CONNECTED INTERSECTIONS PROGRAM:
PROGRAM MANAGEMENT AND TECHNICAL SUPPORT

Test Plan - FINAL

Version 0.2 – March 25, 2022

Prepared by

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Final

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Version History

Table 1. Version History

Version Number	Date	Author(s), Agency	Summary of Changes
0.1	09/24/2021	WSP (TT, FP, VL)	Initial Draft Release
0.2	5/25/2022	WSP (CT, TT, VL)	Comments / Expanded Section 8

1. Introduction

1.1 PURPOSE

The purpose of this work product is to document the test plan for conducting multi-site connected vehicle (CV) message verification activities in support of the goals and objective of the Connected Vehicle Pooled Fund Study (CV PFS) as stated below.

1.2 PROJECT BACKGROUND

The Infrastructure Owner Operator (IOO) and Original Equipment Manufacturer (OEM) communities have the shared goal of building and operating intersections and producing fully interoperable vehicles. This is of the utmost importance to gain the full potential benefit of connected vehicles (CV). While significant progress has been made, there is a need for the IOO and OEM communities to work directly together to address key remaining issues to achieve this goal. This required effort includes collaborative testing in the laboratory and varied field deployments to verify timely, consistent, trusted and reliable message transfer, and joint development of security policies.

These communities have developed the Connected Intersections Program to accomplish this. This program, which was founded on the Connected Signalized Intersection Verification (CSIV) Project in Ann Arbor, Michigan, and has been updated to consider recent Connected Intersection guidance as produced by ITE, will address geographic and equipment variations, security, and message consistency; it will result in clear guidance materials to guide IOO deployment and clarity on testing and operational practices to ensure that the CV infrastructure is providing information vehicles can interpret and trust. In addition, engaging in the ongoing Security Credential Management System (SCMS) Manager effort, also described below, provides the foundation for security necessary for CV applications and a framework for ensuring deployments that are tested and verified for the production environment (as per the outcomes of this project) are trusted by production vehicles.

1.3 GOALS AND OBJECTIVES

The primary objective of the Connected Intersections Program (CIP) project is to verify that the existing requirements, specification and guidance that has been produced related to signalized intersections in a CV ecosystem can support the basic needs of a functional red-light violation warning (RLVW) application as demonstrated by an OEM or other 'production' device.

This will be enabled by verifying that the following are achieved.

- Message Format is compliant with SAE J2735 and the recent ITE CI Implementation Guidance
- Message Content and Timing matches that produced by the Signal Controller
- Message Range satisfies range requirements for RLVW

- System Reliability is >99% uptime

1.4 DOCUMENT ORGANIZATION

The Test Plan is organized as follows:

- Introduction
- References
- Risks and Contingencies
- Site Selection Criteria and Results
- Test Items
- General Test Site Activities
- Site Specific Plans
- Test Cases
- Test Scenarios
- Test Procedures

2. References

- Connected Intersections Implementation Guide, September 2021, ITE
- Clarifications for Consistent Implementations (CCI's) to Ensure Interoperability of Connected Signalized Intersections, May 2019, Cooperative Automation Transportation
- SAE J2735 – Latest Version

3. Risks and Contingencies

Given the short timeframe for this project and the complexity of the systems being tested, a proactive approach to risk management has to be considered. From our experience testing CV deployments, we have identified the following risks and accompanying contingencies.

- Risk: Hardware failure during testing
  - Contingency: Hardware replacement will only take place if a replacement is readily available, else testing will shift to a similarly configured location, or the number of locations tested may be reduced
- Risk: Local IT policy prohibits connection of test equipment in certain locations
  - Contingency: An initial priority of the testing activities will be to ensure access to the necessary test points by communicating with the site to educate on these needs.
- Risk: Critical failure preventing further immediate testing is identified
  - Contingency: Test sites were selected based on existing deployment features. Each site has agreed, within reason, to remedy identified items promptly to allow for testing to be rescheduled
- Risk: Mismatch between Road Side Unit (RSU) and On-Board Unit (OBU) certificates
  - Contingency: The SCMS service provider will be clearly identified to the OBU provider before their expected testing phase.

Additional Testing activities (phases) may be required if a system, functionality, or device is unavailable during initial testing. These additional testing actives will be coordinated and scheduled based on all stakeholder availability.

4. Site Selection Criteria and Results

4.1 SITE SELECTION

A rubric for site selection was established to determine which CV PFS members site(s) had deployments that would be suitable to meet the objectives of this project, based on factors including:

- Site characteristics, including site readiness (does an active deployment already exist), complexity (number of lanes, phasing, diverging diamonds, or other unique intersection design), and use cases of value that are different than that of the current environment
- The ability of the site to quickly support changes to their existing deployment to become conformant to the standards
- Location and the ability of an OEM/ Collision Avoidance Metrics Partnership (CAMP) to support testing
- A site owner that is a CV PFS member and willing to participate
- Coordination with ITE CV test activities

For each interested IOO site, the test team identified and classified the available intersection configurations and compared them against the total set of configurations identified.

Based on the outcomes of these early steps, potential sites were evaluated to provide a detailed analysis and recommendation for consideration by the Panel.

The Panel decided to move forward with specific sites based on the recommendations from the WSP team. Table 2 below shows the primary criteria evaluated and the results

Table 2. Test Site Selection

	Georgia DOT	DriveOhio	Utah DOT	McDOT	Florida DOT
Location	The Ray (signalized)	Marysville	Park City	Anthem	Gainesville
Schedule	Now	Q4-21	Q1-22	Q4-21	TBD
Availability of Integrator Resources?	Yes	Yes	Yes	Yes	Limited, no existing contract
Security	Yes	Yes	Yes, expect for RTCM	Q1-22	Yes
Position Correction	Yes	Yes	TBD	No	Yes
OEM/Vendor Relationship	Work-in-Progress	Honda	CAMP (Ford/GM/Nissan)	Not Presently	Not Presently
Technology	Both	DSRC	C-V2X	DSRC	DSRC
Selection	**Phase 1a, Site 1**	**Phase 1b, Site 2**	**Phase 1c, Site 3**	**Future Phase (?)**	**Future Phase (?)**

Source: WSP USA

4.2 SITE SELECTION

As a result of the site evaluation, email exchanges, and virtual meetings, the following sites are recommended:

1. Georgia DOT – The Ray
2. Drive Ohio – Connected Marysville
3. Utah DOT – Park City[1]

Details for each site follow in **Appendix D.**

[1] UDOT and their CAMP partner are leading the testing efforts independent of the CIP project, and the role of the CV PFS CI project is more of a monitoring and reporting function.

5. Test Items

5.1 TEST COMPONENTS

Table 3 contains devices and subsystems and which devices and subsystems each will be tested against:

Table 3. Device/Subsystem Test Matrix

Device/Subsystem Under Test	Devices/Subsystems tested against
Roadside Unit (RSU)	• Traffic Signal Controller • SCMS • Local Network • Roadside Equipment • Position Correction System
Signal Controller	• Roadside Unit • Roadside Equipment
Onboard Unit (OBU)	• Roadside Unit

Source: WSP USA

5.2 FUNCTIONALITY TO BE TESTED

This section contains a high-level description of the features that will be tested as part of this Test Plan.

5.2.1 Roadside Equipment

The following functionality of the Roadside Equipment will be tested:

- The RSU's ability to broadcast wireless access in vehicular environments (WAVE) service advertisements (WSAs) once per second on the appropriate channel. WSAs will advertise internet protocol (IP) services and contain the WAVE routing advertisements (WRA) for OBUs to download certificates from the SCMS.
  - A successful test of this functionality indicates:
    - The RSU can generate and broadcast WSAs as defined in Institute of Electrical and Electronics Engineers (IEEE) 1609.3
- The RSU's ability to broadcast J2735 SPaT messages 10 times per second on the appropriate channel
  - A successful test of this functionality indicates:

        - The signal controller sends SPaT data to the roadside equipment (RSE)
        - The RSE encodes SPaT data into J2735 SPaT messages
        - RSU broadcasts SPaT messages 10 times per second on the appropriate channel
        - The SPaT message format meets requirements established by the ITE CI Implementation Guide
        - The SPaT message content is correct compared to data from signal controller
        - SPaT message latency from origin to broadcast is less than 300 ms
        - The SPaT message broadcast range is sufficient to support application requirements
        - SPaT message reliability indicates >99% uptime
        - The latency between change in signal head and the change in the SPaT message is less than 50 ms
- The RSU's ability to broadcast J2735 MAP messages once per second on the appropriate channel
    - A successful test of this functionality indicates:
        - Operations Center staff can generate MAP messages
        - The backhaul network supports the connection between the Operation Center and the RSE
        - Operations Center staff can send MAP messages to the RSE
        - RSE stores MAP messages
        - The RSU broadcasts MAP messages on the appropriate channel once per second
        - The MAP message broadcast range is sufficient to support application requirements
        - MAP message reliability indicates >99% uptime
        - MAP message reflects accuracy of <= 0.5 meters
- The RSU's ability to broadcast RTCM messages 3 times per second on the appropriate channel
    - A successful test of this functionality indicates:
        - The backhaul network supports the connection between the Position Correction System and the RSE
        - The Position Correction System sends RTCM data to the RSE
        - The RSE encodes RTCM data into J2735 RCTM messages
        - RSU broadcasts RTCM messages on the appropriate channel 3 time per second
        - The RTCM message format is correct per the ITE CI Implementation Guide
        - The RTCM message content is correct per RTCM v3.1 specification
        - The RTCM message broadcast range is sufficient to support application requirements
        - RTCM message reliability indicates >99% uptime

        - Message latency from generate to broadcast is less than 300 ms
- RSUs ability to request and receive IEEE 1609.2 certificates from the SCMS provider
    - The successful testing of this functionality indicates:
        - The RSU determines it needs additional certificates
        - The RSU sends a certificate request to the SCMS
        - RSU receives and processes new certificates from the SCMS, based on the request

5.2.2 Vehicle On-Board Unit

The functionality of an OEM or other light duty vehicle OBU will be tested to verify the OBU's ability to provide RLVW warnings to drivers.

A successful test of this functionality indicates:

- The RSU is broadcasting SPaT, MAP, and RTCM messages required to provide RLVWs to the vehicle driver
- The OBU RLVW application is functioning as intended
- The OBU HMI is functioning as intended

5.3 FUNCTIONALITY NOT TESTED

This section contains a high-level description of items that will NOT be tested as part of this Test Plan.

The items that will not be tested include, but are not limited to:

- Test Scenarios where the proposed 'Assured Green Time' element is required from the Traffic Signal Controller.
- OBUs ability to receive and process RTCM
- OBUs ability to request and receive IEEE 1609.2 certificates from the SCMS provider through an RSU.
- Performance of any other V2X applications available on either the RSU or OBU, besides RLVW.

6. General Test Site Activities

CIP Testing at each site will be conducted over a span of multiple days, at multiple locations associated with a test site, using multiple configurations of items-under-test, and multiple test tools and methods; each test phase and test approach building on the previous. This section describes, in a general format, the components of testing to be conducted at each of the three test sites. Details for each site follow in subsequent sections. This section is organized by:

- Test Phases
- Test Approach
- Roles
- Schedule
- Test Tools
- Test Environment
- Test Criteria
- Measure and Metrics

6.1 TEST PHASES

CIP Testing is expected to be conducted using a combination of tests phases conducted in the lab or a highly controlled environment (aka bench), performed in the field at operational intersections, and conducted in-vehicle using OEM or similar equipment.

6.1.1 Bench / Controlled Environment Testing

Any test that is considered disruptive, meaning a test that purposefully or unintentionally interrupts the normal operations of a signalized intersection shall be performed outside of an operational intersection, either as a benchtop test at the traffic signal shop (or similar), or in a highly controlled external environment. The expectation is that this environment reasonably replicates the hardware, software and network configuration typical of the deployed environment. Use of a controlled-environment of this form allows for more efficient testing of critical signal transitions and detailed nuisance of the timing output by allowing for repeated restarts and resets of the controller or other system function, and to significantly reduce the duration of signal phases to more suited to repeated and rapid measurement. This environment also allows for better evaluation of negative result test cases, where the requirements dictate for instance, that an event should not occur. Often, to test this, the items under test must be subjected to non-normal but potential scenarios.

Bench testing will focus primarily on the Message Content Testing as described in **Section 6.2.**

6.1.2 Operational Testing

The majority of test scenarios to be performed for CIP require testing on operational intersections in order to confirm the actual operation and performance of the specific intersections, including message format, message latency, communications range, and device reliability. Because this testing is against a live intersection, all attempts to avoid signal timing disruption will be made. Additionally, assuming that all necessary tests targeted for testing on the bench can be completed, the goal is to avoid or limit the need to access the signal cabinet or any of the roadside equipment, with all measurements performed using the over-the-air message capture, OBU visualization tools, and high-frame rate cameras.

The majority of these test will be conducted from a tool-equipped vehicle, capturing data during both stationary and active drives on each approach. Two members of the test team will be in-vehicle to perform these tests, one to perform the driving duties and the second to operate the test equipment.

The exception to this is MAP validation, which is expected to require physical 'boots-on-the-ground' survey-type work with a need for management of traffic (MOT). The goal is to limit this portion of testing to a single day (per site), but that may need to be adjusted as results are evaluated.

6.1.3 Vehicle Drive-Through Testing

The final phase of testing involves the active participation of OEM or representative vehicles hosting the RLVW application. The RLVW-enabled vehicle shall exercise both positive and negative test cases, with the intent to confirm expected infrastructure operations. The test cases and procedures for this phase will likely be proprietary, but the partner is expected to report successes and failures and any necessary or suggested changes to the infrastructure will be thoroughly documented and vetted by the project team before any changes are made.

6.2 TESTING APPROACHES

The primary goal of CIP is to ensure that the correct CV data is delivered to the CV-equipped vehicle in the correct format, timely, reliably and securely, and at a distance sufficient to support the equipped vehicle application use of the data. In order to verify this 'compliance,' the test team has established four distinct but related approaches to conducting the testing.

6.2.1 Message Format Testing

Message Format Testing serves to verify that the over-the-air message meets the requirements for message content, format and range of values as identified by the ITE CI project. The ITE CI project has reclassified a quantity of 'optional' fields, as identified by SAE J2735, to be considered mandatory for purposes of the CI Guidance.

Message Format Testing will be completed first, prior to any other tests, as changes to the system to bring this into compliance will likely require vendor actions.

SPAT Message

Message Format validation for SPAT messages will utilize the JSON-based tool developed by Collision Avoidance Metrics Partnership (CAMP) to evaluate critical elements of the message. Mandatory fields, acceptable values for these fields – both individually and dependent on fields, and sensible values for the fields are included.

The SPAT message will be evaluated by the CAMP partners on the ITE CI Test and Conformity Sub-Committee.

		*** SPaT Message Summary Report v1.5 ***						
Test Nam	SPaT - Test Location:	Report Created: 2021-06-13 14:05:25						
SPaT File:	SPaT_55884_rx_20210528-SPaT-0-55884_Summary_Report.csv							
Date and Time:	2021/05/28 - 13:26:49.788 (UTC)	# of Messages: 2023	Total Test Time: 0:33:48.900					
		# of Sig Group(s): 5	Sig Group [4, 8, 6, 5, 2]					
		Message Signed Flag: 0 (0=Unsigned, 1=Signed, 2=Verified)						
		>>>>>>> ========== <<<<<<<						
		M/O/C i	Pass/Fai	M/O/C in	Pass/Fai	Invaid	Data Rang	Data Rang Remark
	SAE J2735 SPaT Data Frames and Elements	SAE J273	J2735	Impl - RLV	CI Impl RL	Data	Low	High
messageId=DE_DSRC_MessageID=19 (SPaT UPER)		M	Pass	M	Pass		0	32767
timeStamp=DE_MinuteOfTheYear		O	--	M	Pass		0	5274040
name=DE_DescriptiveName (only for debug)		O	--	O	--			
intersections=DF_IntersectionStateList		M	Pass	M	Pass			
name=DE_DescriptiveName (only for debug)		O	--	O	--			
id=DF_IntersectionReferenceID		M	Pass	M	Pass			
region=DE_RoadRegulatorID		O	--	M	--Fail--		0	65535 Missing data
id=DE_IntersectionID		M	Pass	M	Pass		0	65535
revision=DE_MsgCount		M	Pass	M	Pass		0	127
status=DE_IntersectionStatusObject		M	Pass	M	Pass		0	65532
moy=DE_MinuteOfTheYear		O	--	O	--		0	5274040
timeStamp=DE_Dsecond		O	--	M	Pass		0	65535
enabledLanes=DF_EnabledLaneList		O	--	C	--			C-When revocable lane is active
states=DF_MovementList=1 to 255 x DF_MovementState		M	Pass	M	Pass			
movementName=DE_DescriptiveName (only for debu		O	--	O	--			
signalGroup=DE_SignalGroupID		M	Pass	M	Pass		0	255
state-time-speed=DF_MovementEventList		M	Pass	M	Pass			
eventState=DE_MovementPhaseState		M	Pass	M	Pass			
timing=DF_TimeChangeDetails		O	--	M	Pass			
startTime=DE_TimeMark		O	--	C	--		0	36001 C-If available
minEndTime=DE_TimeMark		M	Pass	M	Pass		0	36001
maxEndTime=DE_TimeMark		O	--	M	Pass		0	36001
likelyTime=DE_TimeMark		O	--	--	--		0	36001
confidence=DE_TimeIntervalConfidence		O	--	--	--		0	15
nextTime=DE_TimeMark		O	--	C	--		0	36001 C-If available

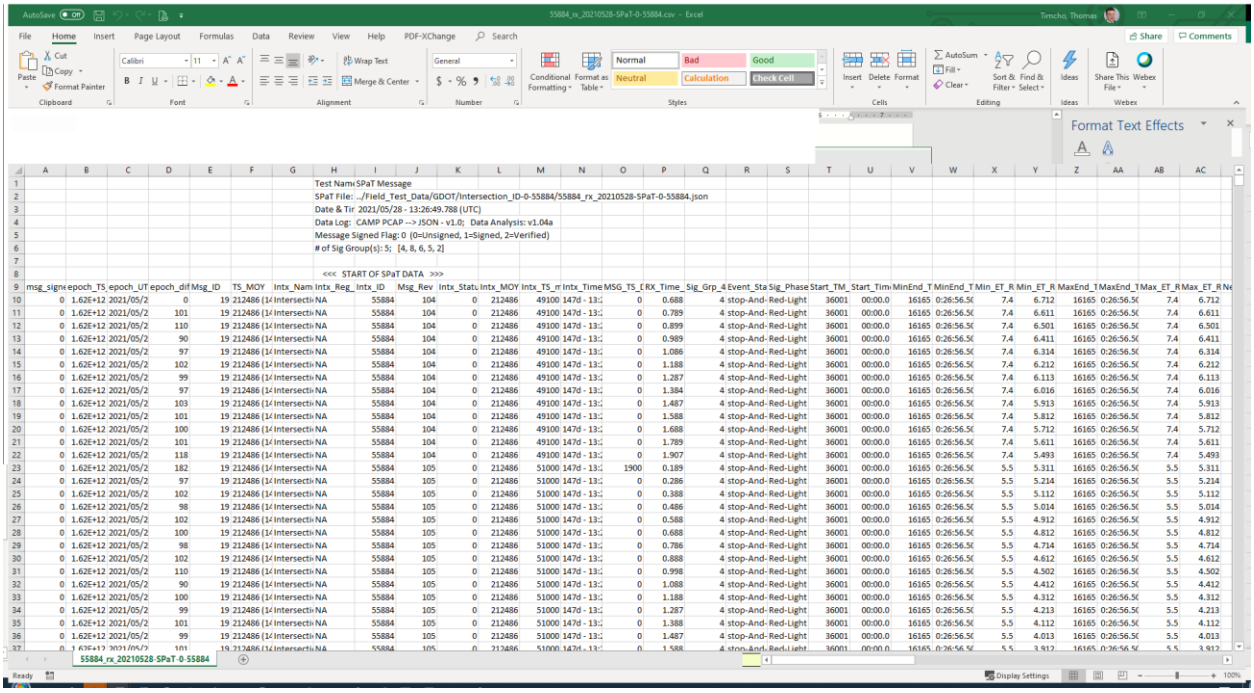
Source: CAMP LLC

Figure 1. Example CI SPAT Analysis Summary

As shown in **Source:** CAMP LLC

Figure 1, all elements (values) in the column 'CI Impl RLVW' shall be verified as included and in range. Those that are not will require updates by the site and re-tested.

Further, a complete timing cycle will be analyzed from the CI SPAT Analysis results, shown in **Figure 2**, with the rubric to include inconsistent values in the time remaining (min and max) and phase status fields.



Source: CAMP LLC

Figure 2. Example CI SPAT Analysis Results

Source: CAMP LLC

Figure 3. Example CI MAP Visualization

MAP Message

MAP evaluation will be performed similarly to that of SPAT with both the data elements captured and evaluated, as well as a visual analysis of the MAP connections. Source: CAMP LLC
Figure 3 shows an example of the available data for this visual analysis. Connections from Ingress to Egress lanes need to be confirmed, and this also gives an initial view of how the MAP message portrays the intersection.

RTCM Message

The ITE CI / CAMP analysis tools do not presently support an RTCM message component analysis, but the RTCM message can be captured in the same data feed. As such, verification of the RTCM will require extraction of the payload from the RTCM message and translation back to the original message structure as sent by the GPS base station. Details of this process are still being developed and will be included in an update of this plan.

6.2.2 Message Content Testing

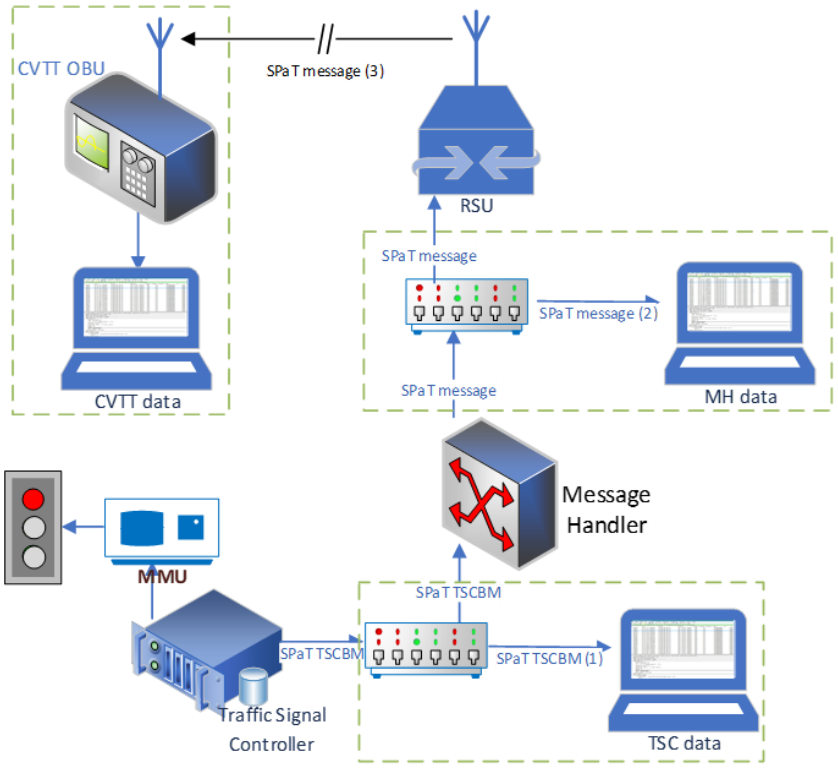
Message Content Testing serves to verify that the data in the respective messages are correct with respect to the intent of the message and that the latency of the message also supports the RLVW application. Unlike the format testing above, message content testing varies significantly for each of the message types below.

