing	The CTW team has scheduled to deploy installations in time for testing activities to occur.
3	Weather Delays	Weather events could potentially impact the ability to conduct some testing or demonstration activities in a timely manner. Additional time will be included in the schedule to consider this risk.
4	Sequence of Testing – failures in early phases of testing will delay subsequent testing activities and demonstrations	Plan for multiple rounds of testing in schedule to accommodate delays.
5	Time to on-board UDOT V2X MMS Vendor	Testing activities will be staggered to begin testing for STPs that are not affected by the V2X MMS.

8 Requirements Traceability Matrix (RTM)

This section includes an updated Requirements Traceability Matrix based on the CTW SyRS document that identifies the specific STP to test each requirement. Table 17 is organized to include the following information in each column:

- User Need ID: Provides traceability for each requirement back to the user need identified in the CTW Concept of Operations document.
- Requirement ID: A unique identifier for each requirement that is notated XX-YY-ZZ, where the initial “XX” digits reference the system of interest (i.e., Central System = CS, FE = Field Equipment, VS = Vehicle Systems, or G = General), the middle “YY” digits are the parent requirement number, and the final “ZZ” digits are child requirements of the parent requirement.
- Type of Requirement: Parent requirements are the main requirements, with child requirements being more detailed subsets of the parent requirements.
- Requirement: The system requirement specification.
- Verification Method: Identifies how each requirement will be verified:
 - o Demonstration: A requirement that the system can demonstrate without external test equipment (e.g., a Central System demonstrating that event reports are created).
 - o Test: A requirement that requires some external piece of test equipment (e.g. an OBU to receive messages).
 - o Analyze: A requirement that is met indirectly through a logical conclusion or mathematical analysis of a result (e.g., comparing the timestamp of message creation and receipt by another system or analyzing the pedestrian crash rate at an intersection compared to the statewide average crash rate per intersection).
 - o Inspection: A verification through a visual comparison (e.g., inspecting the location where Field Equipment are deployed to determine if they are along transit routes).
- Utah: Indicates whether or not the requirement pertains to CTW efforts in Utah.
- Colorado: Indicates whether or not the requirement pertains to CTW efforts in Colorado.
- Wyoming: Indicates whether or not the requirement pertains to CTW efforts in Wyoming.
- Test case: System Test Plan that corresponds to the requirement.

Table 17: Requirements Traceability Matrix*Source: CTW Team, April 2026*

User Need ID	Requirement ID	Type of Requirement	Requirement	Verification Method	Utah	Colorado	Wyoming	Test Case
CTW-13	CS-1	Parent	Create event reports. Central Systems shall create event reports.	Demonstration	Yes	Yes	Yes	STP-1
CTW-13	CS-1.1	Child	<i>Event report content.</i> Central Systems shall create event reports that describe current roadway conditions or activities on the road that are expected to impact drivers. Final decisions on thresholds will be at each state's discretion.	Demonstration	Yes	Yes	Yes	STP-1
CTW-13	CS-1.2	Child	<i>Event report sources.</i> Central Systems in each CTW state acquire data or other content from local sources to generate event reports.	Demonstration	Yes	Yes	Yes	STP-1
CTW-13	CS-1.3	Child	<i>Event report timing.</i> Central Systems shall acquire and process local data and content to create or update event reports at a frequency that is determined by each state and may vary based on the type of event.	Demonstration	Yes	Yes	Yes	STP-1
CTW-13	CS-1.4	Child	<i>Event report structure.</i> Central Systems shall create event reports that follow the CTW agreed-upon structure developed during the design process.	Demonstration	Yes	Yes	Yes	STP-1
CTW-13	CS-2	Parent	Interstate event exchange. Central Systems shall send event reports to the SDX.	Demonstration	Yes	Yes	Yes	STP-1

User Need ID	Requirement ID	Type of Requirement	Requirement	Verification Method	Utah	Colorado	Wyoming	Test Case
CTW-13	CS-2.1	Child	<i>Timing of Interstate event exchange.</i> Central Systems shall initiate the process to send event reports to the SDX within 1 minute of the event report being created.	Analyze and Demonstration	Yes	Yes	Yes	STP-1
CTW-13	CS-2.2	Child	<i>Confirmation of Interstate event exchange.</i> Central Systems shall continue the process of attempting to send event reports to the SDX until the event exchange is confirmed.	Demonstration	Yes	Yes	Yes	STP-1
CTW-9	CS-3	Parent	Update events. Central Systems shall update event reports as data or content from the sources are updated.	Demonstration	Yes	Yes	Yes	STP-1
CTW-9	CS-3.1	Child	<i>Share updates of events.</i> Central Systems shall send event report updates to the SDX within 1 minute after the event is updated, following the same process as the initial send.	Analyze	Yes	Yes	Yes	STP-1
CTW-9	CS-3.2	Child	<i>Share expiration of events.</i> Central Systems shall send event report expirations of events with the SDX within 1 minute after the event is determined to be expired.	Analyze	Yes	Yes	Yes	STP-1
CTW-8	CS-4	Parent	Send TIMs to SDX. Central Systems shall send all TIMs generated to the SDX as fully-formed ASN.1 Unaligned Packet-Enabling Code (UPER)-encoded TIMs.	Inspection	Yes	Yes	Yes	STP-2