SPAT Message

SPAT Message Content Testing will be performed using two analysis approaches: that derived from the time synchronized PCAP files captured at multiple points within the information flow from signal controller to RSU; and visual analysis of the latency of the data as captured using a high-speed camera. *Note: PCAP is the name of a file format used for these types of messages.*

For the former, Wireshark enabled laptops will be connected to the traffic signal network at points where data exits the signal controller, the message handler (if equipped), and the RSU, as shown in **Source**: WSP USA
Figure 4. The corresponding PCAP files will then be timestamp aligned, and a comparison of timing and phase status values compared across the various test points. The first and broader encompassing iteration of this testing will be performed in the bench environment in order to minimize the impact of controller or system restart. The second iteration, to be performed on the operational equipment, serves as a simple spot check of the fully vetted system.

Additionally, a high-framerate camera, such as a GoPro Hero 9 will be used to capture the output of the Kapsch Connected Vehicle Test Tool (CVV) framed in the same video as the signal head. When using 240 frames-per-second, this can subsequently be replayed in super slow-motion mode to capture intervals of less than 5 milliseconds. Captures of each phase/movement from each approach will be performed. This part of the test will support latency testing between the signal head and the OTA message. *Note: The overhead of the CVV tool may add to the observed latency.*



Source: WSP USA

Figure 4. SPAT Message Content Test - Test Configuration

MAP Message

Message Content validation routines for the MAP message are still being developed but are expected to use a combination of GIS software tools coupled with boots-on-the-ground measurements. Survey points will be acquired for key features of the MAP, such as the endpoints of the leading edge of the stop bar, and well as intersection-dependent lane features. Basic geometry concepts will also be applied for sanity checks of the MAP data as well. For instance, given a radius of a curve and the length of the arc, it is easy to determine the minimum number of node points needed in the MAP message to represent the curve when the greatest distance from the arc of the curve to the chord cannot exceed 50 cm. If the corresponding MAP message has less points, then it is likely not of sufficient resolution and additional node points would need to be added to the MAP file.

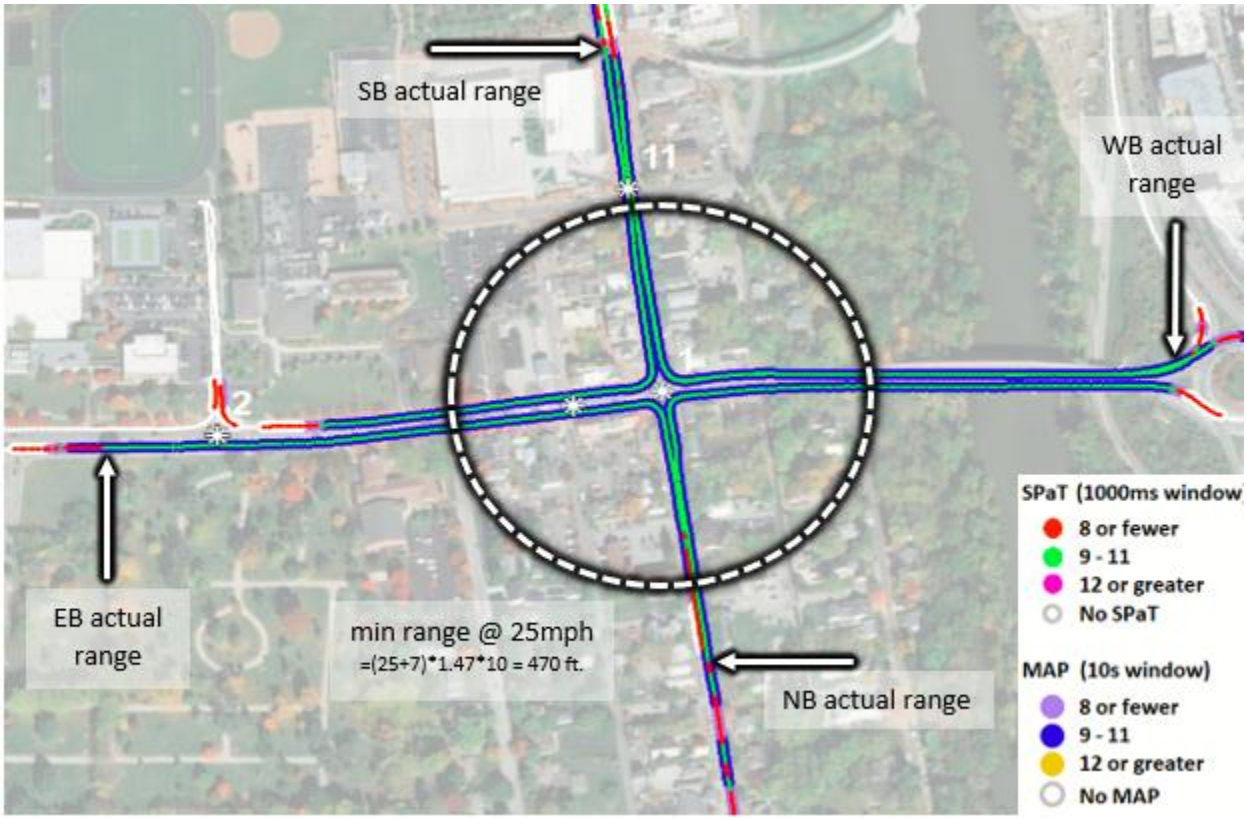
RTCM Message

Given the current state of RTCM capture tools, the analysis performed as part of the Message Format Testing is sufficient to satisfy the Message Content Messaging as well.

6.2.3 Message Range Testing

Message Range Testing is comprised of both a data collection phase and an offline data analysis phase. During the data collection phase, the CVV-equipped vehicle is driven along all approaches of each intersection where roadside equipment is installed. To ensure the data coverage requirement and design details are satisfied, the vehicle should traverse every MAP lane geometry – from the

upstream-most point to the stop bar of each lane without changing lanes. Wireshark PCAPS are captured for the entirety of the vehicle movements. Vehicle location data (from the vehicle's own BSM message) is then related to SPAT, MAP, and RTCM data capture in the PCAPs and are imported in a GIS tool where the reception rate (Hz) can be determined and equated to a reception range. Figure 5 provides an example of what the range testing will produce.



Source: WSP USA

Figure 5. Message Range Test output screen

6.2.4 Message Reliability Testing

Message Reliability testing can be accomplished in one of two ways, enabling logging on adjacent RSUs to capture all messages from the RSU under test, or to configure the CVV (or other OBU), and then install in a cabinet to log all communications at the RSU continuously. Statistics will be compiled on a daily basis. Minimally, the RSU and all corresponding hardware shall remain functional 99% of the time, which translates to an allowable 14-minute daily lapse. A performance requirement of 99.9% equates to a roughly 1.5 second downtime, cumulative, which is a much more ideal target.

6.3 TEST ROLES

Table 4. Test Roles

Title	Description	Responsibility
Site Project Manager	Oversees all activities conducted at each site	GDOT DriveOhio UDOT
Test Facility Owner	Test Facility owners represent the physical location where amenities will be deployed to perform bench testing.	Site Owner
Test Environment Owner	Test Environment owners represent the physical location where amenities will be deployed to perform field testing.	Site Owner
Test Manager	The Test Manager supervises and controls all tests, reviews and approves test procedures, has the authority to direct all test activities, and is responsible for communicating test status to all stakeholders. The Test Manager will notify the site and other key stakeholders of the test schedule at least 1 week in advance of the scheduled start. The Test Manager may not necessarily be present during all test activities but will communicate regularly with the test conductor for status updates. The Test Manager signs off on all completed tests based on functionality demonstration	WSP (GDOT & DriveOhio sites) UDOT (UDOT site)
Test Conductor	The Test Conductor is responsible for running the daily test activities and demonstrating test results to the Test Manager	WSP (GDOT & DriveOhio sites) UDOT (UDOT site)
Traffic Management Staff	The Traffic Management Staff utilize the Traffic Connected Vehicle Management System to collect data from the CVE	Site Owner
Data Recorder	The Data Recorder is responsible for recording the outputs and overall results of each test. The Data Recorder will provide all observations to the Test Manager at the end of the test day.	WSP (GDOT & DriveOhio sites) UDOT (UDOT site)
Data Collection Vehicle Drivers	Data Collection Vehicle Drivers will operate vehicles during each applicable test/demonstration. They will follow the explicit instructions in the test script and will be in constant communication with the test conductor to receive	WSP

	further instructions as well as to inform the test conductor of any incidents or exceptions they experience during a test run.	
OEM / Vendor Vehicle Drivers	Vehicle Drivers will operate vehicles during each applicable test/demonstration for the Drive-Thru portion of the test. They will follow the explicit instructions in the test script and will be in constant communication with the test conductor to receive further instructions as well as to inform the test conductor of any incidents or exceptions they experience during a test run.	WSP UDOT OEM or alternative
Test Observers	Test observers witness test runs at the site owner's discretion.	TBD

Source: WSP USA

6.4 SCHEDULE

Following is an example of a high-level schedule for conducting on-site testing at each site. Refinement and site-specific elements will be generated for each test site.

Day 1 a.m.: Arrive on site, set up a GPS Position Correction base station to support ground survey, perform preliminary site evaluation, identify any additional needs and remedy those needs.

Day 1 p.m.: Conduct Data gathering for CI project tool analysis

Day 2: Conduct Bench Testing

Day 3 a.m.: Conduct Positioning test

Day 3 p.m.: Conduct Field verification

Day 4: Continue Field verification.

Day 5 a.m.: Complete Field verification

Day 5 p.m.: Complete Reporting

6.5 TEST TOOLS

This section describes the tools and equipment utilized to assess individual components, subsystems, and the overall CV system.

6.5.1 Connected Vehicle Test Tool

CVV tool is utilized to visualize SPaT and MAP messages, verify WSA/WRA, and RTCM message content, and capture CV messages for analysis to verify proper format content, and other test requirements. Capture formats include both PCAP and JSON. Both DSRC and C-V2X versions of the CVV will be available.

6.5.2 Wireshark Packet Analyzer

Quantity three (3) laptop computers running the open source Wireshark Packet Analyzer will be available as needed to capture data at different points in the system. It is assumed that the interface to the system under test will be via hardwire ethernet, so as such, the laptop shall support an ethernet connection.

6.5.3 GoPro Hero 9 Camera

A GoPro Hero 9 camera will be used to capture high framerate video (240 fps) that can then be used to capture the signal head and CVV output behavior which can later be used to evaluate correctness and latency.

6.5.4 GoPro Player

The GoPro Player will be used to review and reframe captured test video, including 8x slow mode, which effectively will allow viewing behavior in <5 ms intervals.

6.5.5 Survey Equipment

Survey equipment with high-precession accuracy shall be available to measure the lat/long/alt points for stop bar and other features as determined by the detailed test procedures to be developed for each test site /intersection. The GPS points will be used to calibrate and validate the MAP message lanes.

6.5.6 ESRI Arc GIS

Geographic Information System used as part of MAP validation exercise.

6.5.7 OEM On-Board Unit

The OBU is utilized to demonstrate vehicle-based applications to verify the proper operation of the applications as well as capture CV messages for troubleshooting.

6.5.8 Test Result Log

The test team will rely on tools based on Microsoft Excel to manage the test cases, scenarios, and test results. The Test Result Log (TRL) is utilized to document the Test Case ID, Test Objective, Number of

Test Runs, and the Test Results for each test. The Test Manager is required to enter the run dates, their name, result, and comment where applicable. A template TRL is included in Appendix A.1.

6.5.9 Defect Tracker

A defect tracker is provided for the Test Conductor, which will be used to record anomalies detected during the execution of a test case or scenario. An observation is considered a defect when the result of an activity does not match the expected outcomes outlined in the test procedure.

Test Conductors are encouraged to include as much information as possible when recording defects, so vendors and integrators can use this information (inputs, conditions, the step at which failure occurred, etc.) to try to repeat, identify root cause, and resolve the issue. This includes referencing the appropriate test identifier(s), expected results, actual results, defect frequency (every time, intermittent, etc.). An assessment of the severity of the defect needs to be performed and assigned as critical, high, medium, low – where critical is the most serious classification with the feature or product being unusable. Defects of this severity should be brought to the immediate attention of the Test Manager for further inspection, coordination, and decision-making. A defect with a low severity indicates the observation will have low to no impact on the RLVW Application operation.

The Test Manager will monitor the defect log for corrective action. The Test Conductor is responsible for understanding and reproducing (where possible) the defect, summarizing a response and the activities taken to resolve the issue, and capturing metadata associated with the resolution (e.g., assigned name, date, status, description, etc.). If a conflict arises between a design element that ties to a requirement and the deployed amenity, the Test Manager will coordinate with the appropriate vendor and the system owner to determine if a change to the design and/or requirement is appropriate. The System Owner will be responsible for reviewing and approving all requests to make changes that impact the system design and requirements (see Section 6.5.10., for more information regarding the Change Request Log)

The defect tracker will also be leveraged to measure the feasibility and readiness of the subcomponents to be promoted to production. See Appendix A.2 for a sample template for Defect Tracker.

6.5.10 Change Request Log

The Change Request Log provides the Test Conductor a mechanism to capture and justify requests for change, which often derive from a defect or an enhancement request. The Site Project Manager is responsible for assessing the impact of the change as it relates to the project objectives, schedule, cost, etc., and providing final approval of all change requests. The sample template for a Change Request Log can be found in Appendix A.3 and provides a mechanism to record of all the change requests logged throughout the testing process along with justifications and authorization status.

6.6 TEST ENVIRONMENT

This section describes the general test environments required to conduct all Bench and Operational Area tests. During testing, all items within the Test Environment, including hardware, software, and configuration elements under test will be managed by the test team.

6.6.1 Bench Facility

Bench tests involve conducting tests in a controlled environment to assess the message content (correctness) of the CV system. The list below contains general facilities and equipment.

General Facilities Requirements

The facilities required to conduct the bench tests include:

- Workbench space
- Surge Protection power strips
- A Conference Room, with whiteboard and/or flipcharts, etc. large enough to accommodate a minimum of twelve (12) people
- Internet access for up to twelve (12) people
- Access to the workbench and conference room space: 8:00 a.m. to 4:30 p.m., Monday through Friday

General Equipment Requirements

The equipment required to conduct the bench tests include:

- Two (2) RSUs of each manufacturer to be tested
- Three (3) laptops
- CVV
- Hand tools; pliers, screw drivers, socket set, etc.
- 110 VAC-to-12V DC Power supplies
- Assortment of CAT5 Ethernet patch cables (for connecting laptops to devices being tested)
- Wireshark Protocol Analyzer capable of decoding and logging SPaT, MAP and RTCM
- Other relevant software tools used during device certification testing

6.6.2 Operational (Field) Test Area

The Operational Test Area will be utilized to conduct the majority of the tests associated with this effort.

The list below contains general facility and equipment requirements.

General Facilities Requirements

The Operational Test Area should include:

- At least four (4) operational intersections to include RSU, Signal Controllers, and other devices, as required to broadcast SPaT, MAP, and RTCM
- Parking spaces with a view of each approach for each intersection
- Vehicle from which to perform infrastructure testing.

Vehicles

The OEM vendor(s) will provide vehicles and Vehicle Drivers to conduct RLVW application testing and demonstration. At a minimum, the following are required to demonstrate V2V applications.

- Two (2) Light-duty vehicles
- One (1) OBU installed in each vehicle
- One (1) driver for each vehicle

6.6.3 Test Preparation

Prior to conducting tests, the test environment will be inspected to ensure all hardware and software required to execute each test are readily available.

For Bench Testing, a site survey will be conducted of the applicable test facility(ies) to verify tools and space are available as well as connectivity to the SCMS, and the RTCM source prior to setting up devices.

For Demonstration Area testing, a site survey will be conducted to ensure vantage points are available.

6.7 TEST CRITERIA

6.7.1 Item Pass/Fail

Each test case consists of several unique properties which should be considered holistically during the testing evaluation process. Properties include but are not limited to: test identifier (ID), test objective, expected outcome, number of test runs that must be completed, and status. The following "status" options will be utilized.

1. Planned – the test case has been defined, role identified, testers assigned, and is ready for testing.
2. In Progress – the test case is underway but has not been completed.
3. Pass – a pass value indicates tests have completed the defined number of runs by various testers without error and the expected result has been achieved. It is expected that each time this test is performed, independent of who is testing, the same successful results will be achieved. There may be instances when a tester identifies a defect during the procedure,

yet the test case still achieves the stated outcome. The case can still pass, but the testers must log the defect and bring it to the attention of the test manager. This can happen when there are minor bugs, not critical to essential functionality of the feature being tested, such as an image being out of alignment or a misspelling.

4. Fail – a test case is marked as failed when part or all of the expected outcome is not met. When a defect is detected/observed it will be assigned a Defect ID, for traceability, and a description of the results will be logged for comparison after treatment. All failed test cases must include one or more defects to capture the details surrounding the failure and to track its status.

5. Deferred – a test case is marked as deferred when the case is unable to be performed at the current time of testing or when there is a change in requirements. Most often this will occur when a software product is being released in increments and the functionality is not ready when it's time to test the current release. This also applies to any features the system may include where testing will be performed outside of the scope of this Test Plan. If a test is deferred, the Test Manager should provide a brief reason for the delay. The Test Manager is responsible for tracking deferred cases and evaluating the most appropriate time and/or response for addressing the case.

See Appendix A.5 for a sample Test Case Status form.

6.7.2 Testing Suspension and Resumption

There are cases when a critical, severe defect is detected that is significant enough that – if not addressed – would require one or more iterations of the same tests to be performed again. In these situations, it is better to suspend testing until the defect is resolved to prevent wasting the project budget and the testers' time. The Test Manager should be notified immediately and work with vendors and other appropriate stakeholders to correct the issue as quickly as possible. Testing will resume once the test manager has successfully confirmed the issue has been resolved.
The following situations would cause testing to be suspended:

1. One or more defects found associated with the RSUs ability to broadcast messages.
2. Communication network failure rendering RSUs isolated from the SCMS, or other cloud services required for normal operation.

6.8 MEASURES AND METRICS

The CIP Test team will utilize Microsoft Excel to capture anomalies, incongruences, errors, or any other output inconsistent with the expected test case result. These tools will capture the following testing metrics:

- Total number of test cases
- Number of test runs per case
- Number and percentage of test cases passed
- Number and percentage of test cases failed
- Number and percentage of test cases deferred

- Number and percentage of defects found (relative to total cases)
- Number and percentage of high severity defects
- Number and percentage of defects accepted
- Number and percentage of defects rejected
- Number and percentage of defects deferred
- Total number of testers

A high-level Test Summary Report will be developed to document the overall number of Test Cases executed as well as the number that have passed and failed. A high-level Defect Matrix will be developed to track the number of defects opened, closed, canceled, resoled, and deferred.

See **Appendix A.4** for a sample Test Summary Report and Defect Matrix.

7. Test Deliverables

During testing, there will be several artifacts utilized to support and enhance the testing process. The following artifacts make up part of this testing plan:

- Test cases
- Test scenarios
- Testing matrix
- Defects matrix with corrective actions
- Change request log
- Error logs, bug reports, and/or screen captures (where feasible)
- Acceptance (see Appendix A

8. Test Cases

Table 6 summarizes the test cases that correspond with each of the applicable requirements of the CI Design Guidance. For each requirement, there is a brief description, traceability to the need, a description of the need, verification method, the specific data collection approach used, a preliminary evaluation method, and notes.

Table 5. Test Case 3.3.3.1.1.1

Requirement ID:	3.3.3.1.1.1	Requirement Title:	SPaT Message - SAE J2735
Description: A connected intersection shall transmit signal timing information using signal phase and timing (SPaT) messages that conform to SAE J2735_202007 (MSG_SignalPhaseAndTiming Message).			
Design Detail: See MSG_SignalPhaseAndTiming Message (SPAT) in SAE J2735_202007. NOTE: This CI Implementation Guide references SAE J2735_202007. At the time of publication, most implementations use the SAE J2735_201603 version. There are some differences between the March 2016 version and the July 2020 version - implementers should be aware of the changes, such as the change in definition for DE_TimeMark.			
Need ID:	2.4.3.1.1	Need Title:	Uniform
Description: A connected intersection needs to provide a consistent (or uniform) representation of the situation and operating conditions. Uniform data fields increase interoperability between the infrastructure components and the applications that use the data to aid drivers and VRUs. For example, connected intersections should provide a uniform representation of roadway features. Inconsistencies in how roadway features are represented lead to inconsistent usage and interpretations by applications that use roadway features. A uniform representation of roadway features increases the effectiveness of the applications that aid drivers and vulnerable road users.			

Verification Method	Demonstration	Test	Analyze	Inspection	Other			
				x				
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			X				

Evaluation Methodology:
Check pcap file for SPaT messages from each intersection. To satisfy this requirement, a messageId of signalPhaseAndTimingMessage (19) shall be present in messages received from the roadside device.

System Input(s):

Supported Sites	GDOT	ODOT	UDOT	Other

Notes:

Table 6. Test Case 3.3.3.1.1.2

Requirement ID:	3.3.3.1.1.2	**Requirement Title:**	SPaT Message - Mandatory Data Elements
Description: A connected intersection shall provide those data elements in the SAE J2735_202007 MSG_SignalPhaseAndTiming Message defined as mandatory.			
Design Detail: See MSG_SignalPhaseAndTiming Message (SPAT) in SAE J2735_202007.			
Need ID:	2.4.3.1.1	**Need Title:**	Uniform
Description: A connected intersection needs to provide a consistent (or uniform) representation of the situation and operating conditions. Uniform data fields increase interoperability between the infrastructure components and the applications that use the data to aid drivers and VRUs. For example, connected intersections should provide a uniform representation of roadway features. Inconsistencies in how roadway features are represented lead to inconsistent usage and interpretations by applications that use roadway features. A uniform representation of roadway features increases the effectiveness of the applications that aid drivers and vulnerable road users.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
				x				
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
Check pcap file for SPaT messages from each intersection. To satisfy this requirement, all J2735-required data elements (contained in the required data frames) for the latest approved standard shall be present in the message.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:

Table 7. Test Case 3.3.3.1.1.3

Requirement ID:	3.3.3.1.1.3	**Requirement Title:**	SPaT Message - CI Mandatory Data Elements
Description: A connected intersection shall provide those data elements in the SAE J2735_202007 MSG_SignalPhaseAndTiming Message defined as optional but necessary to fulfill the CI requirements, as indicated in the NRTM (See Table 6).			
Design Detail:			
Need ID:	2.4.3.1.1	**Need Title:**	Uniform
Description: A connected intersection needs to provide a consistent (or uniform) representation of the situation and operating conditions. Uniform data fields increase interoperability between the infrastructure components and the applications that use the data to aid drivers and VRUs. For example, connected intersections should provide a uniform representation of roadway features. Inconsistencies in how roadway features are represented lead to inconsistent usage and interpretations by applications that use roadway features. A uniform representation of roadway features increases the effectiveness of the applications that aid drivers and vulnerable road users.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**
				x	

Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
Check pcap file for SPaT messages from each intersection. To satisfy this requirement, it shall also contain: timeStamp (SPaT msg Frame), region (IntersectionReferenceId), timeStamp (intersectionState data frame), enabledLanes (if needed), startTime, minEndTime, maxEndTime, and nextTime (in the timeChangeDetails data frame).

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:

Table 8. Test Case 3.3.3.1.1.4

Requirement ID:	3.3.3.1.1.4	**Requirement Title:**	SPaT Message PSID
Description: A connected intersection shall broadcast SPaT messages using a Provider Service IDentifier (PSID) of 0x82 (0p80-02). The IEEE PSID Public Listing can be found at https://standards.ieee.org/productsservices/regauth/psid/public.html.			
Design Detail: The PSID for the SPaT message shall be 0x82 (0p80-02). The PSID is used for the destination address in broadcast WSM and in the app Permissions Field in the SPaT signing certificate.			
Need ID:	2.4.3.1.1	**Need Title:**	Uniform
Description: A connected intersection needs to provide a consistent (or uniform) representation of the situation and operating conditions. Uniform data fields increase interoperability between the infrastructure components and the applications that use the data to aid drivers and VRUs. For example, connected intersections should provide a uniform representation of roadway features. Inconsistencies in how roadway features are represented lead to inconsistent usage and interpretations by applications that use roadway features. A uniform representation of roadway features increases the effectiveness of the applications that aid drivers and vulnerable road users.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
				x				
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
Check pcap file for SPaT messages from each intersection. To satisfy this requirement, a PCAP value of 0x00008002 shall be present in the 1609.3 header.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:

Table 9. Test Case 3.3.3.1.1.5

Requirement ID:	3.3.3.1.1.5	**Requirement Title:**	MAP Message - SAE J2735
Description: A connected intersection shall transmit roadway geometry information using MAP messages that conform to SAE J2735_202007 (MSG_MapData).			
Design Detail: See MSG_MapData (MAP) in SAE J2735_202007. NOTE: This CI Implementation Guide references SAE J2735_202007. At the time of publication, most implementations use the SAE J2735_201603 version. There are some differences between the March 2016 version and the July 2020 version;implementers should be aware of the changes.			
Need ID:	2.4.3.1.1	**Need Title:**	Uniform
Description: A connected intersection needs to provide a consistent (or uniform) representation of the situation and operating conditions. Uniform data fields increase interoperability between the infrastructure components and the applications that use the data to aid drivers and VRUs. For example, connected intersections should provide a uniform representation of roadway features. Inconsistencies in how roadway features are represented lead to inconsistent usage and interpretations by applications that use roadway features. A uniform representation of roadway features increases the effectiveness of the applications that aid drivers and vulnerable road users.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**
				x	

Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
Check pcap file for MAP messages from each intersection. To satisfy this requirement, a messageId of mapData (18) shall be present in messages received from the roadside device.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:

Table 10. Test Case 3.3.3.1.1.6

Requirement ID:	3.3.3.1.1.6	**Requirement Title:**	MAP Message - Mandatory Data Elements
Description: A connected intersection shall provide those data elements in the SAE J2735_202007 MSG_MapData that are defined as mandatory.			
Design Detail: See MSG_MapData (MAP) in SAE J2735_202007			
Need ID:	2.4.3.1.1	**Need Title:**	Uniform
Description: A connected intersection needs to provide a consistent (or uniform) representation of the situation and operating conditions. Uniform data fields increase interoperability between the infrastructure components and the applications that use the data to aid drivers and VRUs. For example, connected intersections should provide a uniform representation of roadway features. Inconsistencies in how roadway features are represented lead to inconsistent usage and interpretations by applications that use roadway features. A uniform representation of roadway features increases the effectiveness of the applications that aid drivers and vulnerable road users.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
				x				
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
Check pcap file for MAP messages from each intersection. To satisfy this requirement, all J2735-required data elements (contained in the required data frames) for the latest approved standard shall be present in the message.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:

Table 11. Test Case 3.3.3.1.1.7

Requirement ID:	3.3.3.1.1.7	**Requirement Title:**	MAP Message - Required Data Elements
Description: A connected intersection shall provide those data elements in the SAE J2735_202007 MSG_MapData that are defined as optional but necessary to fulfill the CI requirements, as indicated in the NRTM (See Table 6).			
Design Detail:			
Need ID:	2.4.3.1.1	**Need Title:**	Uniform
Description: A connected intersection needs to provide a consistent (or uniform) representation of the situation and operating conditions. Uniform data fields increase interoperability between the infrastructure components and the applications that use the data to aid drivers and VRUs. For example, connected intersections should provide a uniform representation of roadway features. Inconsistencies in how roadway features are represented lead to inconsistent usage and interpretations by applications that use roadway features. A uniform representation of roadway features increases the effectiveness of the applications that aid drivers and vulnerable road users.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
				x				
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
Check pcap file for MAP messages from each intersection. To satisfy this requirement, it shall also contain: a minimum of 1 intersectionGeometry (in the IntersectionGeometryList), region (IntersectionReferenceId), elevation (refPoint), SpeedLimitType (intersectionGeometry\speedLimit), velocity (intersectionGeometry\speedLimit), allowedManeuvers (connectingLane), lane (connectingLane), maneuvers (connectingLane), signalGroup (connection).

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:

Table 12. Test Case 3.3.3.1.1.8

Requirement ID:	3.3.3.1.1.8	**Requirement Title:**	MAP Message PSID
Description: A connected intersection shall broadcast MAP messages using a Provider Service IDentifier (PSID) of 0x20-40-97 (0pE0-00-00-17).			
Design Detail: The PSID for the MAP message shall be 0x20-40-97 (0pE0-00-00-17). The PSID is used for the destination address in broadcast WSM and in the app Permissions Field in the MAP signing certificate. See https://standards.ieee.org/products-services/regauth/psid/public.html.			
Need ID:	2.4.3.1.1	**Need Title:**	Uniform
Description: A connected intersection needs to provide a consistent (or uniform) representation of the situation and operating conditions. Uniform data fields increase interoperability between the infrastructure components and the applications that use the data to aid drivers and VRUs. For example, connected intersections should provide a uniform representation of roadway features. Inconsistencies in how roadway features are represented lead to inconsistent usage and interpretations by applications that use roadway features. A uniform representation of roadway features increases the effectiveness of the applications that aid drivers and vulnerable road users.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**
				x	

Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
Check pcap file for MAP messages from each intersection. To satisfy this requirement, a PCAP value of 0xe0000017 shall be present in the 1609.3 header.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:

Table 13. Test Case 3.3.3.1.1.9

Requirement ID:	3.3.3.1.1.9	**Requirement Title:**	RTCMcorrections Message - SAE J2735
Description: A connected intersection shall transmit position corrections information using RTCMcorrections messages that conform to SAE J2735_202007 (MSG_RTCMcorrections).			
Design Detail: See MSG_RTCMcorrections (RTCM) in SAE J2735_202007. NOTE: This CI Implementation Guide references SAE J2735_202007. At the time of publication, most implementations use the SAE J2735_201603 version. There are some differences between the March 2016 version and the July 2020 version;implementers should be aware of the changes.			
Need ID:	2.4.3.1.1	**Need Title:**	Uniform
Description: A connected intersection needs to provide a consistent (or uniform) representation of the situation and operating conditions. Uniform data fields increase interoperability between the infrastructure components and the applications that use the data to aid drivers and VRUs. For example, connected intersections should provide a uniform representation of roadway features. Inconsistencies in how roadway features are represented lead to inconsistent usage and interpretations by applications that use roadway features. A uniform representation of roadway features increases the effectiveness of the applications that aid drivers and vulnerable road users.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**
				x	

Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
Check pcap file for RTCM messages from each intersection. To satisfy this requirement, a messageId of rtcmCorrections (28) shall be present in messages received from the roadside device.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:

Table 14. Test Case 3.3.3.1.1.10

Requirement ID:	3.3.3.1.1.10	**Requirement Title:**	RTCMcorrections Message - Mandatory Data Elements
Description: A connected intersection shall provide those data elements in the SAE J2735_202007 MSG_RTCMcorrections that are defined as mandatory.			
Design Detail: See MSG_RTCMcorrections (RTCM) in SAE J2735_202007.			
Need ID:	2.4.3.1.1	**Need Title:**	Uniform
Description: A connected intersection needs to provide a consistent (or uniform) representation of the situation and operating conditions. Uniform data fields increase interoperability between the infrastructure components and the applications that use the data to aid drivers and VRUs. For example, connected intersections should provide a uniform representation of roadway features. Inconsistencies in how roadway features are represented lead to inconsistent usage and interpretations by applications that use roadway features. A uniform representation of roadway features increases the effectiveness of the applications that aid drivers and vulnerable road users.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
				x				
Evaluation Methodology: Check pcap file for RTCM messages from each intersection. To satisfy this requirement, all J2735-required data elements (contained in the required data frames) for the latest approved standard shall be present in the message.								
System Input(s):								

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**
Notes:				

Table 15. Test Case 3.3.3.1.1.11

Requirement ID:	3.3.3.1.1.11	**Requirement Title:**	RTCMcorrections Message - Required Data Elements
Description: A connected intersection shall provide those data elements in the SAE J2735_202007 MSG_RTCMcorrections that are defined as optional but necessary to fulfill the CI requirements, as indicated in the NRTM (See Table 6).			
Design Detail:			
Need ID:	2.4.3.1.1	**Need Title:**	Uniform
Description: A connected intersection needs to provide a consistent (or uniform) representation of the situation and operating conditions. Uniform data fields increase interoperability between the infrastructure components and the applications that use the data to aid drivers and VRUs. For example, connected intersections should provide a uniform representation of roadway features. Inconsistencies in how roadway features are represented lead to inconsistent usage and interpretations by applications that use roadway features. A uniform representation of roadway features increases the effectiveness of the applications that aid drivers and vulnerable road users.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
				x				
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
Check pcap file for RTCM messages from each intersection. To satisfy this requirement, all J2735-required data elements (contained in the required data frames) for the latest approved standard shall be present in the message, along with the following: lat (anchorPoint), long (anchorPoint).

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:

Table 16. Test Case 3.3.3.1.1.12

Requirement ID:	3.3.3.1.1.12	**Requirement Title:**	RTCMcorrections Message PSID
Description: A connected intersection shall broadcast RTCMcorrections messages using a Provider Service Identifier (PSID) of 0x80 (0p80-00).			
Design Detail: The PSID for the RTCMcorrections message shall be 0x80 (0p80-00). The PSID is used for the destination address in broadcast WSM and in the app Permissions Field in the RTCMcorrections signing certificate. See https://standards.ieee.org/products-services/regauth/psid/public.html.			
Need ID:	2.4.3.1.1	**Need Title:**	Uniform
Description: A connected intersection needs to provide a consistent (or uniform) representation of the situation and operating conditions. Uniform data fields increase interoperability between the infrastructure components and the applications that use the data to aid drivers and VRUs. For example, connected intersections should provide a uniform representation of roadway features. Inconsistencies in how roadway features are represented lead to inconsistent usage and interpretations by applications that use roadway features. A uniform representation of roadway features increases the effectiveness of the applications that aid drivers and vulnerable road users.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
				x				
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
Check pcap file for RTCM messages from each intersection. To satisfy this requirement, a PCAP value of 0x00008000 shall be present in the 1609.3 header.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:

Table 17. Test Case 3.3.3.1.2.1

Requirement ID:	3.3.3.1.2.1	Requirement Title:	Broadcast SPaT Message
Description: If the RSU has received valid values from the TSC infrastructure about its status, a connected intersection shall broadcast a SPaT message. Valid values from the TSC infrastructure are properly formatted and within the permitted data ranges.			
Design Detail: Multiple elements in the SPaT message are mandatory to be broadcasted according to SAE J2735_202007 and to conform to this CI Implementation Guide. Table 7 indicates which data frames and elements are mandatory. A SPaT message shall be broadcasted for an intersection if ALL the following conditions are met: • The SPaT message contains a valid Intersection reference identifier (DE_RoadRegulatorID + DE_IntersectionID) • The SPaT message contains a valid revision object (DE_MsgCount) • The SPaT message contains a valid intersection status object (DE_IntersectionStatusObject) • The SPaT message contains a valid timeStamp (DE_Dsecond and DE_MinuteOfTheYear) • The SPaT message is protected based on the IEEE Std 1609.2-2016 security profile for SPaT messages (See Section 3.3.4.6.3, Interface between an RSU and the OBU/MU) • The requirements for Sections 3.3.3.4.8.1, Matching Intersection Reference Identifier and 3.3.3.4.8.2, Matching SPaT and MAP Version are fulfilled. All other data elements required to be included in the SPaT message by the CI Implementation Guide may use a value of unavailable, unknown or not known as appropriate.			
Need ID:	2.4.3.1.2	**Need Title:**	Robustness
Description:			

Verification Method	Demonstration	Test	Analyze	Inspection	Other			
				x				
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
This requirement is considered satisfied if SPaT Messages are being broadcast from the intersection. A thorough analysis of communication between the traffic signal controller, roadside processing hardware, and the RSU will not be performed.

System Input(s):

Supported Sites	GDOT	ODOT	UDOT	Other

Notes:

Table 18. Test Case 3.3.3.3.3.2

Requirement ID:	3.3.3.3.3.2	**Requirement Title:**	Unknown Current Movement State for a Signal Group
Description: If the TSC infrastructure does not provide a value for the current movement state for a signal group, a connected intersection shall use a value of unavailable, as defined by DE_MovementPhaseState in SAE J2735_202007.			
Design Detail: If the current state of a movement through an intersection is unknown, it is represented by a value of unavailable (0) for the eventState (DE_MovementPhaseState), found under data frame DF_MovementEvent in MSG_SignalPhaseAndTiming Message as defined in SAE J2735_202007			
Need ID:	• 2.4.3.1.2 • 2.4.3.3.3	**Need Title:**	• Robustness • Current Movement State
Description: • A connected intersection needs to be robust. When subject to anomalous data and commands, the connected intersection and its components function properly and are not corrupted. These components may have different failure modes operational states that are consistent and repeatable under different operational conditions. An example is what data should still be broadcasted if the connected intersection is unable to provide the current movement state. The connected intersection and its components also function properly under the maximum simultaneous data traffic possible on all communications interfaces. Applications depend on continuous and proper operation under extreme demands on the system. • A connected intersection needs to provide information about the current state of each movement— including a pedestrian movement— at the intersection so an application can provide the proper warnings, information, or guidance to the driver or VRU. The current state identifies if a maneuver through an intersection is currently allowed and any restrictions. For example, the current state may indicate whether a protected or permissive movement is allowed, a protected or permissive clearance (phase change interval) is in effect, the movement is required to stop then proceed, remain, or a movement may proceed with caution with possible conflicting traffic.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
		x						
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
Evaluated by looking at SPaT Messages over an extended period from each RSU in pcap file. Requirement is considered to be met if all signalGroups are constantly included in the SPaT Message.

System Input(s):

Supported Sites	GDOT	ODOT	UDOT	Other	

Notes:
Are there any conditions specifically under which this requirement needs to be tested - e.g. power outage, cabinet flash. Etc.?

GK - Is there no way to simulate the lack of value (i.e. unplug connection to TSC) and see what happens? Maybe I am mis-understanding the requirement and what may be happening. And could a single disconnection allow for testing of the next 3 requirements also?

Table 19. Test Case 3.3.3.3.4.2

Requirement ID:	3.3.3.3.4.2	**Requirement Title:**	Unknown Next Movement State
Description: In a situation where a connected intersection cannot determine the next movement state, a connected intersection shall use unavailable as the next movement state for a signal group, as defined by DE_MovementPhaseState in SAE J2735_202007.			
Design Detail: MSG_SignalPhaseAndTiming Message provides a data frame, DF_MovementEventList, that contains 1 to 16 entries for the same movement at an intersection. Each entry (represented by DF_MovementEvent) represents a movement state for that movement over a period of time. • The first entry describes the current movement state (i.e., DE_MovementPhaseState) and the time change details for the current movement (minEndTime, maxEndTime, and nextTime (if known)) • The second entry describes the movement state immediately after the current movement state terminates; and the start, minimum end, and maximum end times for the next movement state If the next movement state, as represented by DE_MovementPhaseState, is unknown, a second entry for the movement (DF_MovementEvent) shall be sent in DF_MovementEventList as unknown. For example, in Figure 17, lane #1 is tied to signal group #2 and currently a permissive left turn. The minimum end time for signal group 2 is currently 34675 deciseconds and the maximum end time is 35244 deciseconds from the top of the hour. At this point in time, the TSC infrastructure has not determined if the next movement state is a clearance interval or a protected left turn. So, the SPaT message for this movement would be the following: {"signalGroup":2,"state-time-speed":[{"eventState":"permissive-MovementAllowed","timing":{"minEndTime":34675,"maxEndTime":35244}}]}			
Need ID:	• 2.4.3.1.2 • 2.4.3.3.4	**Need Title:**	• Robustness • Next Movement State
Description: • A connected intersection needs to be robust. When subject to anomalous data and commands, the connected intersection and its components function properly and are not corrupted. These components may have different failure modes operational states that are consistent and repeatable under different operational conditions. An example is what data should still be broadcasted if the connected intersection is unable to provide the current movement state. The connected intersection and its components also function properly under the maximum simultaneous data traffic possible on all communications interfaces. Applications depend on continuous and proper operation under extreme demands on the system. • A connected intersection needs to provide information about the next state of each movement at the intersection so an application can provide the proper warnings, information, or guidance to the driver or VRU. The next state identifies if the next signal interval for a maneuver through an intersection will be allowed and any restrictions after a change. For example, the current state may indicate a protected or permissive movement, but the next state indicates when the current state changes, if the maneuver will change to a protected or permissive movement, or a clearance (e.g., yellow indication) interval will be in effect			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**
		x			

Data Collection Type	Stationary	Driving	Video	pcap	Ground Truth	Test Tool	Survey	Other
	x			x				

Evaluation Methodology:
Evaluated by looking at all SPaT movement state details over an extended period from each RSU in pcap file. Requirement is considered to be met if the next movement state is specified for a signalGroup and all required data elements in the timeChangeDetails data frame are within the allowable range for normal times, and 36111 for unknown.

System Input(s):

Supported Sites	GDOT	ODOT	UDOT	Other

Notes:

GK - see previous comment re: forcing no data

what action to take for next movement state to be known/not known?

Table 20. Test Case 3.3.3.3.5.2

Requirement ID:	3.3.3.3.5.2	**Requirement Title:**	Unknown Time Change Detail
Description: If the TSC infrastructure does not provide a value for a mandatory time change detail element, a connected intersection shall use a value of unknown, as defined by DE_TimeMark in SAE J2735_202007. NOTE: The value of DE_TimeMark indicating undefined changed from a value of 36001 in SAE J2735_201603 to a value of 36111 in SAE J2735_202007.			
Design Detail: If any time change detail for a movement is required to be transmitted in the SPaT message, but the value is unknown, then that time change detail is represented by a value of 36111 for DE_TimeMark, found under data frame DF_TimeChangeDetails in MSG_SignalPhaseAndTiming Message as defined in SAE J2735_202007. This CI Implementation Guide requires that the following time change details for each allowed movement be included in all SPaT messages transmitted: • Minimum End Time. The earliest time when the current movement state is expected to end. CTI 4501 v1.00 CI Implementation Guide Page 150 • Maximum End Time. The latest time when the current movement state is expected to end. If the minimum end time or maximum end time is not known by the TSC infrastructure, then a value of unknown is used. If the next time that the movement will be allowed is not known (See Section 4.3.3.3.6.1, Time of Next Allowed Movement), then the nextTime data element is not included in the SPaT message. This CI Implementation Guide references the July 2020 version of SAE J2735 (SAE J2735_202007). The March 2016 version of SAE J2735 (SAE J2735_201603) uses a value of 36001 to represent unknown. The change was made to DE_TimeMark in the July 2020 version to properly address leap seconds.			
Need ID:	• 2.4.3.1.2 • 2.4.3.3.5	**Need Title:**	• Robustness • Time Change Details
Description: • A connected intersection needs to be robust. When subject to anomalous data and commands, the connected intersection and its components function properly and are not corrupted. These components may have different failure modes operational states that are consistent and repeatable under different operational conditions. An example is what data should still be broadcasted if the connected intersection is unable to provide the current movement state. The connected intersection and its components also function properly under the maximum simultaneous data traffic possible on all communications interfaces. Applications depend on continuous and proper operation under extreme demands on the system. • A connected intersection needs to provide information about when the current signal interval (state) for each movement, including a pedestrian interval (state), at the intersection will change so an application can provide the proper warnings, information or guidance to the driver or VRU. The information provided must be accurate under all conditions such as during TSP (transit signal priority) and EVP (emergency vehicle preemption). The need includes the following operational scenarios: 2.6.2.1 - Rest in Green.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
		x						
	Stationary	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**

Data Collection Type	x			x				

Evaluation Methodology:
Evaluated by looking at all SPaT mandatory time change details over an extended period from each RSU in pcap file. Requirement is considered to be met if all values are within the allowable range for normal times, and 36111 for unknown.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:
Given that testing will not occur during when a leap second is expected to be observed, leap seconds will not be specifically evaluated - values in this range should not be observed.

Table 21. Test Case 3.3.3.3.5.5

Requirement ID:	3.3.3.3.5.5	**Requirement Title:**	Unknown Maximum End Time
Description: In a situation where a connected intersection cannot determine a latest end time, a connected intersection shall use a value of unknown, as defined by DE_TimeMark in SAE J2735_202007. NOTE: The value of DE_TimeMark indicating undefined changed from a value of 36001 in SAE J2735_201603 to a value of 36111 in SAE J2735_202007.			
Design Detail: In a situation where a connected intersection cannot determine a latest end time, a connected intersection shall use a value of unknown, as defined by DE_TimeMark in SAE J2735_202007. NOTE: The value of DE_TimeMark indicating undefined changed from a value of 36001 in SAE J2735_201603 to a value of 36111 in SAE J2735_202007.			
Need ID:	• 2.4.3.1.2 • 2.4.3.3.5	**Need Title:**	• Robustness • Time Change Details
Description: • A connected intersection needs to be robust. When subject to anomalous data and commands, the connected intersection and its components function properly and are not corrupted. These components may have different failure modes operational states that are consistent and repeatable under different operational conditions. An example is what data should still be broadcasted if the connected intersection is unable to provide the current movement state. The connected intersection and its components also function properly under the maximum simultaneous data traffic possible on all communications interfaces. Applications depend on continuous and proper operation under extreme demands on the system. • A connected intersection needs to provide information about when the current signal interval (state) for each movement, including a pedestrian interval (state), at the intersection will change so an application can provide the proper warnings, information or guidance to the driver or VRU. The information provided must be accurate under all conditions such as during TSP (transit signal priority) and EVP (emergency vehicle preemption). The need includes the following operational scenarios: 2.6.2.1 - Rest in Green.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
		x						
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: Evaluated by looking at all SPaT mandatory time change details over an extended period from each RSU in pcap file. Requirement is considered to be met if all values are within the allowable range for normal times, and 36111 for unknown.								