User Need ID	Requirement ID	Type of Requirement	Requirement	Verification Method	Utah	Colorado	Wyoming	Test Case
CTW-8	CS-4.1	Child	<i>Timing of TIM Exchanges.</i> Central Systems shall send TIMs to the SDX within 1 minute after the fully-formed, ASN.1 UPER-encoded TIM is generated.	Analyze	Yes	Yes	Yes	STP-2
CTW-8	CS-4.2	Child	<i>Confirmation of TIM exchanges.</i> Central Systems shall continue the process of sending TIMs to the SDX until the TIM exchange is confirmed.	Demonstration	Yes	Yes	Yes	STP-2
CTW-8	CS-5	Parent	Update TIMs in SDX. Central Systems shall send updated TIMs to the SDX within 1 minute after the TIM is updated, following the same process the initial TIM send.	Analyze	Yes	Yes	Yes	STP-2
CTW-8	CS-6	Parent	Expire TIMs in SDX. Central Systems shall send TIM expirations to the SDX within 1 minute after the TIM expiration is determined by the Central System, following the same process as when sending the initial TIM.	Analyze	Yes	Yes	Yes	STP-2
CTW-13	CS-7	Parent	Compatible SAE J2735 versions. When continuing message exchanges that are currently operational in each CTW state, the Central Systems shall exchange messages as defined in SAE J2735 standards.	Inspection	Yes	Yes	Yes	STP-2

User Need ID	Requirement ID	Type of Requirement	Requirement	Verification Method	Utah	Colorado	Wyoming	Test Case
CTW-13	CS-7.1	Child	<i>Central Systems receive J2735 messages. Central Systems shall be capable of receiving and processing messages as defined in J2735 standards in all of the following versions: 2016, 2020, and 2024.</i>	Demonstration	Yes	Yes	Yes	STP-2
CTW-13	CS-7.2	Child	<i>Central Systems send J2735 messages. Central Systems shall generate all messages to be exchanged using C-V2X communications as defined by J2735 according to one of the following versions: 2016, 2020, or 2024.</i>	Inspection and Demonstration	Yes	Yes	Yes	STP-2
CTW-4	CS-8	Parent	Expand ingest of SWIW-related data. Central Systems shall be capable of receiving, processing, and storing BSMs received from additional RSUs deployed in the CTW project.	Inspection and Demonstration	Yes	Yes	Yes	STP-3
CTW-5	CS-9	Parent	Expand locations supported by CSW messages. Central Systems shall increase creation of CSW messages to include messages for curves near expansion RSUs.	Demonstration	Yes	Yes	Yes	STP-3
CTW-6	CS-10	Parent	Expand TIM creation. Central Systems shall expand the type and number of TIMs created.	Demonstration	Yes	Yes	Yes	STP-3

User Need ID	Requirement ID	Type of Requirement	Requirement	Verification Method	Utah	Colorado	Wyoming	Test Case
CTW-6	CS-10.1	Child	<i>Expand TIM locations to include additional RSU locations.</i> Central Systems shall create TIMs, when appropriate, that describe conditions downstream of the additional RSUs added in this project and identify the appropriate RSU for broadcast. Determination of what is appropriate is to be defined by each state and is expected to vary by TIM.	Demonstration	Yes	Yes	No	STP-3
CTW-6	CS-10.2	Child	<i>Expand TIM locations to include all areas of the state.</i> Central Systems shall create TIMs, when appropriate, that describe conditions anywhere in the state to be shared through the SDX. Determination of what is appropriate is to be defined by each state and is expected to vary by TIM.	Demonstration	Yes	Yes	Yes	STP-3
CTW-6	CS-10.3	Child	<i>Expand TIM locations to include other states.</i> Central Systems shall consider TIMs and Event Reports received from adjacent states and create TIMs, when appropriate, that communicate the information to travelers heading in the direction of the adjacent states' events. Determination of what is appropriate is to be defined by each state and is expected to vary by TIM.	Demonstration	Yes	Yes	Yes	STP-3