System Input(s):

Supported Sites	GDOT	ODOT	UDOT	Other	

Notes:
Given that testing will not occur during when a leap second is expected to be observed, leap seconds will not be specifically evaluated - values in this range should not be observed.

Table 22. Test Case 3.3.3.1.3.1

Requirement ID:	3.3.3.1.3.1	**Requirement Title:**	Transport Message Size - WAVE
Description: A connected intersection using WAVE Short Messages (WSM) to broadcast messages to OBUs/Mus shall have message sizes, in bytes, not to exceed the message size allowed by the transport used.			
Design Detail: The default maximum transport message in IEEE Std 1609.3-2020 for a WAVE Short Message (WSM) payload is 1400 bytes; however a maximum of 2302 bytes is supported. SPaT and MAP messages sent over a DSRC V2X interface must be less than 2302, including security overhead (signature, certificate and header). Note that the maximum value of the WSM payload may need to be configured / set to 2302 to support larger MAP messages if the implementer is using the IEEE Std 1609.3 MIB. For C-V2X, 8000 bytes is the maximum payload including security overhead, but implementers are encouraged to keep SPaT and MAP messages as small as possible for both CV2X and DSRC to maximize reliability of reception.			
Need ID:	2.4.3.1.3	**Need Title:**	Concise Messages
Description: A connected intersection needs to provide concise messages so that complete data describing the situation can fit within the maximum message size supported by the communications stack. Small message sizes also suffer much less from packet loss than larger messages.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
				x				
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
Evaluated by assessing the framelength variable in Wireshark

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:
Max size 1400? see design detail.

Table 23. Test Case 3.3.3.1.3.2.1

Requirement ID:	3.3.3.1.3.2.1	Requirement Title:	Nodes by Offsets
Description: A connected intersection shall define the location of a node describing the center of a lane at the intersection using offsets from a reference point or a previous node point.			
Design Detail: If the computed lane is oriented at a different angle from the referenced lane, the angle of the rotation value is represented as rotateXY (DE_Angle) and can be found under the data frame DF_ComputedLane in the MSG_MapData message in SAE J2735_202007. The rotation value is expressed as unsigned units of 0.0125 degrees (from 0 to 359.9875 degrees), with positive values to the "East" if the orientation of the lane is to the North (or to the right in the direction the traveler is facing). The JSON encoding sequence for lane numbers 15 and 17 that follow Figure 16 are examples of how angle is presented in a computed lane.			
Need ID:	2.4.3.1.3	**Need Title:**	Concise Messages
Description: A connected intersection needs to provide concise messages so that complete data describing the situation can fit within the maximum message size supported by the communications stack. Small message sizes also suffer much less from packet loss than larger messages.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
				x				
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
Evaluated by presence of either x-offset and y-offset (for offsets) or identifier, x-offset, y-offset, and angle (for a computed lane).

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:

Table 24. Test Case 3.3.3.1.3.2.2.1

Requirement ID:	3.3.3.1.3.2.2.1	**Requirement Title:**	Computed Lane - Lane Identifier
Description: A connected intersection shall provide the lane identifier of the referenced lane that a computed lane is based on. The attributes of the computed lane are based on the attributes of the referenced lane.			
Design Detail: This requirement requires that an OBU/MU in any lane approaching the intersection can receive the messages broadcasted by the connected intersection. Also see the next design detail section, 4.3.3.1.4.2.			
Need ID:	2.4.3.1.3	**Need Title:**	Concise Messages
Description: A connected intersection needs to provide concise messages so that complete data describing the situation can fit within the maximum message size supported by the communications stack. Small message sizes also suffer much less from packet loss than larger messages.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
				x				

Evaluation Methodology:
Evaluated by presence of either x-offset and y-offset (for offsets) or identifier, x-offset, y-offset, and angle (for a computed lane).

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:

Table 25. Test Case 3.3.3.1.3.2.2.2

Requirement ID:	3.3.3.1.3.2.2.2	**Requirement Title:**	Computed Lane - X-Offset
Description: A connected intersection shall provide the x-offset, in centimeters, between the first node point of the referenced lane and the first node point of the computed lane.			
Design Detail: This requirement is verified (tested) by demonstration.			
Need ID:	2.4.3.1.3	**Need Title:**	Concise Messages
Description: A connected intersection needs to provide concise messages so that complete data describing the situation can fit within the maximum message size supported by the communications stack. Small message sizes also suffer much less from packet loss than larger messages.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
				x				
Evaluation Methodology: Evaluated by presence of either x-offset and y-offset (for offsets) or identifier, x-offset, y-offset, and angle (for a computed lane).								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 26. Test Case 3.3.3.1.3.2.2.3

Requirement ID:	3.3.3.1.3.2.2.3	**Requirement Title:**	Computed Lane - Y-Offset
Description: A connected intersection shall provide the y-offset, in centimeters, between the first node point of the referenced lane and the first node point of the computed lane.			
Design Detail: No design details provided at this time.			
Need ID:	2.4.3.1.3	**Need Title:**	Concise Messages
Description: A connected intersection needs to provide concise messages so that complete data describing the situation can fit within the maximum message size supported by the communications stack. Small message sizes also suffer much less from packet loss than larger messages.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
				x				
Evaluation Methodology: Evaluated by presence of either x-offset and y-offset (for offsets) or identifier, x-offset, y-offset, and angle (for a computed lane).								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 27. Test Case 3.3.3.1.3.2.2.4

Requirement ID:	3.3.3.1.3.2.2.4	**Requirement Title:**	Angle
Description: A connected intersection shall provide the angle of a computed lane relative to the first node point of the referenced lane.			
Design Detail: The latency is defined as from the time when the signals are commanded to change is asserted by the traffic signal controller to change the signal head indication, to when the SPaT message with the change in signal indication (movement state) is received by the OBU/MU. The verification is performed by test. For verification testing, the epoch of the OBU when the message is received will be compared to the timestamp in the SPaT message, but this test only verifies the latency between the RSU and OBU.			
Need ID:	2.4.3.1.3	**Need Title:**	Concise Messages
Description: A connected intersection needs to provide concise messages so that complete data describing the situation can fit within the maximum message size supported by the communications stack. Small message sizes also suffer much less from packet loss than larger messages.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
				x				
Evaluation Methodology: Evaluated by presence of either x-offset and y-offset (for offsets) or identifier, x-offset, y-offset, and angle (for a computed lane).								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 28. Test Case 3.3.3.1.4.1

Requirement ID:	3.3.3.1.4.1	**Requirement Title:**	Data Coverage - Every Lane
Description: A connected intersection shall broadcast messages such that the messages can be received by OBUs/MUs units in each lane approaching the intersection.			
Design Detail: No design details provided at this time.			
Need ID:	2.4.3.1.4	**Need Title:**	Advanced Notification
Description: A connected intersection needs to provide data far enough in advance of the intersection with respect to both time and distance so the application on an OBU/MU can process the data in time to react to a situation. This allows the proper interpretation of the data by the applications and may provide more options for drivers, VRUs or applications to react to the dynamic situation at the intersection. The reaction may involve providing warnings or alerts to the driver or VRU, or taking an appropriate action. For example, the coverage area needed will be different for a CI where average vehicle approach speeds are 20 miles per hour (MPH) when compared to a CI where the average vehicle speed for an approach is 50 mph.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**
			x		

Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
		x		x				

Evaluation Methodology:
Satisfied if 3.3.3.1.4.2 (next requirement) is satisified.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:

Table 29. Test Case 3.3.3.1.4.2

Requirement ID:	3.3.3.1.4.2	**Requirement Title:**	Advanced Notification - Time
Description: A connected intersection shall broadcast messages to a distance of at least 10 seconds at the 85th percentile speed or a speed equal to the posted or statutory speed limit plus 7 miles per hour (mph) before approaching vehicles would reach the stop line for each approaching lane. The value of 10 seconds is based on calculations on how quickly applications can process the data, considers how often messages are sent, and assumes some lost packets.			
Design Detail: This requirement is verified (tested) by demonstration.			
Need ID:	2.4.3.1.4	**Need Title:**	Advanced Notification
Description: A connected intersection needs to provide data far enough in advance of the intersection with respect to both time and distance so the application on an OBU/MU can process the data in time to react to a situation. This allows the proper interpretation of the data by the applications and may provide more options for drivers, VRUs or applications to react to the dynamic situation at the intersection. The reaction may involve providing warnings or alerts to the driver or VRU, or taking an appropriate action. For example, the coverage area needed will be different for a CI where average vehicle approach speeds are 20 miles per hour (MPH) when compared to a CI where the average vehicle speed for an approach is 50 mph.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
				x				
Evaluation Methodology: See Appendix X - Message transmission range methodology. Max range must exceed distance specified in requirement (given 85th percentile speed or speed limit).								
System Input(s):								

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**
Notes: Added suggested methodology to the previous requirement - could the time log be used to confirm this requirement?				

Table 30. Test Case 3.3.3.1.5.1

Requirement ID:	3.3.3.1.5.1	**Requirement Title:**	SPaT Message - Broadcast Periodicity
Description: A connected intersection shall broadcast SPaT messages periodically at average rate of 10 messages per second +/- 1 message over a 10-second period.			
Design Detail: No design details provided at this time.			
Need ID:	2.4.3.1.5	**Need Title:**	Timeliness
Description: A connected intersection needs to indicate changes in state and timing with low latency so that the applications on an OBU/MU can react to the most current information in a timely manner. Timely information to applications provides effective and reliable services that aid road users.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
				x				
Evaluation Methodology: See Appendix X - Close Range Message Reception Assessment								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes: May need to create this methodology - but this is essentially placing the test capture device in very close proximity with the roadside device solely for the purpose of assessing message transmission rates. GK - I think the above makes sense, as long as it does not cause any interference or issues. Would need to set minimum time for test. Same methodology for MAP.								

Table 31. Test Case 3.3.3.1.5.2

Requirement ID:	3.3.3.1.5.2	**Requirement Title:**	SPaT Message - Broadcast Latency
Description: A connected intersection shall broadcast SPaT messages that reflects the actual signal indications of the intersection within a latency of no more than 300 milliseconds.			
Design Detail: The latency is defined as from the time when the signals are commanded to change is asserted by the traffic signal controller to change the signal head indication, to when the SPaT message with the change in signal indication (movement state) is received by the OBU/MU. The verification is performed by test. For verification testing, the epoch of the OBU when the message is received will be compared to the timestamp in the SPaT message, but this test only verifies the latency between the RSU and OBU.			
Need ID:	• 2.4.3.1.5 • 2.4.3.3.8	**Need Title:**	• Timeliness • Signal Timing and Roadway Indications Synchronization
Description: • A connected intersection needs to indicate changes in state and timing with low latency so that the applications on an OBU/MU can react to the most current information in a timely manner. Timely information to applications provides effective and reliable services that aid road users. • A connected intersection needs to provide signal timing data that is synchronized with signal indication changes on the roadway within a defined tolerance. For safety and effectiveness, applications require consistency between the perceived state of the intersection by road users and the signal timing data received by the applications on an OBU/MU. Synchronization enables applications to safely and effectively provide services to road users. For example, the duration of a signal interval may be influenced by external processes. There are configurations when an external process, such as cabinet relays or a separate system controlling the active timing intervals (e.g., hold/force off/stop time), is being used for either supervisory control over the traffic controller timing or post processing of controller outputs. In these cases, the traffic controller may have limited information thereby limiting the ability to predict the future state of the intersection and therefore cannot provide accurate signal interval duration information. For these cases, the source of the signal interval duration data should be the separate system.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
	(2)		(1)					
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x		(2)	(1)		(2)		

Evaluation Methodology:
This requirement is verified through simultaneous capture of a test tool and the signal head at an intersection. See Appendix X - Latency Measurement Methodology.

System Input(s):

Supported Sites	GDOT	ODOT	UDOT	Other

Notes:
Latency measured using this method will contain events that should not be included in the latency measurement (e.g. bluetooth between OBU and test tool). Other more precise method may be needed when latency beyond 300 ms is measured.

GK - see previous related comments and methodology suggestions

Table 32. Test Case 3.3.3.1.5.3

Requirement ID:	3.3.3.1.5.3	**Requirement Title:**	MAP Message - Broadcast Periodicity
Description: A connected intersection shall broadcast MAP messages periodically at an average rate of 1 message per second +/- 1 message over a 10-second period.			
Design Detail: No design details provided at this time.			
Need ID:	2.4.3.1.5	**Need Title:**	Timeliness
Description: A connected intersection needs to indicate changes in state and timing with low latency so that the applications on an OBU/MU can react to the most current information in a timely manner. Timely information to applications provides effective and reliable services that aid road users.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
			x					
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
See Appendix X - Close Range Message Reception Assessment

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:
May need to create this methodology - but this is essentially placing the test capture device in very close proximity with the roadside device solely for the purpose of assessing message transmission rates.

Table 33. Test Case 3.3.3.1.6.1

Requirement ID:	3.3.3.1.6.1	**Requirement Title:**	Completeness - SPaT Message
Description: A connected intersection shall provide a SPaT message containing signal phase and timing information for all movements controlled by the TSC infrastructure and included in the associated MAP message.			
Design Detail: This requirement is fulfilled all movements controlled by the TSC infrastructure and included in the associated MAP message is represented in the SPaT message. This is defined as when every allowed movement in every ingress lane into the intersection is controlled and may have one or more movement state, as represented by DE_MovementPhaseState. This includes pedestrian movements, bicycle movements, and tracked vehicle movements that are controlled by the TSC infrastructure. This requirement is verified by inspection.			
Need ID:	2.4.3.1.6	**Need Title:**	Quality Assurance
Description: The CI needs to produce quality information. The information needs to produce the best set of messages (e.g., SPaT message) that represents the current situation and conditions at the intersection.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
	x							
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x		x			x		

Evaluation Methodology:
Simultaneous observation of test tool output and actual indication on the signal head are used to demonstrate that signal states for all movements are properly reflected in signal groups.
This requirement can be verified using the same data collected for the verification of 3.3.3.1.5.2 (if video capture is used to verify that requirement)

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:
Agreed, but should the methodology be explained? How to test for 'completeness' - all movements? CT: methodology has been added

Table 34. Test Case 3.3.3.1.6.2

Requirement ID:	3.3.3.1.6.2	**Requirement Title:**	Completeness - MAP Message
Description: A connected intersection shall provide a MAP message describing all travel lanes where a movement traversing the intersection is permitted.			
Design Detail: For a connected intersection, this requirement is fulfilled when the ingress lane and egress lane for every allowed movement through the intersection and controlled by the TSC infrastructure is represented in the MAP message. This includes all pedestrian crosswalks, bicycle lanes, and tracked vehicle lanes whose movements are controlled by the TSC infrastructure. This requirement is verified by inspection			
Need ID:	2.4.3.1.6	**Need Title:**	Quality Assurance
Description: The CI needs to produce quality information. The information needs to produce the best set of messages (e.g., SPaT message) that represents the current situation and conditions at the intersection.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
				x				
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x						x	MAP Message

Evaluation Methodology:
See Appendix X - MAP geometry validation methodology.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:
Suggest adding a sentence similar to 3.3.3.1.4.1

Table 35. Test Case 3.3.3.3.2.13

Requirement ID:	3.3.3.3.2.13	**Requirement Title:**	No MAP Available
Description: A connected intersection shall indicate when no valid MAP is available. A MAP is considered not available when any of the following conditions is true. • If a connected intersection does not have a valid MAP message to broadcast			
Design Detail: Whether an RSU is broadcasting a valid MAP message is represented by Bit 12 in the DE_IntersectionStatusObject and found under the data frame DF_IntersectionState in MSG_SignalPhaseAndTiming Message in SAE J2735_202007. A value of 0 for Bit 12 indicates that the RSU is broadcasting a properly formatted MAP message with a PSID of 0px20-40-97, and a valid IEEE Std 1609.2-2016 certificate. A value of 1 for Bit 12 indicates that either the MAP is unavailable, or it is invalid. Situations when a MAP may be invalid include temporary lane closures, when the RSU may still be transmitting the MAP message since the IOO may not have CTI 4501 v1.00 CI Implementation Guide Page 145 been notified by the contractor for lane closure or time lags. This applies when contractor is setting up cones/barrels for lane closures, presence of flaggers, etc. A MAP message can be broadcasted without a SPaT message, but the SPaT message must be sent with a valid MAP message describing the intersection associated with the SPaT message. However, there are scenarios when the intersection is operating properly, but the IOO decides not to generate MAP message, maybe for operational or maintenance purposes or the MAP message doesn't have a valid IEEE Std 1609.2-2016 certificate. Note: If the UPER-encoded SAE J2735_202007 SPaT message is generated by the TSC infrastructure and the MAP message is generated elsewhere, the TSC infrastructure must be informed if the RSU is broadcasting a MAP message to properly set Bit 12. Note the CI Implementation Guide does not define a requirement for the TSC infrastructure to be informed if a new MAP message is being broadcasted.			
Need ID:	• 2.4.3.1.6 • 2.4.3.3.2	**Need Title:**	• Quality Assurance • Intersection Status
Description: • The CI needs to produce quality information. The information needs to produce the best set of messages (e.g., SPaT message) that represents the current situation and conditions at the intersection. • A connected intersection needs to provide information about the current operational status of a signalized intersection so that an OBU/MU application can better interpret signal timing data provided about that intersection. For example, the operational status may indicate if the signalized intersection is operating in preempt, external logic, or in flash.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
		x						
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
This requirement is considered to be met given the presence of the intersectionStatus data element in the SPaT messages, and the No MAP Available flag is correctly specified - as noted during data collection.

System Input(s):

Supported Sites	GDOT	ODOT	UDOT	Other

Notes:
If this condition is noted during data collection, then this requirement can be tested. However, if this condition is not noted, then this requirement cannot be verified.

GK - can it be simulated by killing a comm. link or stopping a MAP process?

Requires input to Test:

- broadcast and cease broadcasting MAP messages
- Yes. Need to broadcast invalid MAP message

Table 36. Test Case 3.3.3.3.8

Requirement ID:	3.3.3.3.8	**Requirement Title:**	SPaT Message - Accuracy
Description: A connected intersection shall broadcast SPaT messages that accurately reflect the physical signal indications at the intersection.			
Design Detail: No design details provided at this time			
Need ID:	• 2.4.3.1.6 • 2.4.3.3.8	**Need Title:**	• Quality Assurance • Signal Timing and Roadway Indications Synchronization
Description: • The CI needs to produce quality information. The information needs to produce the best set of messages (e.g., SPaT message) that represents the current situation and conditions at the intersection. • A connected intersection needs to provide signal timing data that is synchronized with signal indication changes on the roadway within a defined tolerance. For safety and effectiveness, applications require consistency between the perceived state of the intersection by road users and the signal timing data received by the applications on an OBU/MU. Synchronization enables applications to safely and effectively provide services to road users. For example, the duration of a signal interval may be influenced by external processes. There are configurations when an external process, such as cabinet relays or a separate system controlling the active timing intervals (e.g., hold/force off/stop time), is being used for either supervisory control over the traffic controller timing or post processing of controller outputs. In these cases, the traffic controller may have limited information thereby limiting the ability to predict the future state of the intersection and therefore cannot provide accurate signal interval duration information. For these cases, the source of the signal interval duration data should be the separate system.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
	x							
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x		x	x		x		

Evaluation Methodology:
This requirement is verified through simultaneous capture of a test tool and the signal head at an intersection. The signal state as indicated on the test tool shall closely align with the actual signal state.

Potential methodology description:
- Install a capture tool(s) that visually records the signal head display and logs SPaT messages

- confirm that physical signal state changes occur accurately in comarison to the SPaT data (would need to define 'accurate')

System Input(s):

Supported Sites	GDOT	ODOT	UDOT	Other	

Notes:

Table 37. Test Case 3.3.3.4.7

Requirement ID:	3.3.3.4.7	**Requirement Title:**	MAP Message - Accuracy
Description: A connected intersection shall broadcast MAP messages that accurately reflect the physical location and dimensions of all travel lanes traversing the intersection within defined tolerances.			
Design Detail: No design details provided at this time			
Need ID:	• 2.4.3.1.6 • 2.4.3.4.7	**Need Title:**	• Quality Assurance • Road Geometry Accuracy
Description: • The CI needs to produce quality information. The information needs to produce the best set of messages (e.g., SPaT message) that represents the current situation and conditions at the intersection. • A connected intersection needs to provide assurances that the road geometry data provided by the infrastructure is accurate and represents the roadway geometrics at the intersection within a defined tolerance. Inaccurate data reduces the effectiveness of the applications that use the data. NOTE: Enough accuracy is needed so the vehicle can determine which lane it is in, since different lanes may be controlled by different signal indications being in different states.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
				x				
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x			x	MAP Message

Evaluation Methodology:
See Appendix X - MAP geometry validation methodology

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:
GK - This may be tested if the records for the previous requirement have different allowable movements in different cycles.

Table 38. Test Case 3.3.3.3.1

Requirement ID:	3.3.3.2.1	**Requirement Title:**	Time Accuracy
Description: For messages that include time, a connected intersection shall utilize time that is accurate to within 10 milliseconds (ms) of Coordinated Universal Time (UTC).			
Design Detail: This requirement is verified by testing.			
Need ID:	2.4.3.2.1	**Need Title:**	Time Source
Description: A connected intersection needs to use the same time reference and with sufficient precision as OBUs/MUs so non-infrastructure applications can properly interpret time points. This allows the proper interpretation of time-sensitive data by applications and permits reactions to be based on the same understanding of time.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**
			x		

Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
				x				

Evaluation Methodology:

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:
Unsure if there is a true method of measuring ground truth here

GK - could the 3.3.3.3.8 capture tool independently sync to UTC and add it to the video and/or log?

Table 39. Test Case 3.3.3.2.2.1

Requirement ID:	3.3.3.2.2.1	**Requirement Title:**	SPaT Message - Revision Counter Increment
Description: A connected intersection shall increment a revision counter by 1 whenever the value of any data element in the SPaT message, except for the timestamp, describing the signal phase and timing for that intersection changes.			
Design Detail: The revision counter for a SPaT message is represented by revision (DE_MsgCount) and found under the data frame DF_IntersectionState in MSG_SignalPhaseAndTiming Message in SAE J2735_202007. The revision counter shall remain the same during a stream of messages when the content within each message has not changed except the timestamp from the prior message sent. The OBU/MU may ignore processing a new message in the stream if the revision count has not changed from the prior message. This requirement is verified by inspection.			
Need ID:	2.4.3.2.2	**Need Title:**	Message Revision
Description: A connected intersection needs to indicate if the data provided on a specific topic (other than the timestamp) is new and must be processed by the receiving application or is the same as a previous message and can be ignored.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**
			x		

Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
Wireshark assessment of the SPaT payload to determine if the messageCount increments when changes in other message data elements have changed and has not incremented when other message data elements have not (with the exception of the timestamp variable).