User Need ID	Requirement ID	Type of Requirement	Requirement	Verification Method	Utah	Colorado	Wyoming	Test Case
CTW-14	CS-11	Parent	Central Systems support storage of data for expansion sites and services. Central Systems shall provide capacity to store the additional data added by expansion systems.	Demonstration	Yes	Yes	No	STP-4
CTW-14	CS-11.1	Child	<i>Support storage for additional BSM data.</i> Central Systems shall provide capacity to store BSM messages collected by RSUs added by the CTW Program to meet the retention policies of each CTW state.	Demonstration	Yes	Yes	No	STP-4
CTW-14	CS-11.2	Child	<i>Support storage for additional TIMs.</i> Central Systems shall provide capacity to store the additional TIMs created by the expanded functions in CTW, to meet the retention policies of each CTW state.	Demonstration	Yes	Yes	No	STP-4
CTW-14	CS-11.3	Child	<i>Support storage for additional SRMs and SSMS.</i> Central Systems shall provide capacity to store the additional SRMs and SSMS created and exchanged for the expanded CIs supporting CIPT, to meet the retention policies of each CTW state.	Demonstration	Yes	Yes	No	STP-4

User Need ID	Requirement ID	Type of Requirement	Requirement	Verification Method	Utah	Colorado	Wyoming	Test Case
CTW-14	CS-11.4	Child	<i>Support storage for additional CI data.</i> Central Systems shall provide capacity to store the additional SPaT, MAP, and RTCM messages and associated data created and exchanged for the expanded CIs, to meet the retention policies of the CTW state adding CIs.	Demonstration	Yes	No	No	STP-4
CTW-14	CS-11.5	Child	<i>Support storage for SDSM messages.</i> Central Systems shall provide capacity to store the SDSM messages created and exchanged in support of the VRU Safety Systems added in Utah, to meet the retention policies of the state of Utah.	Demonstration	Yes	No	No	STP-4
CTW-15	CS-12	Parent	Central Systems monitor expansion sites. Central Systems shall monitor health of additional Field Equipment deployed in each state, as documented in the ConOps Sections 3.2.1.2, 3.2.2.2, 3.3.1.2, and 3.4.1.2.	Demonstration	Yes	Yes	No	STP-5
CTW-18	CS-13	Parent	TIMs' adherence to documented best practices. Central Systems shall generate the content and structure of TIMs in a way that adheres to CTW-agreed TIM guidance and best practices documented in the design process.	Demonstration	Yes	Yes	Yes	STP-3

User Need ID	Requirement ID	Type of Requirement	Requirement	Verification Method	Utah	Colorado	Wyoming	Test Case
CTW-8	CS-14	Parent	SDX Functionality. Existing SDX functions should be able to exchange the additional number of TIMs generated from expanded CTW locations.	Demonstration	Yes	Yes	Yes	STP-3
CTW-6	CS-15	Parent	Acquire events from other CTW states. Central Systems shall acquire event reports from the SDX.	Demonstration	Yes	Yes	Yes	STP-1
CTW-6	CS-15.1	Child	<i>Frequency of acquiring Event Reports from SDX.</i> Central Systems shall acquire event reports from the SDX at a frequency defined locally by each CTW state.	Demonstration	Yes	Yes	Yes	STP-1
CTW-6	CS-15.2	Child	<i>Parameters of Event Report Queries from SDX.</i> Central Systems shall query the SDX for event reports within a geographic boundary set by the Central System and defined locally by each CTW state.	Demonstration	Yes	Yes	Yes	STP-1
CTW-6	CS-16	Parent	Create TIMs based on other states' event reports. Central Systems should create TIMs based on the Event Reports received from other CTW states.	Demonstration	Yes	Yes	Yes	STP-3
CTW-6	CS-17	Parent	Acquire TIMs from other CTW states. Central Systems may acquire TIMs from the SDX.	Demonstration	Yes	Yes	Yes	STP-3

User Need ID	Requirement ID	Type of Requirement	Requirement	Verification Method	Utah	Colorado	Wyoming	Test Case
CTW-6	CS-17.1	Child	<i>Location-based query of SDX TIMs.</i> Central Systems may query the SDX for active TIMs within a geographic boundary set by the Central System and defined locally by each CTW state.	Demonstration	Yes	Yes	Yes	STP-3
CTW-6	CS-17.2	Child	<i>Acquire TIMs from other CTW states.</i> Central Systems may acquire TIMs from the SDX at a frequency determined by each site.	Demonstration	Yes	Yes	Yes	STP-3
CTW-6	CS-18	Parent	<i>Distribute TIMs received from other states. Central Systems may distribute TIMs that were acquired from the SDX to RSUs for broadcast if the TIM valid region is within a defined distance (to be defined individually by each state) downstream of the RSU location.</i>	Demonstration	Yes	Yes	Yes	STP-3
CTW-13	FE-1	Parent	<i>Field Equipment-compatible SAE J2735 versions. All CTW Field Equipment added through this effort shall send and receive messages as defined in SAE J2735 standards.</i>	Inspection and Demonstration	Yes	Yes	No	STP-6

User Need ID	Requirement ID	Type of Requirement	Requirement	Verification Method	Utah	Colorado	Wyoming	Test Case
CTW-13	FE-1.1	Child	<i>Field Equipment receive messages in compatible SAE J2735 versions. All CTW Field Equipment added through this effort shall be capable of receiving and processing messages as defined in J2735 standards in all of the following versions: 2016, 2020, and 2024.</i>	Demonstration	Yes	Yes	No	STP-6
CTW-13	FE-1.2	Child	<i>Field Equipment send messages in compatible SAE J2735 versions. CTW Field Equipment added through this effort that generate messages shall generate and send messages as defined in SAE J2735 according to one of the following versions: 2016, 2020, 2024.</i>	Inspection	Yes	Yes	No	STP-6
CTW-1	FE-2	Parent	Expansion sites adhere to earlier qualifications. Expansion sites for CIPT shall be identified that meet location qualifications defined in earlier deployments.	Inspection	Yes	No	No	STP-7
CTW-1	FE-2.1	Child	<i>Expansion sites support transit use. Expansion sites for CIPT shall include intersections along core transit routes that would benefit from improved schedule adherence.</i>	Inspection	Yes	No	No	STP-7
CTW-1	FE-2.2	Child	<i>Expansion sites support snowplow use. Expansion sites for CIPT shall include intersections along UDOT snowplow routes and where snowplows are (or planned to be) equipped to send CIPT requests.</i>	Inspection	Yes	No	No	STP-7

User Need ID	Requirement ID	Type of Requirement	Requirement	Verification Method	Utah	Colorado	Wyoming	Test Case
CTW-1	FE-2.3	Child	<i>Expansion sites support emergency vehicle use.</i> Expansion sites for CIPT shall include intersections used by emergency vehicles that are (or planned to be) equipped to send CIPT requests.	Inspection	Yes	No	No	STP-7
CTW-2	FE-3	Parent	<i>CI expansion sites to address needs.</i> CI expansion sites supporting CIPT shall be in locations where there is existing or planned vehicular traffic that will be equipped to submit priority requests.	Inspection	Yes	No	No	STP-7
CTW-3	FE-4	Parent	<i>CI expansion sites shall continue adherence to CTI 4501/1.</i> CI expansion sites shall follow CTI 4501/1 to the extent possible considering legacy systems involved (e.g., traffic signal controllers) as of April 2025 and as determined in the design process.	Inspection and Demonstration	Yes	No	No	STP-6
CTW-7	FE-5	Parent	<i>Connected Roadway expansion sites to address needs.</i> RSUs deployed at Connected Roadway expansion sites shall be in locations where there is current or planned vehicular traffic that will be equipped to receive messages.	Inspection	Yes	Yes	No	STP-7

User Need ID	Requirement ID	Type of Requirement	Requirement	Verification Method	Utah	Colorado	Wyoming	Test Case
CTW-7	FE-6	Parent	Connected Roadway expansion sites interoperable with legacy Central Systems. RSUs deployed at Connected Roadway expansion sites shall be interoperable with legacy Central Systems deployed in Utah and Colorado as described in the CTW ConOps Sections 3.2.2 (Utah) and 3.4.2 (Colorado).	Inspection and Demonstration	Yes	Yes	No	STP-6
CTW-10	FE-7	Parent	Connected Roadway expansion sites to address needs. Connected Roadway expansion sites that receive BSMs broadcast by passing vehicles shall be in locations where existing or planned equipped vehicles travel.	Inspection	Yes	Yes	No	STP-7
CTW-11	FE-8	Parent	SCMS credentialing interoperability Connected Roadway Expansions. SCMS credentialing on Connected Roadway and CI expansion sites shall be interoperable with credentialing performed for existing CTW systems, as defined in the CTW ConOps Sections 3.2 and 3.4.	Inspection	Yes	Yes	No	STP-6