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:

Table 40. Test Case 3.3.3.2.2.2

Requirement ID:	3.3.3.2.2.2	**Requirement Title:**	SPaT Message - Revision Counter Not Increment
Description: A connected intersection shall not increment a message counter if the value of no data element in the SPaT message, except for the timestamp, describing the signal phase and timing for that intersection changes.			
Design Detail: This requirement is tested by inspection.			
Need ID:	2.4.3.2.2	**Need Title:**	Message Revision
Description: A connected intersection needs to indicate if the data provided on a specific topic (other than the timestamp) is new and must be processed by the receiving application or is the same as a previous message and can be ignored.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
			x					
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
same test as for 3.3.3.2.2.1 (above)

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:

Table 41. Test Case 3.3.3.2.2.3

Requirement ID:	3.3.3.2.2.3	**Requirement Title:**	MAP Message - Revision Counter Increment
Description: A connected intersection shall increment a revision counter if the value of any data element in the MAP message other than the time stamp changes			
Design Detail: The revision counter for a MAP message is represented by msgIssueRevision (DE_MsgCount) and found in the MSG_MapData message in SAE J2735_202007.			
Need ID:	2.4.3.2.2	**Need Title:**	Message Revision
Description: A connected intersection needs to indicate if the data provided on a specific topic (other than the timestamp) is new and must be processed by the receiving application or is the same as a previous message and can be ignored.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
		?	x					
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: same test as for 3.3.3.2.2.1 (above), except for MAP messages.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes: Do we set up a specific scenario where a MAP message changes? If we are performing testing under real-world conditions, it is highly likely that there will not be a change in the MAP message during testing.								

Table 42. Test Case 3.3.3.2.2.4

Requirement ID:	3.3.3.2.2.4	**Requirement Title:**	MAP Message - Revision Counter Not Increment
Description: A connected intersection shall not increment a message counter if the value of no data element in the MAP message other than the time stamp changes			
Design Detail: This requirement is verified by inspection.			
Need ID:	2.4.3.2.2	**Need Title:**	Message Revision
Description: A connected intersection needs to indicate if the data provided on a specific topic (other than the timestamp) is new and must be processed by the receiving application or is the same as a previous message and can be ignored.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
			x					
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: same test as for 3.3.3.2.2.3 (above)								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 43. Test Case 3.3.3.2.2.5

Requirement ID:	3.3.3.2.2.5	**Requirement Title:**	MAP Message - Intersection Revision Counter Increment
Description: A connected intersection shall increment a revision counter for the intersection description within a MAP message whenever any data element describing that intersection changes. Since a MAP message may contain descriptions of more than one intersection, it is possible for the MAP message revision counter to increment but the intersection revision counter to not increment. This happens when a different intersection description in the MAP message changes but not this intersection description.			
Design Detail: The revision counter for the geometric description of an intersection is represented by revision (DE_MsgCount) and found under the data frame DF_IntersectionGeometry in the MSG_MapData message in SAE J2735_202007. This requirement is verified by inspection.			
Need ID:	2.4.3.2.2	**Need Title:**	Message Revision
Description: A connected intersection needs to indicate if the data provided on a specific topic (other than the timestamp) is new and must be processed by the receiving application or is the same as a previous message and can be ignored.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**
			x		

Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
same test as for 3.3.3.2.2.3 (above)

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:
Most MAP messages contain only a single intersection geometry, so this test should be very similar to the test above.

Table 44. Test Case 3.3.3.2.2.6

Requirement ID:	3.3.3.2.2.6	**Requirement Title:**	MAP Message - Intersection Revision Counter Not Increment
Description: A connected intersection shall not increment a revision counter for an intersection description within a MAP message if no data element describing the intersection changes.			
Design Detail: This requirement is verified by inspection.			
Need ID:	2.4.3.2.2	**Need Title:**	Message Revision
Description: A connected intersection needs to indicate if the data provided on a specific topic (other than the timestamp) is new and must be processed by the receiving application or is the same as a previous message and can be ignored.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: same test as for 3.3.3.2.2.3 (above)								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 45. Test Case 3.3.3.2.2.7

Requirement ID:	3.3.3.2.2.7	**Requirement Title:**	RTCMcorrections Message - Sequence Number Increment
Description: A connected intersection shall increment a sequence number if there is a change in the corrections content in the RTCMcorrections message.			
Design Detail: The sequence number of a RTCMcorrections message is provided by msgCnt (DE_MsgCount) and found in the MSG_ RTCMcorrections message in SAE J2735_202007. MsgCount shall be incremented when the contents of RTCMmessageList changes. This requirement is verified by inspection. Note: RTCMmessageList is a sequence of RTCMmessage containers. If any information within any those containers changes, MsgCount is incremented. RTCM corrections information changes rapidly, and as a result, so does MsgCount.			
Need ID:	2.4.3.2.2	**Need Title:**	Message Revision
Description: A connected intersection needs to indicate if the data provided on a specific topic (other than the timestamp) is new and must be processed by the receiving application or is the same as a previous message and can be ignored.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: same test as for 3.3.3.2.2.1 (above), except for RTCM messages.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 46. Test Case 3.3.3.2.2.8

Requirement ID:	3.3.3.2.2.8	**Requirement Title:**	RTCMcorrections Message - Sequence Number Not Increment
Description: A connected intersection shall not increment the sequence number if there is no change in the corrections content received from the RTCM base in the RTCMcorrections message other than the change in UTC time.			
Design Detail: This requirement is verified by inspection.			
Need ID:	2.4.3.2.2	**Need Title:**	Message Revision
Description: A connected intersection needs to indicate if the data provided on a specific topic (other than the timestamp) is new and must be processed by the receiving application or is the same as a previous message and can be ignored.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: same test as for 3.3.3.2.2.7 (above)								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 47. Test Case 3.3.3.2.3.1

Requirement ID:	3.3.3.2.3.1	**Requirement Title:**	SPaT Message - Message Time Stamp
Description: A connected intersection shall provide a timestamp indicating the minute of the year when the SPaT message was created			
Design Detail: The timestamp indicating the minute of the year when the SPaT message was created is represented by timestamp (DE_MinuteOfTheYear) and found in the MSG_SignalPhaseAndTiming Message fulfill in SAE J2735_202007.			
Need ID:	2.4.3.2.3	**Need Title:**	Timestamp
Description: A connected intersection needs to identify the time that the data provided by the infrastructure was generated. This allows an application using the same time source to determine the timeliness of the data.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
				x				
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
This requirement is considered to be met given the presence of the minuteOfTheYear data element in the SPaT message.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:

Table 48. Test Case 3.3.3.2.3.2

Requirement ID:	3.3.3.2.3.2	**Requirement Title:**	SPaT Message - Intersection Time Stamp
Description: A connected intersection shall provide a timestamp indicating the milliseconds within the current minute when the SPaT message was generated, for each intersection within the SPaT message.			
Design Detail: The timestamp indicating the milliseconds within the current minute when the SPaT message was created is represented by timestamp (DE_DSecond) and found under the data frame DF_IntersectionState in the MSG_SignalPhaseAndTiming Message Dedekind in SAE J2735_202007.			
Need ID:	2.4.3.2.3	**Need Title:**	Timestamp
Description: A connected intersection needs to identify the time that the data provided by the infrastructure was generated. This allows an application using the same time source to determine the timeliness of the data.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
				x				
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
This requirement is considered to be met given the presence of the minuteOfTheYear data element in each intersectionState data frames in the SPaT message.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:

Table 49. Test Case 3.3.3.3.3.1

Requirement ID:	3.3.3.3.1.1	**Requirement Title:**	Intersection Signal Timing Information
Description: A connected intersection shall provide signal timing information for one or more intersections			
Design Detail: Signal phase and timing information for an intersection is represented by intersections (DF_IntersectionStateList) in the MSG_SignalPhaseAndTiming Message in SAE J2735_202007			
Need ID:	2.4.3.3.1	**Need Title:**	Intersection Identification
Description: A connected intersection needs to provide the unique identifier of an intersection so an application can associate the signal timing data received with the intersection map data.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
				x				
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
This requirement is considered to be met given the presence of at least one intersectionState data frame in the intersectionStateList in a SPaT Message.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:

Table 50. Test Case 3.3.3.3.1.2

Requirement ID:	3.3.3.3.1.2	**Requirement Title:**	Road Regulator Identifier
Description: A connected intersection shall provide a road regulator identifier unique within North America.			
Design Detail: The road regulator identifier is represented as region (DE_RoadRegulatorID) and found under the data frame DF_IntersectionReferenceID in MSG_SignalPhaseAndTiming Message in SAE J2735_202007. The following is a recommendation until a standards development organization agrees to create and maintain a registry for road regulator identifiers. The CI Committee considered various proposals to assign road regulator identifiers, including a proposal by ISO TC 204, but none of the viable proposals were able to fit within the value range currently allowed by SAE J2735_202007 for road regulator identifiers. A comment has been forwarded to the SAE Core Technical Committee responsible for SAE J2735_202007 to provide a road regulator identifier field with a sufficient range to support existing jurisdiction codes (See Annex H.1.5). From SAE J2735_202007, road regulator identifiers are values from 0 to 65535, with the value of 0 reserved for testing. These values need to support road regulator identifiers for all of the contiguous North America. The recommendation is as follows: 0 = Value for testing 1 – 99 = Reserved for future special values 100 – 19,999 = To be assigned by Canada at its discretion 20,000 – 36,800 = Assigned as per formula below for US states and District of Columbia 36,801 – 39,999 = Reserved for future designation in the US 40,000 – 59,999 = To be assigned by Mexico and Central American countries at their discretion 60,000 – 65,534 = Reserved for future designation 65,535 = Reserved for future special value For the United States, each state and District of Columbia gets one statewide road regulator ID and 299 additional road regulator IDs to designate at their discretion (Note that Texas has 254 counties). Each state department of transportation is assigned a road regulator ID = 19,700 + (300 * STATE_NUMERIC code from Geographic Names Information System (GNIS) [formerly called the Federal Information Processing Standard (FIPS) code]). Each state is also assigned an additional 299 sequential road regulator ID codes following the state department of transportation road regulator ID. An agency should reach out to their state DOT to be assigned a road regulator ID at this time. Note that STATE_NUMERIC (FIPS) codes 03, 07, 14, 43, and 52 are not assigned to states or the District of Columbia. The 300 road regulator IDs that would correspond to each of those codes are reserved for future designation in the United States. CTI 4501 v1.00 CI Implementation Guide Page 142 NOTE: At the time of publication, SAE is revisiting the DE_RoadRegulatorID concept using an object identifier (OID) based data structure based on GNIS but the solution has not been approved yet.			
Need ID:	2.4.3.3.1	**Need Title:**	Intersection Identification
Description: A connected intersection needs to provide the unique identifier of an intersection so an application can associate the signal timing data received with the intersection map data.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
			x					
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
This requirement is considered to be met given the presence of the roadRegulatorId data element in the SPaT and MAP messages, and it is the same between all intersections within each test site (unless multiple jurisdictions are involved, where the roadRegulator Id is expected to be the same at intersection with each jurisdiction).

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:
It is unknown if there are other sites that will be broadcasting the same roadRegulatorId, so this will not be thoroughly tested. To pass, all jurisdictions at all test sites must have different roadRegulatorIds.

Table 51. Test Case 3.3.3.3.1.3

Requirement ID:	3.3.3.3.1.3	**Requirement Title:**	Intersection Reference Identifier
Description: A connected intersection shall provide an intersection reference identifier unique to a road regulator identifier			
Design Detail: The intersection reference identifier is represented as id (DE_IntersectionID) and found under the data frame DF_IntersectionReferenceID in MSG_SignalPhaseAndTiming Message in SAE J2735_202007. The intersection reference identifier is assigned by the IOO represented by the road regulator identifier and is unique within the road regulator identifier.			
Need ID:	2.4.3.3.1	**Need Title:**	Intersection Identification
Description: A connected intersection needs to provide the unique identifier of an intersection so an application can associate the signal timing data received with the intersection map data.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**
			x		

Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
This requirement is considered to be met given the presence of the intersectionId data element in the SPaT and MAP messages, and its value is different between all intersections within each test site (unless multiple jurisdictions are involved, where the intersectionId is expected to be different at intersections with each jurisdiction.). Furthermore, the intersectionId should be the same at each intersection at each jurisdiction for both SPaT and MAP messages. The intersection MAC address will need to be used to make sure SPaT and MAP (with the same IntersectionId) are being broadcast from the same intersection.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:

Table 52. Test Case 3.3.3.3.2.1

Requirement ID:	3.3.3.3.2.1	**Requirement Title:**	Manual Control
Description: A connected intersection shall indicate whether it is operating under manual control.			
Design Detail: Whether the intersection is operating under manual control is represented by Bit 0 in the DE_IntersectionStatusObject and found under the data frame DF_IntersectionState in MSG_SignalPhaseAndTiming Message in SAE J2735_202007. A value of 1 for Bit 0 indicates that the intersection is operating under manual control. Those conditions are defined in Section 4.3.2.2.1.			
Need ID:	2.4.3.3.2	**Need Title:**	Intersection Status
Description: A connected intersection needs to provide information about the current operational status of a signalized intersection so that an OBU/MU application can better interpret signal timing data provided about that intersection. For example, the operational status may indicate if the signalized intersection is operating in preempt, external logic, or in flash.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**
		x			

Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
This requirement is considered to be met given the presence of the intersectionStatus data element in the SPaT messages, and the Manual Control flag is correctly specified - as noted during data collection.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:
If this condition is noted during data collection, then this requirement can be tested. However, if this condition is not noted, then this requirement cannot be verified.

GK - can these states not be forced through the central/local signal system? Note: at least those that are supported. The methodology could be written similar to:

If supported, ensure each intersection is in Manual Control and confirm that it is correctly identified in the intersetcionStatus data element of the SPaT messages.

Requires input to Test: Yes. Manual Control needs to be enabled/disabled to test

Table 53. Test Case 3.3.3.3.2.2

Requirement ID:	3.3.3.3.2.2	**Requirement Title:**	Stop Time
Description: A connected intersection shall indicate whether it is operating under stop time.			
Design Detail: Whether a signalized intersection has stopped timing for traffic operations is represented by Bit 1 in the DE_IntersectionStatusObject and found under the data frame DF_IntersectionState in MSG_SignalPhaseAndTiming Message in SAE J2735_202007. A value of 1 for Bit 1 indicates that timing has stopped for the signalized intersection. The conditions for stop time are defined in Section 4.3.2.2.2.			
Need ID:	2.4.3.3.2	**Need Title:**	Intersection Status
Description: A connected intersection needs to provide information about the current operational status of a signalized intersection so that an OBU/MU application can better interpret signal timing data provided about that intersection. For example, the operational status may indicate if the signalized intersection is operating in preempt, external logic, or in flash.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**
		x			

Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
This requirement is considered to be met given the presence of the intersectionStatus data element in the SPaT messages, and the Stop Time flag is correctly specified - as noted during data collection.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:
If this condition is noted during data collection, then this requirement can be tested. However, if this condition is not noted, then this requirement cannot be verified.

Requires input to Test: Yes. Stop Time needs to be enabled/disabled to test

Table 54. Test Case 3.3.3.3.2.3

Requirement ID:	3.3.3.3.2.3	Requirement Title:	Failure Flash
Description: A connected intersection shall indicate whether the intersection is in a signal flash condition invoked outside of the TSC (e.g., a fault, toggle switch, police panel).			
Design Detail: Whether a signalized intersection is in exception (failure) flash is represented by Bit 2 in the DE_IntersectionStatusObject and found under the data frame DF_IntersectionState in MSG_SignalPhaseAndTiming Message in SAE J2735_202007. A value of 1 for Bit 2 indicates that the signalized intersection is in exception flash. The conditions for exception flash are defined in Section 4.3.2.2.3. While the TSC infrastructure may be aware of several forms of failure flash, it may not be aware of all forms of failure flash, depending on how the connected intersection is wired. For example, the TSC infrastructure may not be aware of a cabinet flash or a conflict flash. Separate wiring may be needed so that the RSU or the TSC infrastructure is aware of a cabinet/conflict/failure flash, depending on where the UPER-encoded SPaT message is generated. This may be addressed in a future version of the CI Implementation Guide. Note: This may not be possible in an unmodified TS-1 cabinet. It may be possible for this to work for a TS2 controller in a TS1 cabinet.			
Need ID:	2.4.3.3.2	**Need Title:**	Intersection Status
Description: A connected intersection needs to provide information about the current operational status of a signalized intersection so that an OBU/MU application can better interpret signal timing data provided about that intersection. For example, the operational status may indicate if the signalized intersection is operating in preempt, external logic, or in flash.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**
		x			

Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
This requirement is considered to be met given the presence of the intersectionStatus data element in the SPaT messages, and the Failure Flash flag is correctly specified - as noted during data collection.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:
If this condition is noted during data collection, then this requirment can be tested. However, if this condition is not noted, then this requirement cannot be verified.

Requires input to Test: A fault, toggle switch, police panel needs to be enabled to send intersection into failure flash

Table 55. Test Case 3.3.3.3.2.4

Requirement ID:	3.3.3.3.2.4	**Requirement Title:**	Preemption
Description: A connected intersection shall indicate whether it is in preemption operation.			
Design Detail: Whether a signalized intersection is in preemption mode is represented by Bit 3 in the DE_IntersectionStatusObject and found under the data frame DF_IntersectionState in MSG_SignalPhaseAndTiming Message in SAE J2735_202007. A value of 1 for Bit 3 indicates that the traffic signal controller is in preemption mode. The definition for preemption mode is in Section 4.3.2.2.5.			
Need ID:	2.4.3.3.2	**Need Title:**	Intersection Status
Description: A connected intersection needs to provide information about the current operational status of a signalized intersection so that an OBU/MU application can better interpret signal timing data provided about that intersection. For example, the operational status may indicate if the signalized intersection is operating in preempt, external logic, or in flash.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**
		x			

Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
This requirement is considered to be met given the presence of the intersectionStatus data element in the SPaT messages, and the Preemption flag is correctly specified - as noted during data collection.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:
If this condition is noted during data collection, then this requirement can be tested. However, if this condition is not noted, then this requirement cannot be verified.

Requires input to Test: Yes. Preemption needs to be triggered

Table 56. Test Case 3.3.3.3.2.5

Requirement ID:	3.3.3.3.2.5	Requirement Title:	Priority
Description: A connected intersection shall indicate whether it is in priority operation.			
Design Detail: Whether a signalized intersection is servicing a priority request is represented by Bit 4 in the DE_IntersectionStatusObject and found under the data frame DF_IntersectionState in MSG_SignalPhaseAndTiming Message in SAE J2735_202007. A value of 1 for Bit 4 indicates that the traffic signal controller is servicing a priority request, as defined in Section 4.3.2.2.6.			
Need ID:	2.4.3.3.2	**Need Title:**	Intersection Status
Description: A connected intersection needs to provide information about the current operational status of a signalized intersection so that an OBU/MU application can better interpret signal timing data provided about that intersection. For example, the operational status may indicate if the signalized intersection is operating in preempt, external logic, or in flash.			

Verification Method	Demonstration	Test	Analyze	Inspection	Other
		x			

Data Collection Type	Stationary	Driving	Video	pcap	Ground Truth	Test Tool	Survey	Other
	x			x				

Evaluation Methodology:
This requirement is considered to be met given the presence of the intersectionStatus data element in the SPaT messages, and the Priority flag is correctly specified - as noted during data collection.

System Input(s):

Supported Sites	GDOT	ODOT	UDOT	Other

Notes:
If this condition is noted during data collection, then this requirement can be tested. However, if this condition is not noted, then this requirement cannot be verified.

Requires input to Test: Yes. Priority needs to be triggered

Table 57. Test Case 3.3.3.3.2.6

Requirement ID:	3.3.3.3.2.6	**Requirement Title:**	Fixed Time
Description: A connected intersection shall indicate whether it is operating under fixed time control.			
Design Detail: Whether a signalized intersection is operating in fixed time mode is represented by Bit 5 in the DE_IntersectionStatusObject and found under the data frame DF_IntersectionState in MSG_SignalPhaseAndTiming Message in SAE J2735_202007. A value of 1 for Bit 5 indicates that the traffic signal controller is operating in fixed time, as defined in Section 4.3.2.2.7.			
Need ID:	2.4.3.3.2	**Need Title:**	Intersection Status
Description: A connected intersection needs to provide information about the current operational status of a signalized intersection so that an OBU/MU application can better interpret signal timing data provided about that intersection. For example, the operational status may indicate if the signalized intersection is operating in preempt, external logic, or in flash.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**
		x			

Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
This requirement is considered to be met given the presence of the intersectionStatus data element in the SPaT messages, and the Fixed Time flag is correctly specified - as noted during data collection.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:
If this condition is noted during data collection, then this requirement can be tested. However, if this condition is not noted, then this requirement cannot be verified. It is probable a site may include a signal that exhibits this condition.

Requires input to Test: Yes. A fixed time signal timing plan needs to be implemented

Table 58. Test Case 3.3.3.3.2.7

Requirement ID:	3.3.3.3.2.7	Requirement Title:	Traffic Dependent Mode

Description:
A connected intersection shall indicate whether it is not operating in fixed time control.

Design Detail:
Whether a signalized intersection that is operating in a traffic dependent mode is represented by Bit 6 in the DE_IntersectionStatusObject and found under the data frame DF_IntersectionState in MSG_SignalPhaseAndTiming Message in SAE J2735_202007. A value of 1 for Bit 6 indicates that the traffic signal controller is operating in a non-fixed time mode, as defined in Section 4.3.2.2.8. Note that Traffic Dependent Mode and Fixed Time (Section 4.3.3.3.2.6) are mutually exclusive - that is the traffic signal controller cannot be operating in Traffic Dependent Mode and Fixed Time at the same time

Need ID:	2.4.3.3.2	Need Title:	Intersection Status

Description:
A connected intersection needs to provide information about the current operational status of a signalized intersection so that an OBU/MU application can better interpret signal timing data provided about that intersection. For example, the operational status may indicate if the signalized intersection is operating in preempt, external logic, or in flash.

Verification Method	Demonstration	Test	Analyze	Inspection	Other
		x			

Data Collection Type	Stationary	Driving	Video	pcap	Ground Truth	Test Tool	Survey	Other
	x			x				

Evaluation Methodology:
This requirement is considered to be met given the presence of the intersectionStatus data element in the SPaT messages, and the Traffic Dependent Mode flag is correctly specified - as noted during data collection.