User Need ID	Requirement ID	Type of Requirement	Requirement	Verification Method	Utah	Colorado	Wyoming	Test Case
CTW-12	FE-9	Parent	VRU Safety System expansion sites adhere to earlier qualifications. Expansion sites for VRU Safety Systems shall be identified that meet location qualifications defined in existing deployments.	Inspection	Yes	No	No	STP-6
CTW-12	FE-9.1	Child	<i>VRU Safety System expansion sites at sites with consistent pedestrian traffic.</i> Expansion sites for VRU Safety Systems shall be identified that have pedestrian crash rates that are above the average number of pedestrian crashes per intersection over a 10-year period (currently 3.2 crashes/year) at SIs.	Inspection	Yes	No	No	See Section 2.3.4
CTW-12	FE-10	Parent	SDSM messages interoperable to legacy systems. SDSM messages broadcast by VRU Safety Systems in expansion sites shall be as defined in SAE J3224.	Assess	Yes	No	No	STP-6
CTW-16	FE-11	Parent	Process SCMS certificates from external agency fleet vehicles. RSUs in CTW states shall have the capability to validate SCMS certificates that accompany messages broadcast by fleet vehicles owned by other CTW sites.	Test	Yes	Yes	Yes	STP-6

User Need ID	Requirement ID	Type of Requirement	Requirement	Verification Method	Utah	Colorado	Wyoming	Test Case
CTW-17	FE-12	Parent	Enable Fleet Vehicles to receive SCMS top-offs without cellular connection. Selected sites shall include the capability to enable C-V2X-equipped fleet vehicles without cellular connectivity to connect to the Internet through Wi-Fi to enable the fleet vehicles to download SCMS top-offs from the contracted SCMS provider.	Test	Yes	Yes	No	STP-8
CTW-13	VS-1	Parent	Vehicle Systems-compatible SAE J2735 versions. All CTW Vehicle Systems added through this effort shall send and receive messages as defined in SAE J2735 standards.	Inspection and Demonstration	Yes	No	No	STP-9
CTW-13	VS-1.1	Child	Vehicle Systems receive in compatible SAE J2735 versions. All CTW Vehicle Systems added through this effort shall be capable of receiving and processing messages as defined in J2735 standards in all of the following versions: 2016, 2020, and 2024.	Demonstration	Yes	No	No	STP-9
CTW-13	VS-1.2	Child	Vehicle Systems send in compatible SAE J2735 versions. All CTW Vehicle Systems added through this effort shall generate and send messages as defined in SAE J2735 according to one of the following versions: 2016, 2020, or 2024.	Inspection	Yes	No	No	STP-9

User Need ID	Requirement ID	Type of Requirement	Requirement	Verification Method	Utah	Colorado	Wyoming	Test Case
CTW-1	VS-2	Parent	<i>SRM messages interoperable to legacy systems.</i> SRM messages broadcast by Vehicle Systems deployed in the CTW project that are CIPT-participating vehicles shall be interoperable with legacy CIPT Field Equipment.	Test	Yes	No	No	STP-9
CTW-16	VS-3	Parent	<i>Process SCMS certificates from external agency RSUs.</i> Vehicle Systems operated by CTW members shall have the capability to validate SCMS certificates that accompany messages broadcast from RSUs operated by other CTW sites.	Test	Yes	Yes	Yes	STP-9
CTW-17	VS-4	Parent	<i>Receive Wi-Fi top-offs of SCMS certificates.</i> Vehicle Systems without cellular communications shall include the capability to establish internet connection through Wi-Fi to receive top-offs of SCMS certificates directly from contracted SCMS providers.	Test	Yes	No	No	STP-8

Appendix A. List of CTI-4501 (v1) Summary of Functional Requirements Addressed by the CIMMS System

Table 18 presents a list of functional requirements from CTI 4501 v1 and describes which are supported by CIMMS.

Table 18. Functional Requirements in CTI-4501 v1 Addressed by CIMMS

Source: CTW Team, April 2026

Functional Requirement ID	Functional Requirement	CIMMS Support	Notes
3.3.2.2.1	Traffic Signal Controller (TSC) Infrastructure Manual Control Indication	No	CIMMS cannot check this directly, but can collect decoded messages enabling easy human verification.
3.3.2.2.2	TSC Infrastructure Stop Time Indication	No	CIMMS cannot check this directly, but can collect decoded messages enabling easy human verification.
3.3.2.2.3	TSC Infrastructure Cabinet Flash (Exception Flash) Indication	No	CIMMS cannot check this directly, but can collect decoded messages enabling easy human verification.
3.3.2.2.4	TSC Infrastructure Controller Flash (Operational Flash) Indication	No	CIMMS cannot check this directly, but can collect decoded messages enabling easy human verification.
3.3.2.2.5	TSC Infrastructure Preemption Operation Indication	No	CIMMS cannot check this directly, but can collect decoded messages enabling easy human verification.
3.3.2.2.6	TSC Infrastructure Priority Operation Indication	No	CIMMS cannot check this directly, but can collect decoded messages enabling easy human verification.
3.3.2.2.7	TSC Infrastructure Fixed Time Control Indication	No	CIMMS cannot check this directly, but can collect decoded messages enabling easy human verification.