System Input(s):

Supported Sites	GDOT	ODOT	UDOT	Other

Notes:
If this condition is noted during data collection, then this requirement can be tested. However, if this condition is not noted, then this requirement cannot be verified. It is probable a site may include a signal that exhibits this condition.

Requires input to Test: Yes. An actuated signal timing plan needs to be implemented

Table 59. Test Case 3.3.3.3.2.8

Requirement ID:	3.3.3.3.2.8	**Requirement Title:**	Standby Mode
Description: A connected intersection shall indicate whether it is in a signal flash condition invoked by the TSC infrastructure (e.g., TOD Flash, Start-Up Flash, Preemption Flash).			
Design Detail: Whether a signalized intersection that is operating in operational flash (standby mode) is represented by Bit 7 in the DE_IntersectionStatusObject and found under the data frame DF_IntersectionState in MSG_SignalPhaseAndTiming Message in SAE J2735_202007. A value of 1 for Bit 7 indicates that the traffic signal controller is in operational flash, as defined in Section 4.3.2.2.4.			
Need ID:	2.4.3.3.2	**Need Title:**	Intersection Status
Description: A connected intersection needs to provide information about the current operational status of a signalized intersection so that an OBU/MU application can better interpret signal timing data provided about that intersection. For example, the operational status may indicate if the signalized intersection is operating in preempt, external logic, or in flash.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**
		x			

Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
This requirement is considered to be met given the presence of the intersectionStatus data element in the SPaT messages, and the Standby Mode flag is correctly specified - as noted during data collection.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:

If this condition is noted during data collection, then this requirement can be tested. However, if this condition is not noted, then this requirement cannot be verified. It is probable a site may include a signal that exhibits this condition.

Requires input to Test: Yes. A 'flash' signal timing plan needs to be implemented

Table 60. Test Case 3.3.3.3.2.9

Requirement ID:	3.3.3.3.2.9	Requirement Title:	Failure Mode
Description: A connected intersection shall indicate whether the TSC infrastructure has a problem or failure in operation.			
Design Detail: Whether a signalized intersection is in a failure mode is represented by Bit 8 in the DE_IntersectionStatusObject and found under the data frame DF_IntersectionState in MSG_SignalPhaseAndTiming Message in SAE J2735_202007. A value of 1 for Bit 8 indicates that the TSC infrastructure is in failure mode. CTI 4501 v1.00 CI Implementation Guide Page 144 A signalized intersection may be considered in a failure mode when the intersection is in a hard flash condition. See Annex A.2.1.6, Hard Flashing Operation and A.2.1.7, Tech Flash.			
Need ID:	2.4.3.3.2	**Need Title:**	Intersection Status
Description: A connected intersection needs to provide information about the current operational status of a signalized intersection so that an OBU/MU application can better interpret signal timing data provided about that intersection. For example, the operational status may indicate if the signalized intersection is operating in preempt, external logic, or in flash.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**
		x			

Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
This requirement is considered to be met given the presence of the intersectionStatus data element in the SPaT messages, and the Failure Mode flag is correctly specified - as noted during data collection.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:
If this condition is noted during data collection, then this requirement can be tested. However, if this condition is not noted, then this requirement cannot be verified.

Requires input to test: Yes. But uncertain how a failure is generated

Table 61. Test Case 3.3.3.3.2.10

Requirement ID:	3.3.3.3.2.10	**Requirement Title:**	Controller Off
Description: A connected intersection shall indicate whether the TSC infrastructure is not providing valid data.			
Design Detail: Whether an RSU is receiving valid data from the TSC infrastructure is represented by Bit 9 in the DE_IntersectionStatusObject and found under the data frame DF_IntersectionState in MSG_SignalPhaseAndTiming Message in SAE J2735_202007. A value of 1 for Bit 9 indicates that the RSU is not receiving valid SPaT information messages from the TSC infrastructure within the last 0.3 seconds. Note: if the TSC infrastructure generates the UPER-encoded SAE J2735_202007 SPaT message, and the controller is off, no SPaT message will be generated.			
Need ID:	2.4.3.3.2	**Need Title:**	Intersection Status
Description: A connected intersection needs to provide information about the current operational status of a signalized intersection so that an OBU/MU application can better interpret signal timing data provided about that intersection. For example, the operational status may indicate if the signalized intersection is operating in preempt, external logic, or in flash.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**
		x			

Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x		x	x				

Evaluation Methodology:
This requirement is considered to be met given the presence of the intersectionStatus data element in the SPaT messages, and the Controller Off flag is correctly specified - as noted during data collection.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:

Table 62. Test Case 3.3.3.3.2.11

Requirement ID:	3.3.3.3.2.11	**Requirement Title:**	Recent MAP Update
Description: A connected intersection shall indicate whether it has had a recent MAP message update.			
Design Detail: A pedestrian Steady DON'T WALK interval is represented by a value of stop-And-Remain (3) for the eventState (DE_MovementPhaseState), found under data frame DF_MovementEvent in MSG_SignalPhaseAndTiming Message as defined in SAE J2735_202007			
Need ID:	2.4.3.3.2	**Need Title:**	Intersection Status
Description: Whether an RSU is broadcasting a new MAP message is represented by Bit 10 in the DE_IntersectionStatusObject and found under the data frame DF_IntersectionState in MSG_SignalPhaseAndTiming Message in SAE J2735_202007. A value of 1 for Bit 10 indicates that the MAP message transmitted by the RSU has recently been updated. However, in practice this bit is not expected to be used by RLVW applications on OBUs. RLVW applications are expected to use the revision counter in the MAP message to determine if there are changes in the MAP messages. Bit 10 shall be set to a value of 1. Note: the MAP message can be broadcasted without a SPaT message, but the SPaT message must be sent with a MAP message describing the intersection associated with the SPaT message.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
		x						
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
This requirement is considered to be met given the presence of the intersectionStatus data element in the SPaT messages, and the Recent MAP Update flag is correctly specified - as noted during data collection.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:
Requires input to Test: place calls as needed to ensure all signal states for each signal group are experienced.

Table 63. Test Case 3.3.3.3.2.12

Requirement ID:	3.3.3.3.2.12	**Requirement Title:**	New Lane IDs
Description: A connected intersection shall indicate whether it has had a recent change in MAP assigned lane IDs or which revocable lanes are currently enabled.			
Design Detail: Whether an RSU is broadcasting a MAP message with changes in lane assignments or which lanes are enabled in the SPaT message is represented by Bit 11 in the DE_IntersectionStatusObject and found under the data frame DF_IntersectionState in MSG_SignalPhaseAndTiming Message in SAE J2735_202007. A value of 1 for Bit 11 indicates that the lane definitions in the MAP message or the enabled lanes in the SPaT message transmitted by the RSU has recently been updated. However, in practice this bit is not expected to be used by RLVW applications on OBUs. RLVW applications are expected to use the revision counter in the SPaT and MAP message to determine if there are changes in either message. Bit 11 shall be set to a value of 1.			
Need ID:	2.4.3.3.2	**Need Title:**	Intersection Status
Description: A connected intersection needs to provide information about the current operational status of a signalized intersection so that an OBU/MU application can better interpret signal timing data provided about that intersection. For example, the operational status may indicate if the signalized intersection is operating in preempt, external logic, or in flash.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**
		x			

Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
This requirement is considered to be met given the presence of the intersectionStatus data element in the SPaT messages, and the New Lane IDs flag is correctly specified - as noted during data collection.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:
Requires input to Test: place calls as needed to ensure all signal states for each signal group are experienced.

Table 64. Test Case 3.3.3.3.2.13

Requirement ID:	3.3.3.3.2.13	Requirement Title:	No MAP Available
Description: A connected intersection shall indicate when no valid MAP is available. A MAP is considered not available when any of the following conditions is true. • If a connected intersection does not have a valid MAP message to broadcast			
Design Detail: Whether an RSU is broadcasting a valid MAP message is represented by Bit 12 in the DE_IntersectionStatusObject and found under the data frame DF_IntersectionState in MSG_SignalPhaseAndTiming Message in SAE J2735_202007. A value of 0 for Bit 12 indicates that the RSU is broadcasting a properly formatted MAP message with a PSID of 0px20-40-97, and a valid IEEE Std 1609.2-2016 certificate. A value of 1 for Bit 12 indicates that either the MAP is unavailable, or it is invalid. Situations when a MAP may be invalid include temporary lane closures, when the RSU may still be transmitting the MAP message since the IOO may not have CTI 4501 v1.00 CI Implementation Guide Page 145 been notified by the contractor for lane closure or time lags. This applies when contractor is setting up cones/barrels for lane closures, presence of flaggers, etc. A MAP message can be broadcasted without a SPaT message, but the SPaT message must be sent with a valid MAP message describing the intersection associated with the SPaT message. However, there are scenarios when the intersection is operating properly, but the IOO decides not to generate MAP message, maybe for operational or maintenance purposes or the MAP message doesn't have a valid IEEE Std 1609.2-2016 certificate. Note: If the UPER-encoded SAE J2735_202007 SPaT message is generated by the TSC infrastructure and the MAP message is generated elsewhere, the TSC infrastructure must be informed if the RSU is broadcasting a MAP message to properly set Bit 12. Note the CI Implementation Guide does not define a requirement for the TSC infrastructure to be informed if a new MAP message is being broadcasted.			
Need ID:	2.4.3.3.2	**Need Title:**	Intersection Status
Description: A connected intersection needs to provide information about the current operational status of a signalized intersection so that an OBU/MU application can better interpret signal timing data provided about that intersection. For example, the operational status may indicate if the signalized intersection is operating in preempt, external logic, or in flash.			

Verification Method	Demonstration	Test	Analyze	Inspection	Other			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x		x	x				
Evaluation Methodology: This requirement is considered to be met given the presence of the intersectionStatus data element in the SPaT messages, and the No MAP Available flag is correctly specified - as noted during data collection.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				

Notes:
Requires input to Test: place calls as needed to ensure all signal states for each signal group are experienced.

Table 65. Test Case 3.3.3.3.2.14

Requirement ID:	3.3.3.3.2.14	Requirement Title:	No SPaT Available
Description: A connected intersection shall indicate when no valid SPaT information is available. SPaT information is considered not available under the following conditions: • If an RSU has received no valid SPaT information message from the TSC infrastructure for more than 300 milliseconds. Valid values from the TSC infrastructure are properly formatted and within the permitted data ranges.			
Design Detail: Whether an RSU is broadcasting a valid SPaT message is represented by Bit 13 in the DE_IntersectionStatusObject and found under the data frame DF_IntersectionState in MSG_SignalPhaseAndTiming Message in SAE J2735_202007. An RSU (or the TSC infrastructure) may set Bit 13 to 1 if the signalized intersection is under test and is not broadcasting a valid SPaT message. An RSU may also set Bit 13 to 1 if the RSU is not receiving valid SPaT information messages from the TSC infrastructure within the last 300 milliseconds. Note: If the TSC infrastructure generates the UPER-encoded SAE J2735_202007 SPaT message and if the controller is off, no SPaT message will be generated.			
Need ID:	2.4.3.3.2	**Need Title:**	Intersection Status
Description: A connected intersection needs to provide information about the current operational status of a signalized intersection so that an OBU/MU application can better interpret signal timing data provided about that intersection. For example, the operational status may indicate if the signalized intersection is operating in preempt, external logic, or in flash.			

Verification Method	Demonstration	Test	Analyze	Inspection	Other
		x			

Data Collection Type	Stationary	Driving	Video	pcap	Ground Truth	Test Tool	Survey	Other
	x			x				

Evaluation Methodology:
This requirement is considered to be met given the presence of the intersectionStatus data element in the SPaT messages, and the No SPaT Available flag is correctly specified - as noted during data collection.

System Input(s):

Supported Sites	GDOT	ODOT	UDOT	Other

Notes:
If this condition is noted during data collection, then this requirement can be tested. However, if this condition is not noted, then this requirement cannot be verified.

Requires input to test: Yes. Need to cease broadcast of SPaT information from controller

Table 66. Test Case 3.3.3.3.3.1

Requirement ID:	3.3.3.3.3.1	**Requirement Title:**	Current Movement State for a Signal Group
Description: A connected intersection shall provide the current movement state for each signal group identified in the MAP message. The valid values for the current movement state for a signal group are defined by DE_MovementPhaseState in SAE J2735_202007.			
Design Detail: The state of a movement through an intersection is represented as eventState (DE_MovementPhaseState) and found under data frame DF_MovementEvent in MSG_SignalPhaseAndTiming Message in SAE J2735_202007. Each movement is tied to an identifier called the signalGroup (DE_SignalGroupID), which represents a collection of movements of a common type through the intersection. If the signal group does not correspond to an actual signal head and therefore is not in the MAP message, then sending information about that fictitious signal group is prohibited. If the signal group does correspond to an actual signal head and is in the MAP message, then the current movement state has to be sent, even if the current movement state is dark (1). An application will be expecting a state for signal group since it is in the MAP message.			
Need ID:	2.4.3.3.3	**Need Title:**	Current Movement State
Description: A connected intersection needs to provide information about the current state of each movement—including a pedestrian movement— at the intersection so an application can provide the proper warnings, information, or guidance to the driver or VRU. The current state identifies if a maneuver through an intersection is currently allowed and any restrictions. For example, the current state may indicate whether a protected or permissive movement is allowed, a protected or permissive clearance (phase change interval) is in effect, the movement is required to stop then proceed, remain, or a movement may proceed with caution with possible conflicting traffic.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x		x	x		x		
Evaluation Methodology: This requirement is verified through a combination of video collection and pcap file analysis. It is considered satisfied if the signal states in the test tool match actual signal states in the field.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes: GK - could this group of requirements be tested in coordination with 3.3.3.3.8?								

Table 67. Test Case 3.3.3.3.3.2

Requirement ID:	3.3.3.3.3.2	Requirement Title:	Unknown Current Movement State for a Signal Group
Description: If the TSC infrastructure does not provide a value for the current movement state for a signal group, a connected intersection shall use a value of unavailable, as defined by DE_MovementPhaseState in SAE J2735_202007.			
Design Detail: If the current state of a movement through an intersection is unknown, it is represented by a value of unavailable (0) for the eventState (DE_MovementPhaseState), found under data frame DF_MovementEvent in MSG_SignalPhaseAndTiming Message as defined in SAE J2735_202007			
Need ID:	2.4.3.3.3	**Need Title:**	Current Movement State
Description: A connected intersection needs to provide information about the current state of each movement—including a pedestrian movement— at the intersection so an application can provide the proper warnings, information, or guidance to the driver or VRU. The current state identifies if a maneuver through an intersection is currently allowed and any restrictions. For example, the current state may indicate whether a protected or permissive movement is allowed, a protected or permissive clearance (phase change interval) is in effect, the movement is required to stop then proceed, remain, or a movement may proceed with caution with possible conflicting traffic.			

Verification Method	Demonstration	Test	Analyze	Inspection	Other			
		X						
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x		x	x		x		
Evaluation Methodology: Evaluated by looking at SPaT Messages over an extended period from each RSU in pcap file. Requirement is considered to be met if all signalGroups are constantly included in the SPaT Message.								
System Input(s):								

Supported Sites	GDOT	ODOT	UDOT	Other
Notes:				

Table 68. Test Case 3.3.3.3.3.3

Requirement ID:	3.3.3.3.3.3	**Requirement Title:**	Flashing Yellow Arrow Permissive Movement
Description: At an intersection that uses a flashing yellow arrow to control a permissive movement as part of a protected/permissive turn, a connected intersection shall use the value of permissive-Movement-Allowed as the current movement state for the signal group when the flashing yellow arrow is active, as defined by DE_MovementPhaseState in SAE J2735_202007.			
Design Detail: A flashing yellow arrow for a permissive movement is represented by a value of permissive-MovementAllowed (5) for the eventState (DE_MovementPhaseState), found under data frame DF_MovementEvent in MSG_SignalPhaseAndTiming Message as defined in SAE J2735_202007.			
Need ID:	2.4.3.3.3	**Need Title:**	Current Movement State
Description: A connected intersection needs to provide information about the current state of each movement—including a pedestrian movement— at the intersection so an application can provide the proper warnings, information, or guidance to the driver or VRU. The current state identifies if a maneuver through an intersection is currently allowed and any restrictions. For example, the current state may indicate whether a protected or permissive movement is allowed, a protected or permissive clearance (phase change interval) is in effect, the movement is required to stop then proceed, remain, or a movement may proceed with caution with possible conflicting traffic.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**
	x				

Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x		x	x				

Evaluation Methodology:
This requirement is verified through a combination of video collection and pcap file analysis. It is considered satisfied if the state of a vehicular movement is permissive-movement-allowed when the flashing yellow arrow is active.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:
This requirement is only applicable to movements controlled by a flashing yellow arrow

Requires input to test: ens

Table 69. Test Case 3.3.3.3.3.4

Requirement ID:	3.3.3.3.3.4	**Requirement Title:**	Protected and Permissive Clearance
Description: A connected intersection shall use the value of protected-clearance or permissive-clearance as the current movement state of a signal group to correspond with the protected or permissive condition of the CTI 4501 v1.00 CI Implementation Guide Page 75 allowed movement immediately preceding the current (clearance) interval, as defined by DE_MovementPhaseState in SAE J2735_202007.			
Design Detail: A clearance state immediately following a protected-Movement-Allowed is represented by a value of protected-clearance (8) for the eventState (DE_MovementPhaseState), found under data frame DF_MovementEvent in MSG_SignalPhaseAndTiming Message as defined in SAE J2735_202007. A clearance state immediately following a permissive-Movement-Allowed is represented by a value of permissive-clearance (7) for the eventState (DE_MovementPhaseState), found under data frame DF_MovementEvent in MSG_SignalPhaseAndTiming Message as defined in SAE J2735_202007.			
Need ID:	2.4.3.3.3	**Need Title:**	Current Movement State
Description: A connected intersection needs to provide information about the current state of each movement—including a pedestrian movement— at the intersection so an application can provide the proper warnings, information, or guidance to the driver or VRU. The current state identifies if a maneuver through an intersection is currently allowed and any restrictions. For example, the current state may indicate whether a protected or permissive movement is allowed, a protected or permissive clearance (phase change interval) is in effect, the movement is required to stop then proceed, remain, or a movement may proceed with caution with possible conflicting traffic.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
				x				
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x		x	x				

Evaluation Methodology:
This requirement is verified through a combination of video collection and pcap file analysis. It is considered satisfied if the state of a vehicular movement is permissive-clearance when proceeding a permissive-movement-allowed signal state OR if the state of a vehicular movement is protected-clearance when proceeding a protected-movement-allowed signal state.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:
Requires input to Test: place calls as needed to ensure all signal states for each signal group are experienced.

Table 70. Test Case 3.3.3.3.3.5

Requirement ID:	3.3.3.3.3.5	**Requirement Title:**	Resolve Protected Versus Permissive Movement
Description: When an allowed movement controlled by a signal group is sometimes protected and sometimes permissive, such as a protected/permissive left turn, a connected intersection shall determine whether the currently allowed movement is protected or permissive and use the corresponding current movement state (protected-Movement-Allowed, permissive-Movement-Allowed) for the signal group, as defined by DE_MovementPhaseState in SAE J2735_202007			
Design Detail: An allowed movement that is in conflict with another movement is represented by a value of permissiveMovement-Allowed (5) for the eventState (DE_MovementPhaseState), as defined in SAE J2735_202007; and represented by a value of protected-Movement-Allowed (6) when the same allowed movement is not in conflict with another movement. Note that there is some question if NTCIP 1202 v03A currently addresses protected and permissive movements correctly as stated. The question has been posed to the NTCIP Actuated Signal Controllers Working Group. See Annex H.2.1, Protected / Permissive Movements. In the meantime, the RSU could be configured to resolve the protected permissive state of a protected permissive signal group in the same way that it does not for TSCBM. The controller could send the state of the protected movement channel and the permissive movement channel/overlap and the RSU could resolve it using a custom configured table. Also, while the TSCBM can indicate if the current movement state is green, yellow or red, it does not indicate if the movement allowed, or the clearance state is a protected movement/clearance or a permissive movement/clearance. The RSU receiving the TSCBM has to be configured to determine when a phase or overlap movement is protected or permissive. There is currently no standardized interface to configure this information.			
Need ID:	2.4.3.3.3	**Need Title:**	Current Movement State
Description: A connected intersection needs to provide information about the current state of each movement—including a pedestrian movement— at the intersection so an application can provide the proper warnings, information, or guidance to the driver or VRU. The current state identifies if a maneuver through an intersection is currently allowed and any restrictions. For example, the current state may indicate whether a protected or permissive movement is allowed, a protected or permissive clearance (phase change interval) is in effect, the movement is required to stop then proceed, remain, or a movement may proceed with caution with possible conflicting traffic.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x		x	x				
Evaluation Methodology: This requirement is verified through a combination of video collection and pcap file analysis. It is considered satisfied if the state of a vehicular movement is permissive-movement-allowed when a green indication is provided when there are potential conflicting movements AND if the state of a vehicular movement is protected-movement-allowed when an arrow indication is provided when there are no conflicting movements.								

System Input(s):

Supported Sites	GDOT	ODOT	UDOT	Other	

Notes:
This requirement is only verified on movements that could be protected or permissive in nature. This is not exclusive to left turn movements.

Requires input to Test: place calls as needed to ensure all signal states combinations for potentially conflicting signal groups are experienced.

Table 71. Test Case 3.3.3.3.3.6

Requirement ID:	3.3.3.3.3.6	**Requirement Title:**	Conflict Causes Permissive
Description: When any allowed movement controlled by a signal group includes a maneuver in conflict with any other movement that is in a permitted or clearance state, a connected intersection shall use permissiveMovement-Allowed or permissive-clearance as the current movement state for the signal group, as defined by DE_MovementPhaseState in SAE J2735_202007. Examples include a green ball with an opposing green ball, and a green ball with a permitted pedestrian movement for a turn.			
Design Detail: An allowed movement that is in potential conflict with another movement is represented by a value of permissive-Movement-Allowed (5) for the eventState (DE_MovementPhaseState), found under data frame DF_MovementEvent in MSG_SignalPhaseAndTiming Message as defined in SAE J2735_202007.			
Need ID:	2.4.3.3.3	**Need Title:**	Current Movement State
Description: A connected intersection needs to provide information about the current state of each movement—including a pedestrian movement— at the intersection so an application can provide the proper warnings, information, or guidance to the driver or VRU. The current state identifies if a maneuver through an intersection is currently allowed and any restrictions. For example, the current state may indicate whether a protected or permissive movement is allowed, a protected or permissive clearance (phase change interval) is in effect, the movement is required to stop then proceed, remain, or a movement may proceed with caution with possible conflicting traffic.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x		x	x				
Evaluation Methodology: This requirement is verified through a combination of video collection and pcap file analysis. It is considered satisfied if the state of a vehicular movement is permissive-movement-allowed when a green indication is provided when there are potential conflicting movements.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes: This requirement does not explicitly define under what conditions another movement potentially conflicts with the movement in question. For the purpose of this verification, it will be assumed that the intent of this requirement is that two movements that conflict with each other when 'green' should indicate a permissive-movement-allowed. Through movements and right turn movements, even if they are green at the same time as conflicting movements, may be considered permissive (as to be consistent with signal indication - solid ball)								

Requires input to Test: place calls as needed to ensure all signal states combinations for potentially conflicting signal groups are experienced.