Functional Requirement ID	Functional Requirement	CIMMS Support	Notes
3.3.2.2.8	TSC Infrastructure Non-Fixed Time Control	No	CIMMS cannot check this directly, but can collect decoded messages enabling easy human verification.
3.3.2.3.1	TSC Infrastructure Assured Green End Time (AGET)	Yes	None
3.3.2.3.2	TSC Infrastructure Assured Green Period	Yes	None
3.3.2.3.3	TSC Infrastructure Minimum End Time with AGP	Yes	None
3.3.3.1.1.1	SPaT Message - SAE J2735	Yes	None
3.3.3.1.1.2	SPaT Message - Mandatory Data Elements	Yes	None
3.3.3.1.1.3	SPaT Message - CI Mandatory Data Elements	Yes	None
3.3.3.1.1.5	MAP Message - SAE J2735	Yes	None
3.3.3.1.1.6	MAP Message - Mandatory Data Elements	Yes	None
3.3.3.1.1.7	MAP Message - Required Data Elements	Yes	None
3.3.3.1.1.9	RTCMcorrections Message - SAE J2735	Yes	None
3.3.3.1.1.10	RTCMcorrections Message - Mandatory Data Elements	Yes	None
3.3.3.1.1.11	RTCMcorrections Message - Required Data Elements	Yes	None
3.3.3.1.3.2.1	Nodes by Offsets	Partial	CIMMS can handle the various map data formats (offset XY, or explicit long-lat), but will not raise an event if the wrong one (verbose long-lats instead of offsets) is used

Functional Requirement ID	Functional Requirement	CIMMS Support	Notes
3.3.3.1.3.2.2	Computed Lanes Requirements	Partial	CIMMS can handle the various map data formats (offsets, computed lane), but will not throw an error if the wrong encoding is used.
3.3.3.1.3.2.2.1	Computed Lane - Lane Identifier	Yes	None
3.3.3.1.3.2.2.2	Computed Lane - X-Offset	Yes	None
3.3.3.1.3.2.2.3	Computed Lane - Y-Offset	Yes	None
3.3.3.1.3.2.2.4	Computed Lane - Angle	Yes	None
3.3.3.1.4.1	Data Coverage - Every Lane	Yes	None
3.3.3.1.4.2	Advanced Notification - Time	No	The CIMMS visualization tools could assist with this analysis.
3.3.3.1.5.1	SPaT Message - Broadcast Periodicity	Yes	None
3.3.3.1.5.2	SPaT Message - Broadcast Latency	Yes	None
3.3.3.1.5.3	MAP Message - Broadcast Periodicity	Yes	None
3.3.3.1.6.1	Completeness - SPaT Message	Yes	None
3.3.3.1.6.2	Completeness - MAP Message	Yes	None
3.3.3.2.1	Time Accuracy	Partial	The CIMMS system can check if timing information is significantly off, but cannot verify the 10 millisecond range.
3.3.3.2.2.1	SPaT Message - Revision Counter Increment	Yes	None
3.3.3.2.2.2	SPaT Message - Revision Counter Not Increment	Yes	None
3.3.3.2.2.3	MAP Message - Revision Counter Increment	Yes	None
3.3.3.2.2.4	MAP Message - Revision Counter Not Increment	Yes	None

Functional Requirement ID	Functional Requirement	CIMMS Support	Notes
3.3.3.2.2.5	MAP Message - Intersection Revision Counter Increment	Yes	None
3.3.3.2.2.6	MAP Message - Intersection Revision Counter Not Increment	Yes	None
3.3.3.2.2.7	RTCMcorrections Message - Sequence Number Increment	Yes	None
3.3.3.2.2.8	RTCMcorrections Message - Sequence Number Not Increment	Yes	None
3.3.3.2.3.1	SPaT Message - Message Time Stamp	Yes	None
3.3.3.2.3.2	SPaT Message - Intersection Time Stamp	Yes	None
3.3.3.3.1.1	Intersection Signal Timing Information	Yes	None
3.3.3.3.1.2	Road Regulator Identifier	Partial	CIMMS verifies that an ID is present and valid, but cannot check if it is registered to the proper authority
3.3.3.3.1.3	Intersection Reference Identifier	Yes	None
3.3.3.3.2	Intersection Status Requirements	Partial	CIMMS checks to see if these bits are populated, but cannot verify if they are correct compared to the TSC.
3.3.3.3.2.2	Stop Time	Partial	CIMMS checks to see if these bits are populated, but cannot verify if they are correct compared to the TSC.
3.3.3.3.2.3	Failure Flash	Partial	CIMMS checks to see if these bits are populated, but cannot verify if they are correct compared to the TSC.
3.3.3.3.2.4	Preemption	Partial	CIMMS checks to see if these bits are populated, but cannot verify if they are correct compared to the TSC.
3.3.3.3.2.5	Priority	Partial	CIMMS checks to see if these bits are populated, but cannot verify if they are correct compared to the TSC.