Table 72. Test Case 3.3.3.3.3.7

Requirement ID:	3.3.3.3.3.7	**Requirement Title:**	No Conflict Causes Protected
Description: When an allowed movement controlled by a signal group includes no maneuver in conflict with any other vehicle, pedestrian, or bicycle movement that is in a permitted or clearance state, a connected intersection shall use protected-Movement-Allowed or protected-clearance as the current movement state for the signal group, as defined by DE_MovementPhaseState in SAE J2735_202007.			
Design Detail: An allowed movement that does not conflict with another movement is represented by a value of protected-Movement-Allowed (6) for the eventState (DE_MovementPhaseState), found under data frame DF_MovementEvent in MSG_SignalPhaseAndTiming Message as defined in SAE J2735_202007.			
Need ID:	2.4.3.3.3	**Need Title:**	Current Movement State
Description: A connected intersection needs to provide information about the current state of each movement—including a pedestrian movement— at the intersection so an application can provide the proper warnings, information, or guidance to the driver or VRU. The current state identifies if a maneuver through an intersection is currently allowed and any restrictions. For example, the current state may indicate whether a protected or permissive movement is allowed, a protected or permissive clearance (phase change interval) is in effect, the movement is required to stop then proceed, remain, or a movement may proceed with caution with possible conflicting traffic.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x		x	x				
Evaluation Methodology: This requirement is verified through a combination of video collection and pcap file analysis. It is considered satisfied if the state of a vehicular movement is protected-movement-allowed when an arrow indication is provided when there are no conflicting movements.								
System Input(s):								

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**
Notes: This requirement does not explicitly define under what conditions another movement potentially conflicts with the movement in question. For the purpose of this verification, it will be assumed that the intent of this requirement is that protected-movement-allowed when there are no other conflicting movement that are 'green' at the same time.				

Requires input to test: place calls as needed to ensure all signal states combinations for potentially conflicting signal groups are experienced.

Table 73. Test Case 3.3.3.3.3.8

Requirement ID:	3.3.3.3.3.8	**Requirement Title:**	WALK State Enumeration (No Conflict)
Description: When an allowed pedestrian movement has no conflict with a vehicle movement controlled by a signal group that is in a permitted or clearance state, a connected intersection shall use protected-MovementAllowed as the current movement state for the pedestrian WALK interval, as defined by DE_MovementPhaseState in SAE J2735_202007. Examples of a WALK state with no conflict include leading pedestrian intervals or exclusive pedestrian interval (Barnes Dance).			
Design Detail: A pedestrian WALK interval that has no conflict with a vehicle movement is represented by a value of protected-Movement-Allowed (6) for the eventState (DE_MovementPhaseState), found under data frame DF_MovementEvent in MSG_SignalPhaseAndTiming Message as defined in SAE J2735_202007. CTI 4501 v1.00 CI Implementation Guide Page 147 NOTE: A WALK may have no conflict for part of its duration and change to having a conflict. For example, a leading pedestrian interval brings up the WALK indication for a few seconds before the parallel vehicle movements gets a permissive green that includes turning movements in conflict with the WALK.			
Need ID:	2.4.3.3.3	**Need Title:**	Current Movement State
Description: A connected intersection needs to provide information about the current state of each movement—including a pedestrian movement— at the intersection so an application can provide the proper warnings, information, or guidance to the driver or VRU. The current state identifies if a maneuver through an intersection is currently allowed and any restrictions. For example, the current state may indicate whether a protected or permissive movement is allowed, a protected or permissive clearance (phase change interval) is in effect, the movement is required to stop then proceed, remain, or a movement may proceed with caution with possible conflicting traffic.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x		x	x				
Evaluation Methodology: This requirement is verified through a combination of video collection and pcap file analysis. It is considered satisfied if the state of a pedestrian movement is protected-movement-allowed when a WALK indication is provided when there are no conflicting movements.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				

Notes:
See discussion for 3.3.3.3.3.7 above.

Requires input to test: place calls as needed to ensure all signal states combinations for potentially conflicting signal groups are experienced.

Table 74. Test Case 3.3.3.3.3.9

Requirement ID:	3.3.3.3.3.9	**Requirement Title:**	WALK State Enumeration (Potential Conflict)
Description: When an allowed pedestrian movement is in conflict with a vehicle movement controlled by a signal group that is in a permitted or clearance state, a connected intersection shall use permissive-Movement-Allowed as the current movement state for the pedestrian WALK interval, as defined by DE_MovementPhaseState in SAE J2735_202007. Examples of a WALK state with potential conflicts include vehicles turning right on green across the pedestrian crosswalk in a WALK state.			
Design Detail: A pedestrian WALK interval that is in conflict with a vehicle movement is represented by a value of permissive-Movement-Allowed (5) for the eventState (DE_MovementPhaseState), found under data frame DF_MovementEvent in MSG_SignalPhaseAndTiming Message as defined in SAE J2735_202007.			
Need ID:	2.4.3.3.3	**Need Title:**	Current Movement State
Description: A connected intersection needs to provide information about the current state of each movement—including a pedestrian movement— at the intersection so an application can provide the proper warnings, information, or guidance to the driver or VRU. The current state identifies if a maneuver through an intersection is currently allowed and any restrictions. For example, the current state may indicate whether a protected or permissive movement is allowed, a protected or permissive clearance (phase change interval) is in effect, the movement is required to stop then proceed, remain, or a movement may proceed with caution with possible conflicting traffic.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x		x	x				
Evaluation Methodology: This requirement is verified through a combination of video collection and pcap file analysis. It is considered satisfied if the state of a pedestrian movement is permissive-movement-allowed when a WALK indication is provided concurrent with a permissive indication for a conflicting traffic movement.								
System Input(s):								

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**
Notes: See discussion for 3.3.3.3.3.6 above. Requires input to test: place calls as needed to ensure all signal states combinations for potentially conflicting signal groups are experienced.				

Table 75. Test Case 3.3.3.3.3.10

Requirement ID:	3.3.3.3.3.10	**Requirement Title:**	Flashing DON'T WALK State Enumeration
Description: A connected intersection shall use the protected-clearance or permissive-clearance as the current movement state for the pedestrian Flashing DON'T WALK interval, as defined by DE_MovementPhaseState in SAE J2735_202007, to correspond with the protected or permissive condition of the allowed WALK movement immediately preceding the current (clearance) interval.			
Design Detail: A pedestrian Flashing DON'T WALK interval that may be in conflict with another movement is represented by a value of permissive-clearance (7) for the eventState (DE_MovementPhaseState), found under data frame DF_MovementEvent in MSG_SignalPhaseAndTiming Message as defined in SAE J2735_202007. A pedestrian Flashing DON'T WALK interval that has no conflict with another movement is represented by a value of protected-clearance (8) for the eventState (DE_MovementPhaseState), found under data frame DF_MovementEvent in MSG_SignalPhaseAndTiming Message as defined in SAE J2735_202007			
Need ID:	2.4.3.3.3	**Need Title:**	Current Movement State
Description: A connected intersection needs to provide information about the current state of each movement—including a pedestrian movement— at the intersection so an application can provide the proper warnings, information, or guidance to the driver or VRU. The current state identifies if a maneuver through an intersection is currently allowed and any restrictions. For example, the current state may indicate whether a protected or permissive movement is allowed, a protected or permissive clearance (phase change interval) is in effect, the movement is required to stop then proceed, remain, or a movement may proceed with caution with possible conflicting traffic.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x		x	x				
Evaluation Methodology: This requirement is verified through a combination of video collection and pcap file analysis. It is considered satisfied if the state of a pedestrian movement is permissive-clearance when a steady DON'T WALK indication is provided.								
System Input(s):								

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**
Notes: See discussion for 3.3.3.3.3.6 above. Requires input to Test: place calls as needed to ensure all signal states for each signal group are experienced.				

Table 76. Test Case 3.3.3.3.3.11

Requirement ID:	3.3.3.3.3.11	**Requirement Title:**	Steady DON'T WALK State Enumeration
Description: A connected intersection shall use stop-And-Remain as the current movement state for the pedestrian Steady DON'T WALK interval, as defined by DE_MovementPhaseState in SAE J2735_202007.			
Design Detail: A pedestrian Steady DON'T WALK interval is represented by a value of stop-And-Remain (3) for the eventState (DE_MovementPhaseState), found under data frame DF_MovementEvent in MSG_SignalPhaseAndTiming Message as defined in SAE J2735_202007			
Need ID:	2.4.3.3.3	**Need Title:**	Current Movement State
Description: A connected intersection needs to provide information about the current state of each movement—including a pedestrian movement— at the intersection so an application can provide the proper warnings, information, or guidance to the driver or VRU. The current state identifies if a maneuver through an intersection is currently allowed and any restrictions. For example, the current state may indicate whether a protected or permissive movement is allowed, a protected or permissive clearance (phase change interval) is in effect, the movement is required to stop then proceed, remain, or a movement may proceed with caution with possible conflicting traffic.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x		x	x				
Evaluation Methodology: This requirement is verified through a combination of video collection and pcap file analysis. It is considered satisfied if the state of a pedestrian movement is stop-and-remain when a steady DON'T WALK indication is provided.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes: Requires input to Test: place calls as needed to ensure all signal states for each signal group are experienced.								

Table 77. Test Case 3.3.3.3.3.12

Requirement ID:	3.3.3.3.3.12	**Requirement Title:**	Movement State for Signal Groups Identified
Description: A connected intersection shall provide the current movement state for only signal groups identified in the MAP message. The connected intersection will not provide a movement state for any signal group not identified by the corresponding MAP message.			
Design Detail: No Further Design Details			
Need ID:	2.4.3.3.3	**Need Title:**	Current Movement State
Description: A connected intersection needs to provide information about the current state of each movement—including a pedestrian movement— at the intersection so an application can provide the proper warnings, information, or guidance to the driver or VRU. The current state identifies if a maneuver through an intersection is currently allowed and any restrictions. For example, the current state may indicate whether a protected or permissive movement is allowed, a protected or permissive clearance (phase change interval) is in effect, the movement is required to stop then proceed, remain, or a movement may proceed with caution with possible conflicting traffic.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x		x	x				
Evaluation Methodology: This requirement is verified through a combination of video collection and pcap file analysis. It is considered satisfied if each signalGroup in the message is directly related to a connection in the MAP message.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes: Requires input to Test: place calls as needed to ensure all signal states for each signal group are experienced.								

Table 78. Test Case 3.3.3.3.4.1

Requirement ID:	3.3.3.3.4.1	**Requirement Title:**	Next Movement State

Description:
A connected intersection shall provide the next (future) movement state to follow the current movement state for a signal group. The valid values for the next movement state for a signal group are defined by DE_MovementPhaseState in SAE J2735_202007.

Design Detail:
MSG_SignalPhaseAndTiming Message provides a data frame, DF_MovementEventList, that contains 1 to 16 entries for the same movement at an intersection. Each entry (represented by DF_MovementEvent) represents a movement state for that movement over a period of time.

- The first entry describes the current movement state (i.e., DE_MovementPhaseState) and the time change details for the current movement (minEndTime, maxEndTime, and nextTime).
- The second entry describes the movement state immediately after the current movement state terminates; and the start, minimum end, and maximum end times (i.e., startTime, minEndTime, and maxEndTime) for the next movement state. If the TSC infrastructure knows the next movement state, the TSC infrastructure shall provide the next movement state in the second entry of DF_MovementEventList, as eventState (DE_MovementPhaseState), found under data frame DF_MovementEvent in MSG_SignalPhaseAndTiming Message as defined in SAE J2735_202007.
- If the next movement state, as represented by DE_MovementPhaseState, is unknown, a second entry for the movement (DF_MovementEvent) shall not be sent in DF_MovementEventList. Note that during an AGP, the next movment state is known and is broadcasted. For example, in Figure 17, lane #1 is tied to signal group #2 and currently a permitted left turn (FY (Flashing Yellow) in Figure 17). The minimum end time for signal group 2 is currently 34675 deciseconds CTI 4501 v1.00 CI Implementation Guide Page 148 and the maximum end time is 35244 deciseconds from the top of the hour.
- At this point in time, the TSC infrastructure has not determined if the next movement state is a clearance interval or a protected left turn. So, the SPaT message for this movement would be the following:

{"signalGroup":2,"state-time-speed":[{"eventState":"permissive-MovementAllowed","timing":{"minEndTime":34675,"maxEndTime":35244}}]}

- Several seconds later, two different scenarios may occur. In the first scenario, the TSC infrastructure does not detect any more demand for the left turn, so the TSC infrastructure decides to terminate the permissive left at 34675 deci-seconds after the top of the hours and the next movement interval will be a clearance interval of 4 seconds (SY (Steady Yellow) in Figure 17). So, the SPaT message for this movement is now:

{"signalGroup":2,"state-time-speed":[{"eventState":"permissive-MovementAllowed","timing":{"minEndTime":34675,"maxEndTime":34675}},{"eventState":"permissive-clearance","timing":{"startTime":34675,"minEndTime":34715,"maxEndTime":34715}}]}

- However, in the second scenario, if the TSC infrastructure detects additional demand for the left turn, the TSC infrastructure may decide the next movement interval is a minimum 6-second protected left turn (G (Green) in Figure 17) with a maximum 24-second duration, in which case the SPaT message for this movement is:

{"signalGroup":2,"state-time-speed":[{"eventState":"permissive-MovementAllowed","timing":{"minEndTime":34675,"maxEndTime":34675}},{"eventState":"protected MovementAllowed,""timing":{"startTime":34675,"minEndTime":34735,"maxEndTime":34915}}]}

Need ID:	2.4.3.3.4	**Need Title:**	Next Movement State

Description:
A connected intersection needs to provide information about the next state of each movement at the intersection so an application can provide the proper warnings, information, or guidance to the driver or VRU. The next state identifies if the next signal interval for a maneuver through an intersection will be allowed and any restrictions after a change. For example, the current state may indicate a protected or permissive movement, but the next state indicates when the current state changes, if the maneuver will change to a protected or permissive movement, or a clearance (e.g., yellow indication) interval will be in effect

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
This requirement is verified through assessing data elements within the timeChangeDetails data frame for subsequent movementEvents for a signal group in SPaT messages. The requirement is considered met if the startTime of the next signal state is specified when the minEndTime is equal to the maxEndTime for the current phase. The minEndTime of the next signalState must be greater than the startTime, and the maxEndTime must be greater than or equal to the minEndTime.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**	

Notes:
If this condition is noted during data collection, then this requirement can be tested. However, if this condition is not noted, then this requirement cannot be verified. Due to traffic signal controller limitations, information regarding the next movement is not expected to be found in SPaT messages

Table 79. Test Case 3.3.3.3.4.2

Requirement ID:	3.3.3.3.4.2	**Requirement Title:**	xt Movement State
Description: In a situation where a connected intersection cannot determine the next movement state, a connected intersection shall use unavailable as the next movement state for a signal group, as defined by DE_MovementPhaseState in SAE J2735_202007.			
Design Detail: MSG_SignalPhaseAndTiming Message provides a data frame, DF_MovementEventList, that contains 1 to 16 entries for the same movement at an intersection. Each entry (represented by DF_MovementEvent) represents a movement state for that movement over a period of time. • The first entry describes the current movement state (i.e., DE_MovementPhaseState) and the time change details for the current movement (minEndTime, maxEndTime, and nextTime (if known)) • The second entry describes the movement state immediately after the current movement state terminates; and the start, minimum end, and maximum end times for the next movement state If the next movement state, as represented by DE_MovementPhaseState, is unknown, a second entry for the movement (DF_MovementEvent) shall be sent in DF_MovementEventList as unknown. For example, in Figure 17, lane #1 is tied to signal group #2 and currently a permissive left turn. The minimum end time for signal group 2 is currently 34675 deciseconds and the maximum end time is 35244 deciseconds from the top of the hour. At this point in time, the TSC infrastructure has not determined if the next movement state is a clearance interval or a protected left turn. So, the SPaT message for this movement would be the following: {"signalGroup":2,"state-time-speed":[{"eventState":"permissive-MovementAllowed","timing":{"minEndTime":34675,"maxEndTime":35244}}]}			
Need ID:	2.4.3.3.4	**Need Title:**	Next Movement State
Description: A connected intersection needs to provide information about the next state of each movement at the intersection so an application can provide the proper warnings, information, or guidance to the driver or VRU. The next state identifies if the next signal interval for a maneuver through an intersection will be allowed and any restrictions after a change. For example, the current state may indicate a protected or permissive movement, but the next state indicates when the current state changes, if the maneuver will change to a protected or permissive movement, or a clearance (e.g., yellow indication) interval will be in effect			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: Evaluated by looking at all SPaT movement state details over an extended period from each RSU in pcap file. Requirement is considered to be met if the next movement state is specified for a signalGroup and all required data elements in the timeChangeDetails data frame are within the allowable range for normal times, and 36111 for unknown.								

System Input(s):					
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**	
Notes:					

Table 80. Test Case 3.3.3.3.4.3

Requirement ID:	3.3.3.3.4.3	**Requirement Title:**	No Past State
Description: A connected intersection shall not provide the state or timing for intervals that are already completed.			
Design Detail: No design details provided at this time			
Need ID:	2.4.3.3.4	**Need Title:**	Next Movement State
Description: A connected intersection needs to provide information about the next state of each movement at the intersection so an application can provide the proper warnings, information, or guidance to the driver or VRU. The next state identifies if the next signal interval for a maneuver through an intersection will be allowed and any restrictions after a change. For example, the current state may indicate a protected or permissive movement, but the next state indicates when the current state changes, if the maneuver will change to a protected or permissive movement, or a clearance (e.g., yellow indication) interval will be in effect			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: This requirement is verified through assessing data elements within the timeChangeDetails data frame in SPaT messages. None of the timemarks should indicate a time that is prior to the current message time (if available).								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 81. Test Case 3.3.3.3.5.1

Requirement ID:	3.3.3.3.5.1	**Requirement Title:**	Time Change Details
Description: A connected intersection shall provide time change details for each signal group identified in the MAP message.			
Design Detail: The details on when the current movement state of a movement through an intersection will change is represented as timing (DF_TimeChangeDetails) and found under data frame DF_MovementEvent in MSG_SignalPhaseAndTiming Message in SAE J2735_202007. Each movement is tied to an identifier called the signalGroup (DE_SignalGroupID), which represents a collection of movements of a common type through the intersection. Note, the signalGroup identifier is not necessarily equal to the phase number. For example, overlaps movements also have to be assigned a signalGroup identifier.			
Need ID:	2.4.3.3.5	**Need Title:**	Time Change Details
Description: A connected intersection needs to provide information about when the current signal interval (state) for each movement, including a pedestrian interval (state), at the intersection will change so an application can provide the proper warnings, information or guidance to the driver or VRU. The information provided must be accurate under all conditions such as during TSP (transit signal priority) and EVP (emergency vehicle preemption). The need includes the following operational scenarios: 2.6.2.1 - Rest in Green.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: This requirement is verified through assessing data elements within the timeChangeDetails data frame for subsequent movementEvents for a signal group in SPaT messages. All required data elements should be specified to satisfy this requirement.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 82. Test Case 3.3.3.3.5.3

Requirement ID:	3.3.3.3.5.3	**Requirement Title:**	Minimum End Time
Description: A connected intersection shall provide the soonest time, in tenths of a second in the current or next hour, that the current and any future interval in the SPaT message for a signal group could end in the absence of unpredicted events such as preemption or priority calls.			
Design Detail: The earliest time that the current and any future interval could end is represented by minEndTime (DE_TimeMark), found under the data frame DF_TimeChangeDetails in MSG_SignalPhaseAndTiming Message in SAE J2735_202007. The earliest time that a green interval could end may be constrained by the minimum green time setting, pedestrian WALK and flashing DON'T WALK times, coordination holds, or vehicle extensions. Yellow interval durations are generally fixed. The earliest time does not consider that the interval could abruptly change due to unpredictable events such as signal preemptions, or failures such as a watchdog failure or a conflict monitor			
Need ID:	2.4.3.3.5	**Need Title:**	Time Change Details
Description: A connected intersection needs to provide information about when the current signal interval (state) for each movement, including a pedestrian interval (state), at the intersection will change so an application can provide the proper warnings, information or guidance to the driver or VRU. The information provided must be accurate under all conditions such as during TSP (transit signal priority) and EVP (emergency vehicle preemption). The need includes the following operational scenarios: 2.6.2.1 - Rest in Green.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
This requirement is verified through assessing data elements within the timeChangeDetails data frame in SPaT messages. Specifically, in the absence of operational interruptions, the minEndTime shall not decrease in a given cycle. Yellow Intervals should be constant in length (i.e. minEndTime should not change during the yellow interval) and should be consistent in overall duration within a signal group from one cycle to the next.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**	

Notes:

Table 83. Test Case 3.3.3.3.5.4

Requirement ID:	3.3.3.3.5.4	**Requirement Title:**	Maximum End Time
Description: A connected intersection shall provide the latest time, in tenths of a second in the current or next hour, that the current and any future interval could end in the absence of unpredictable events such as preemption or priority calls.			
Design Detail: The latest time that the current and any future interval could end is represented by maxEndTime (DE_TimeMark), found under the data frame DF_TimeChangeDetails in MSG_SignalPhaseAndTiming Message in SAE J2735_202007. The latest time that an interval could end may be constrained by the maximum green time settings or coordination force-offs. When the interval duration is fixed, such as when the TSC infrastructure is operating in fixed time or the yellow interval duration, the minimum end time will equal the maximum end time.			
Need ID:	2.4.3.3.5	**Need Title:**	Time Change Details
Description: A connected intersection needs to provide information about when the current signal interval (state) for each movement, including a pedestrian interval (state), at the intersection will change so an application can provide the proper warnings, information or guidance to the driver or VRU. The information provided must be accurate under all conditions such as during TSP (transit signal priority) and EVP (emergency vehicle preemption). The need includes the following operational scenarios: 2.6.2.1 - Rest in Green.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: This requirement is verified through assessing data elements within the timeChangeDetails data frame in SPaT messages. Specifically, in the absence of operational interruptions, the maxEndTime shall not increase in a given cycle. Yellow Intervals should be constant in length (i.e. maxEndTime should not change during the yellow interval) and should be consistent in overall duration within a signal group from one cycle to the next.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 84. Test Case 3.3.3.3.5.5

Requirement ID:	3.3.3.3.5.5	**Requirement Title:**	Unknown Maximum End Time
Description: In a situation where a connected intersection cannot determine a latest end time, a connected intersection shall use a value of unknown, as defined by DE_TimeMark in SAE J2735_202007. NOTE: The value of DE_TimeMark indicating undefined changed from a value of 36001 in SAE J2735_201603 to a value of 36111 in SAE J2735_202007.			
Design Detail: See Section 4.3.3.3.5.2.			
Need ID:	2.4.3.3.5	**Need Title:**	Time Change Details
Description: A connected intersection needs to provide information about when the current signal interval (state) for each movement, including a pedestrian interval (state), at the intersection will change so an application can provide the proper warnings, information or guidance to the driver or VRU. The information provided must be accurate under all conditions such as during TSP (transit signal priority) and EVP (emergency vehicle preemption). The need includes the following operational scenarios: 2.6.2.1 - Rest in Green.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: Evaluated by looking at all SPaT mandatory time change details over an extended period from each RSU in pcap file. Requirement is considered to be met if all values are within the allowable range for normal times, and 36111 for unknown.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes: Given that testing will not occur during when a leap second is expected to be observed, leap seconds will not be specifically evaluated - values in this range should not be observed.								