Functional Requirement ID	Functional Requirement	CIMMS Support	Notes
3.3.3.3.2.6	Fixed Time	Partial	CIMMS checks to see if these bits are populated, but cannot verify if they are correct compared to the TSC.
3.3.3.3.2.7	Traffic Dependent Mode	Partial	CIMMS checks to see if these bits are populated, but cannot verify if they are correct compared to the TSC.
3.3.3.3.2.8	Standby Mode	Partial	CIMMS checks to see if these bits are populated, but cannot verify if they are correct compared to the TSC.
3.3.3.3.2.9	Failure Mode	Partial	CIMMS checks to see if these bits are populated, but cannot verify if they are correct compared to the TSC.
3.3.3.3.2.13	No MAP Available	Yes	Can be checked by missing MAP message forward.
3.3.3.3.2.14	No SPaT Available	Yes	Can be checked by missing SPaT message forward .
3.3.3.3.3.1	Current Movement State for a Signal Group	Yes	None
3.3.3.3.3.2	Unknown Current Movement State for a Signal Group	Yes	None
3.3.3.3.3.3	Flashing Yellow Arrow Permissive Movement	Partial	CIMMS will check if lights conflict with one another but cannot verify if they match the traffic bulb
3.3.3.3.3.4	Protected and Permissive Clearance	Partial	CIMMS will check if lights are in contact with one another, but cannot verify if they match the traffic bulb.
3.3.3.3.3.5	Resolve Protected Versus Permissive Movement	No	CIMMS does not currently check this requirement, but has the information to do so. This could be added with additional development.
3.3.3.3.3.6	Conflict Causes Permissive	Yes	None
3.3.3.3.3.9	WALK State Enumeration (Potential Conflict)	Yes	None
3.3.3.3.3.10	Flashing DON'T WALK State Enumeration	Partial	CIMMS can check out the pedestrian state represented, but not if it matches the walk state at the intersection.

Functional Requirement ID	Functional Requirement	CIMMS Support	Notes
3.3.3.3.3.11	Steady DON'T WALK State Enumeration	Partial	CIMMS can check out the pedestrian state represented, but not if it matches the walk state at the intersection.
3.3.3.3.3.12	Movement State for Signal Groups Identified	Yes	None
3.3.3.3.4.1	Next Movement State	No	J2735 SPaT messages do not contain this information unless it is added as regional specific data.
3.3.3.3.5.1	Time Change Details	Yes	None
3.3.3.3.5.2	Unknown Time Change Detail	Yes	None
3.3.3.3.5.3	Minimum End Time	Yes	None
3.3.3.3.5.4	Maximum End Time	Yes	None
3.3.3.3.5.5	Unknown Maximum End Time	Yes	None
3.3.3.3.5.6	Current Movement State Start Time	No	CIMMS does not currently check this requirement, but has the information to do so. This could be added with additional development.
3.3.3.3.5.7	Next Movement State Start Time	Yes	None
3.3.3.3.5.8	Next State Start Time Equals Current State Minimum End Time	No	CIMMS doesn't currently check this requirement but has the information to do so. This could be added with additional development.
3.3.3.3.6.1	Time of Next Allowed Movement	Yes	Please note, these times are subject to SRM/SSM and pedestrian pressing the button. It is easy to check if the time is available, but not if it is correct.
3.3.3.3.7	Enabled Lanes Indication	Yes	None
3.3.3.3.8	SPaT Message - Accuracy	Partial	The CIMMS system tries to check this using vehicle traffic and comparison to Automated Traffic Signal Performance Measures (ATSPM) data.

Functional Requirement ID	Functional Requirement	CIMMS Support	Notes
3.3.3.4.1.1	Intersection Geometry Information	Yes	None
3.3.3.4.1.2	Intersection Geometry - Road Regulator Identifier	Yes	Can verify if this is present but not if it is valid.
3.3.3.4.1.3	Intersection Geometry - Intersection Identifier	Yes	None
3.3.3.4.1.4.1	Intersection Reference Point - Position	Partial	CIMMS can check the availability of this point, but not its geographic accuracy.
3.3.3.4.1.4.2	Intersection Reference Point - Description	Yes	None
3.3.3.4.1.5	Default Lane Width	Yes	None
3.3.3.4.1.6	Lane Identifier	Partial	CIMMS can check the presence of a lane ID but will not check for duplicates. This could be added with additional development.
3.3.3.4.1.7	Center of Vehicle Lane Geometry	Yes	None
3.3.3.4.1.8	Center of Crosswalk Lane Geometry	Yes	None
3.3.3.4.1.9	Center of Pedestrian Landings Geometry	Yes	None
3.3.3.4.1.10	Lane Description	Partial	None
3.3.3.4.1.11	First Node Point - Ingress Vehicle Lane	No	The CIMMS system does not check this automatically, but the visualizer will make it clear if there is a problem here.
3.3.3.4.1.12	First Node Point - Egress Vehicle Lane	No	The CIMMS system does not check this automatically, but the visualizer will make it clear if there is a problem here.
3.3.3.4.1.13	Node Offset from Intersection Reference Point	Partial	Note 6: CIMMS can check if this field is present, but will not verify that it conforms to the units required by CTI 4501.
3.3.3.4.1.14	Node Elevation Offset from Intersection Reference Point	Partial	Note 6: CIMMS can check if this field is present, but will not verify that it conforms to the units required by CTI 4501.
3.3.3.4.1.15	Offset from Previous Node	Partial	Note 6: CIMMS can check if this field is present, but will not verify that it conforms to the units required by CTI 4501.

Functional Requirement ID	Functional Requirement	CIMMS Support	Notes
3.3.3.4.1.16	Elevation Offset from Previous Node	Partial	Note 6: CIMMS can check if this field is present, but will not verify that it conforms to the units required by CTI 4501.
3.3.3.4.1.17	Advanced Notification - Ingress Vehicle Lane	No	CIMMS does not currently check this requirement, but has the information to do so. This could be added with additional development,
3.3.3.4.1.20	Maximum Distance between Nodes	No	CIMMS does not currently check this requirement, but has the information to do so. This could be added with additional development.
3.3.3.4.1.21	Maximum Number of Nodes	No	CIMMS does not currently check this requirement but has the information to do so. This could be added with additional development.
3.3.3.4.1.23	Node Accuracy	Partial	CIMMS attempts to determine the validity of lane accuracy using BSM traffic.
3.3.3.4.2.1	Direction of Travel	Yes	None
3.3.3.4.2.2	Lane Sharing	Yes	None
3.3.3.4.2.3	Lane Type Attributes	Yes	None
3.3.3.4.2.4	Lane Attributes - Vehicle	Yes	None
3.3.3.4.2.5	Lane Attributes - Crosswalk	Yes	None
3.3.3.4.2.6	Lane Attributes - Bicycle	Yes	None
3.3.3.4.2.7	Lane Attributes - Tracked Vehicles	Yes	None
3.3.3.4.2.8	Lane Attributes - Parking	Yes	None
3.3.3.4.3	Lane Maneuvers	Yes	None
3.3.3.4.4.1	Lane Connections	Yes	None
3.3.3.4.4.2	Connection Egress Lane	Yes	None

Functional Requirement ID	Functional Requirement	CIMMS Support	Notes
3.3.3.4.4.3	Connection Maneuvers	Yes	None
3.3.3.4.4.4	Connection Signal Group	Yes	None
3.3.3.4.4.5	Include Only Permitted Connections	Partial	The CIMMS system will attempt to find and alert on invalid lane connections. However, it is not comparing to an absolute reference.
3.3.3.4.5.1	Default Speed Limit	Yes	None
3.3.3.4.5.2	Change in Lane Speed Limit	Yes	None
3.3.3.4.6	Revocable Lanes	Partial	CIMMS will check revocable lane behavior, but has no way to know if a lane that should be revocable was not defined as such.
3.3.3.4.7	MAP Message - Accuracy	Yes	None
3.3.3.4.8.1	Matching Intersection Reference Identifier	Yes	None
3.3.3.4.8.2	Matching SPaT and MAP Version	Yes	None
3.3.3.5.1	Positioning Corrections	Yes	None
3.3.4.7.2.11	Determine Operational Status	Yes	None
3.3.4.7.2.12	Determine Operational Performance	Yes	None

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