Table 85. Test Case 3.3.3.3.5.6

Requirement ID:	3.3.3.3.5.6	Requirement Title:	No Current Movement State Start Time
Description: A connected intersection shall not provide the start time of the current movement state. Note: this prohibited time mark would be a past time and is not needed for RLVW. Prohibiting this data element for currently timing intervals removes any ambiguity as to whether start time is intended as a past time or a future time.			
Design Detail: No design details provided at this time.			
Need ID:	2.4.3.3.5	**Need Title:**	Time Change Details
Description: A connected intersection needs to provide information about when the current signal interval (state) for each movement, including a pedestrian interval (state), at the intersection will change so an application can provide the proper warnings, information or guidance to the driver or VRU. The information provided must be accurate under all conditions such as during TSP (transit signal priority) and EVP (emergency vehicle preemption). The need includes the following operational scenarios: 2.6.2.1 - Rest in Green.			

Verification Method	Demonstration	Test	Analyze	Inspection	Other			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: See verification related to 3.3.3.3.4.3								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 86. Test Case 3.3.3.3.5.7

Requirement ID:	3.3.3.3.5.7	**Requirement Title:**	Next Movement State Start Time
Description: A connected intersection shall provide the start time, in tenths of a second in the current or next hour, of the next (future) movement state to follow the current movement state for a signal group. Note: this is a future time.			
Design Detail: MSG_SignalPhaseAndTiming Message provides a data frame, DF_MovementEventList, that contains 1 to 16 entries for the same movement at an intersection. Each entry (represented by DF_MovementEvent) represents a movement state for that movement over a period of time. The first entry describes the current movement state (i.e., DE_MovementPhaseState) and the time change details for the current movement (minEndTime, maxEndTime, and nextTime (if known)). The second entry describes the movement state immediately after the current movement state terminates; and the start, minimum end, and maximum end times for the next movement state. If the next movement state, as represented by DE_MovementPhaseState, is known with a high level of confidence, a second entry for the movement shall be included in the SPaT message. The start time for the next movement state, represented by startTime (DE_TimeMark) and found under the data frame DF_TimeChangeDetails in MSG_SignalPhaseAndTiming Message in SAE J2735_202007, shall also be included in the second entry, even if the value is unknown. Note that the minEndTime and maxEndTime for the second entry shall also be included in the second entry, even if the value is unknown. If the next movement state, as represented by DE_MovementPhaseState, is unknown (or known but not with a high level of confidence), a second entry for the movement (DF_MovementEvent) shall not be sent in DF_MovementEventList. This CI Implementation Guide references the July 2020 version of SAE J2735 (SAE J2735_202007). The March 2016 version of SAE J2735 (SAE J2735_201603) uses a value of 36001 to represent unknown. The change was made to DE_TimeMark in the July 2020 version to properly address leap seconds. See the example in Section 4.3.3.3.4.1, Next Movement State.			
Need ID:	2.4.3.3.5	**Need Title:**	Time Change Details
Description: A connected intersection needs to provide information about when the current signal interval (state) for each movement, including a pedestrian interval (state), at the intersection will change so an application can provide the proper warnings, information or guidance to the driver or VRU. The information provided must be accurate under all conditions such as during TSP (transit signal priority) and EVP (emergency vehicle preemption). The need includes the following operational scenarios: 2.6.2.1 - Rest in Green.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
	Stationary	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**

Data Collection Type	x			x				

Evaluation Methodology:
This requirement is verified through assessing the timemarks in the timeChangeDetails for subsequent movementEvents for a signal group in SPaT messages. If the minEndTime and maxEndTime are equal for the current phase, a movementEvent for a subsequent phase is expected to be included in the MovementEventList, as the change is known with a high degree of confidence. The startTime of this subsequent event should be provided.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**	

Notes:
If this condition is noted during data collection, then this requirement can be tested. However, if this condition is not noted, then this requirement cannot be verified. Due to traffic signal controller limitations, information regarding the next movement (i.e., multiple movementEvents) is not expected to be found in SPaT messages - even if that state is not known

Table 87. Test Case 3.3.3.3.5.8

Requirement ID:	3.3.3.3.5.8	**Requirement Title:**	Next State Start Time Equals Current State Minimum End Time
Description: A connected intersection shall provide a start time for the next (future) movement state that is the same as the soonest time the current movement state could end.			
Design Detail: If the TSC infrastructure knows the next movement state, the start time of the next movement state, represented by startTime (DE_TimeMark) in the second entry of data frame DF_MovementEventList, shall be the same time point as the minimum end time of the current movement state, as represented by minEndTime (DE_TimeMark) in the first entry of data frame, DF_MovementEventList. If the next movement state is unknown, a second entry for the movement (DF_MovementEvent) shall not be sent in DF_MovementEventList and this entry is not applicable.			
Need ID:	2.4.3.3.5	**Need Title:**	Time Change Details
Description: A connected intersection needs to provide information about when the current signal interval (state) for each movement, including a pedestrian interval (state), at the intersection will change so an application can provide the proper warnings, information or guidance to the driver or VRU. The information provided must be accurate under all conditions such as during TSP (transit signal priority) and EVP (emergency vehicle preemption). The need includes the following operational scenarios: 2.6.2.1 - Rest in Green.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: This requirement is verified through assessing the timemarks in the timeChangeDetails for subsequent movementEvents for a signal group in SPaT messages. The startTime for the proceeding state shall be equal to the minEndTime of the current state. If proceeding movement state is not provided, it is assumed that it is unknown, and the requirement is not applicable.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes: If this condition is noted during data collection, then this requirement can be tested. However, if this condition is not noted, then this requirement cannot be verified. Due to traffic signal controller limitations, information regarding the next movement (i.e., multiple movementEvents) is not expected to be found in SPaT messages - even if that state is not known								

Table 88. Test Case 3.3.3.3.6.1

Requirement ID:	3.3.3.3.6.1	**Requirement Title:**	Time of Next Allowed Movement
Description: A connected intersection shall provide the estimated time, in tenths of a second in the current or next hour, that the current movement will next be in the permissive-Movement-Allowed or protectedMovement-Allowed (green) state in the absence of unpredictable events such as preemption or priority calls.			
Design Detail: The next time that the current movement is allowed to move is represented by nextTime (DE_TimeMark), found under the data frame DF_TimeChangeDetails in MSG_SignalPhaseAndTiming Message in SAE J2735_202007. A movement is "allowed to move" when the signal indication for that movement is green or a flashing yellow arrow for a vehicle movement; or a "WALK" signal for a pedestrian movement; or, more precisely, the movement state, as represented by DE_MovementPhaseState, is permissiveMovement-Allowed or protected-Movement-Allowed. Next time may be used by ECO (environmental) applications on an OBU/MU to determine when the vehicle or pedestrian is estimated to be allowed to move again. This may affect if a driver is advised to travel faster or slower to improve overall fuel consumption. For fixed time and coordinated signals (and possibly others), next time can be estimated by the TSC infrastructure, subject to unpredictable events such as signal preemptions, or failures such as a watchdog failure or a conflict monitor. If next time cannot be estimated with a high level of confidence, a value of unknown is used, represented by a value of 36111 for DE_TimeMark. Otherwise, a nextTime other than unknown is provided and only in the first entry (DF_MovementEvent) of DF_MovementEventList, which represents the current movement state. If the next time is unknown (or known but not with a high level of confidence), nextTime shall not be sent in DF_MovementEvent. CTI 4501 v1.00 CI Implementation Guide Page 152 Note: The value of DE_TimeMark indicating undefined or unknown changed from a value of 36001 in SAE J2735_201603 to a value of 36111 in SAE J2735_202007. For example, Figure 18 is a mid-block pedestrian crossing with a pedestrian pushbutton for the cross walk. The signal indication for the vehicle movement (signal group 1) is currently green with a minimum end time of 34675 deciseconds and the maximum end time is 35244 deciseconds from the top of the hour. At this point in time, the TSC infrastructure does not know when the movement will end, so it does not know the next time the movement will be allowed again. So, the SPaT message for this movement would be the following: {"signalGroup":1,"state-time-speed":[{"eventState":"protected-MovementAllowed","timing":{"minEndTime":34675,"maxEndTime":35244}}]} Several seconds later, a pedestrian depresses the pushbutton and the TSC infrastructure decides to terminate the green at 34675 deciseconds after the top of the hour, with a clearance interval of 4 seconds. The pedestrian WALK plus flashing DON'T WALK time is 26 seconds. The next time is now known to be 34975 deciseconds after the top of the hour. So, the SPaT message for this movement is now the following: {"signalGroup":1,"state-time-speed":[{"eventState":"protected-MovementAllowed,""timing":{"minEndTime":34675,"maxEndTime":34675,"nextTime":34975}},{"even tState":"protectedclearance,""timing":{"startTime":34675,"minEndTime":34715,"maxEndTime":34715}}]}			
Need ID:	2.4.3.3.6	**Need Title:**	Next Allowed Movement Time
Description: A connected intersection needs to provide the estimated time when each movement at an intersection is next allowed to proceed (e.g., green or flashing yellow), excluding unexpected events such as a preemption request. This feature allows an application to provide information or guidance to a driver or VRU. The next allowed-to-move information partially satisfies the needs of an eco-driving application. The next allowed-to-move information also helps an OBU/MU determine whether a permissive turn movement will change directly to a protected movement, will change to a protected movement after a clearance interval, or will change to a stop condition after a clearance interval.			

Verification Method	Demonstration	Test	Analyze	Inspection	Other			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
This requirement is verified through assessing data elements within the timeChangeDetails data frame for subsequent movementEvents for a signal group in SPaT messages. The requirement is considered met if the minEndTime is equal to the maxEndTime for all signal states including the current signal state and any other signal states that occur between the current signal state and the (green) signal state of interest.

System Input(s):

Supported Sites	GDOT	ODOT	UDOT	Other	

Notes:

Table 89. Test Case 3.3.3.3.7

Requirement ID:	3.3.3.3.7	**Requirement Title:**	Enabled Lanes Indication
Description: If the MAP message for the intersection includes lanes indicated as being revocable lanes, a connected intersection shall identify which revocable lanes are currently enabled.			
Design Detail: Active ('enabled') revocable lanes for an intersection are represented by the lane identifier (DE_LaneId) in enabledLanes (DF_EnabledLaneList), found under data frame DF_IntersectionState in MSG_SignalPhaseAndTiming Message as defined in SAE J2735_202007. This requirement is conditional, if the intersection does not have a revocable lane defined in the MAP message for the same intersection (See 4.3.3.4.6, Revocable Lanes), OR no revocable lane is currently active ('enabled') then the data frame DF_EnabledLaneList is not transmitted in the SPaT message. However, if the MAP message for the intersection defines a revocable lane for the intersection AND a revocable lane is currently active ('enabled'), then the data frame DF_EnabledList shall be transmitted as part of the SPaT message for the intersection. This is an example: CTI 4501 v1.00 CI Implementation Guide Page 153 {"messageId":19,"value":{"intersections":[{"id":{"id":173},"revision":89,"status":"0000","mo y":19230,"timeStamp":45484,"states":[{"signalGroup":2,"state-timespeed":[{"eventState":"protected- MovementAllowed","timing":{"minEndTime":34654,"maxEndTime":35244}}]},{"signalGroup":4,"statetime- speed":[{"eventState":"stop-AndRemain","timing":{"minEndTime":34711,"maxEndTime":35301}}]}]}]}} {"messageId":19,"value":{"intersections":[{"id":{"id":173},"revision":89,"status":"0000","mo y":19230,"timeStamp":45484,"enabledLanes":5,["states":[{"signalGroup":2,"state- timespeed":[{"eventState":"protected- MovementAllowed","timing":{"minEndTime":34654,"maxEndTime":35244}}]},{"signalGroup":4,"statetime- speed":[{"eventState":"stop-AndRemain","timing":{"minEndTime":34711,"maxEndTime":35301}}]}]}]}} An implementation should provide a check that a SPaT message does not assert mutually exclusive enabled lanes simultaneously. Note: NTCIP 1202 v03A defines a table, spatEnabledLanesConcurrencyTable, which indicates which lanes may be active concurrently and serves as a check that mutually exclusive enabled lanes are not enabled simultaneously			
Need ID:	2.4.3.3.7	**Need Title:**	Enabled Lanes
Description: A connected intersection needs to provide information about which revocable lanes are currently enabled so an application can determine what movements are currently allowed at an intersection. An IOO may define the same physical lane for different uses or with different restrictions depending on the time of day or on specific days. For example, a lane may be defined as an HOV lane during the morning rush hours, a reversible lane for special events (such as at an arena), and as a normal vehicle lane during all other times. This feature allows the connected intersection to indicate what restrictions are in effect.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
This requirement is verified through assessing MAP messages to determine which lanes are enabledLanes. The SPaT message is then assessed to ensure that those lanes are included in the enabledlanes list as appropriate to accurately reflect ground conditions.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**	

Notes:
This requirement is only applicable to intersections that exhibit enabled lanes. There is no guarantee that all conditions that are associated with each enabled lane will be exhibited during the data collection period - though an effort will be made to observe each condition.

Table 90. Test Case 3.3.3.3.8

Requirement ID:	3.3.3.3.8	**Requirement Title:**	SPaT Message - Accuracy
Description: A connected intersection shall broadcast SPaT messages that accurately reflect the physical signal indications at the intersection.			
Design Detail: No design details provided at this time			
Need ID:	2.4.3.3.8	**Need Title:**	Signal Timing and Roadway Indications Synchronization
Description: A connected intersection needs to provide signal timing data that is synchronized with signal indication changes on the roadway within a defined tolerance. For safety and effectiveness, applications require consistency between the perceived state of the intersection by road users and the signal timing data received by the applications on an OBU/MU. Synchronization enables applications to safely and effectively provide services to road users. For example, the duration of a signal interval may be influenced by external processes. There are configurations when an external process, such as cabinet relays or a separate system controlling the active timing intervals (e.g., hold/force off/stop time), is being used for either supervisory control over the traffic controller timing or post processing of controller outputs. In these cases, the traffic controller may have limited information thereby limiting the ability to predict the future state of the intersection and therefore cannot provide accurate signal interval duration information. For these cases, the source of the signal interval duration data should be the separate system.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x		X	x		X		
Evaluation Methodology: This requirement is verified through simultaneous capture of a test tool and the signal head at an intersection. See Appendix X - Latency Measurement Methodology.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 91. Test Case 3.3.3.4.1.1

Requirement ID:	3.3.3.4.1.1	**Requirement Title:**	Intersection Geometry Information
Description: A connected intersection shall provide travel lane information for one or more intersections			
Design Detail: See intersections (DF_IntersectionGeometryList) for MSG_MapData in SAE J2735_202007			
Need ID:	2.4.3.4.1	**Need Title:**	Intersection Geometry
Description: A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop lines, crosswalks and landing geometry of the intersection.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: This requirement is consider satisfied if there is at least one intersection geometry in each MAP message.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes: GK - Observation/question: what is the ground truth for geometry and MAP data? Do they get evaluated with respect to survey data and/or independently calculated values?								

Table 92. Test Case 3.3.3.4.1.2

Requirement ID:	3.3.3.4.1.2	**Requirement Title:**	Intersection Geometry - Road Regulator Identifier
Description: As part of the roadway geometry information, a connected intersection shall provide a road regulator identifier unique within North America.			
Design Detail: The road regulator identifier is represented as region (DE_RoadRegulatorID) and found under the data frame DF_IntersectionReferenceID in the MSG_MapData message in SAE J2735_202007. See Section 4.3.3.3.1.2, Road Regulator Identifier, for a discussion on how road regulator identifiers may be assigned. A comment to the SAE Technical Committee responsible for maintaining SAE J2735_202007. The comment can be found in Annex H.1.5, DE_RoadRegulatorID.			
Need ID:	2.4.3.4.1	**Need Title:**	Intersection Geometry
Description: A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop lines, crosswalks and landing geometry of the intersection.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: This requirement is considered to be met given the presence of the roadRegulatorId data element in the SPaT and MAP messages, and it is the same between all intersections within each test site (unless multiple jurisdictions are involved, where the roadRegulator Id is expected to be the same at intersection with each jurisdiction).								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes: It is unknown if there are other sites that will be broadcasting the same roadRegulatorId, so this will not be thoroughly tested. To pass, all jurdisdictions at all test sites must have different roadRegulatorIds.								

Table 93. Test Case 3.3.3.4.1.3

Requirement ID:	3.3.3.4.1.3	**Requirement Title:**	Intersection Geometry - Intersection Identifier
Description: As part of the roadway geometry information, a connected intersection shall provide an intersection reference identifier unique to a road regulator identifier.			
Design Detail:			
Need ID:	2.4.3.4.1	**Need Title:**	Intersection Geometry
Description: A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop lines, crosswalks and landing geometry of the intersection.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: This requirement is considered to be met given the presence of the intersectionId data element in the SPaT and MAP messages, and its value is different between all intersections within each test site (unless multiple jurisdictions are involved, where the intersectionId is expected to be different at intersections with each jurisdiction.). Furthermore, the intersectionId should be the same at each intersection at each jurisdiction for both SPaT and MAP messages. The intersection MAC address will need to be used to make sure SPaT and MAP (with the same IntersectionId) are being broadcast from the same intersection.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 94. Test Case 3.3.3.4.1.4.1

Requirement ID:	3.3.3.4.1.4.1	**Requirement Title:**	Intersection Reference Point - Position
Description: A connection intersection shall select an intersection reference point located close enough to the first node point of all lanes associated with the intersection such that the offset can be represented using the DE_Offset_B16 in SAE J2735_202007 (327.67 meters).			
Design Detail: Although the requirement states that the first node point should be within 327.67 meters of the intersection reference point, the preference is that the selected intersection reference point should be located such that the first node point of all lanes associated with the intersection can be represented by DE_Offset_B13 (within 40.95 meters) to allow the vehicle application to properly identify the intersection that is relevant as opposed to the other intersections that are in close proximity within the RF range. It is customary and preferred to select a point in the middle of the intersection "crash box" or conflict area as the intersection reference point. The intersection "crash box" is defined as the inside of the crosswalk markings (or stop lines) along the outside boundary of the intersection; or between the first node of all the lanes that ingress and egress the intersection (i.e., does not include internal storage lanes). However, the intersection reference point shall be referenced to a surveyed point, i.e., the x-, y- axis offset between the intersection reference point and a surveyed point shall be known. While it is preferred that the surveyed point be in the middle of the intersection conflict area, it is not always practical. A surveyed point can be outside the intersection conflict area, for example, signal controller cabinet or a light pole; but it shall be at the same elevation as the intersection conflict area or the z- axis offset shall be known. In such a case, an intersection reference point inside the intersection conflict area can be computed using X and Y offset distance in centimeters from the surveyed point. Figure 19 and Figure 20 illustrates three different scenarios whe re the following occur: 1) The surveyed point is inside the intersection as the reference point, such as a manhole, 2) The surveyed point is outside the intersection at the traffic signal controller, and 3) The surveyed point at the signal controller is outside the two intersections in proximity. It is required that the surveyed point is within 0.2 meter radial accuracy and the intersection reference point computed from the surveyed point is also within 0.2 meter accuracy.			
Need ID:	2.4.3.4.1	**Need Title:**	Intersection Geometry
Description: A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop lines, crosswalks and landing geometry of the intersection.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: This requirement is verified by inspection of the first offset point of every lane. The requirement is considered satisfied in the x and y offsets are represented using an offset of type Offset_B16 (or lower).								

System Input(s):					
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**	
Notes:					

Table 95. Test Case 3.3.3.4.1.4.2

Requirement ID:	3.3.3.4.1.4.2	**Requirement Title:**	Intersection Reference Point - Description
Description: A connected intersection shall provide the following information regarding an intersection reference point. a) Latitude, in 1/10th microdegrees, as defined by DE_Latitude in SAE J2735_202007 b) Longitude, in 1/10th microdegrees, as defined by DE_Longitude in SAE J2735_202007 c) Elevation in 10 centimeter units as defined by DE_Elevation in SAE J2735_202007			
Design Detail: An intersection's reference point is represented as refpoint (DF_Position3D) and found under the data frame DF_IntersectionGeometry in MSG_MapData message in SAE J2735_202007. DF_Position3D consists of three data elements to represent the position. Latitude is represented as lat (DE_Latitude), longitude is represented as long (DE_Longitude), and elevation is represented as elevation (DE_Elevation) in DF_Position3D. The reference ellipsoid for DE_Elevation is WGS-84. Unlike SAE J2735_202007, elevation is a mandatory element to conform with the CI Implementation Guide.			
Need ID:	2.4.3.4.1	**Need Title:**	Intersection Geometry
Description: A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop lines, crosswalks and landing geometry of the intersection.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: This requirement is verified by inspection of the latitude, longitude, and elevation data elements contained in the refPoint data frame, and is considered met if all three values are present and are in the correct range.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 96. Test Case 3.3.3.4.1.4.3

Requirement ID:	3.3.3.4.1.4.3	**Requirement Title:**	Intersection Reference Point Accuracy
Description: A connected intersection shall provide an intersection reference point whose total accuracy is within +/- 0.2 meters of ground truth.			
Design Detail: The circular error of the intersection reference point location must not exceed 0.2 meters from the true location. Because the intersection maps for connected intersections are generated using surveyed points that are aligned with the WGS 84 datum, drift of the underlying continental plate will move the intersection away from the GNSS locations of the originally surveyed node points. The North American Plate moves generally in a southwest direction at a speed of around 2.3 centimeters per year. This would mean that a node that is surveyed with centimeter accuracy could move out of that accuracy requirement within between 10 years at the most and likely sooner. Parts of the United States also are located on the Pacific Plate, which in California moves about 5 centimeters per year to the northwest. This means that intersections west of the San Andreas Fault might have to be re-mapped more often than in other places in the country. If the local plate movement vector is known, the MAP data could be corrected periodically and/or the intersections could be resurveyed every couple of years. By using offsets for the lane nodes, rather than absolute latitude and longitude, as required in this CI guidance, the entire intersection geometry can be CTI 4501 v1.00 CI Implementation Guide Page 156 corrected by simply correcting the reference point. All the other points then move to keep the same relative location from the reference point.			
Need ID:	2.4.3.4.1	**Need Title:**	Intersection Geometry
Description: A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop lines, crosswalks and landing geometry of the intersection.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: This requirement is considered satisfied if verification for 3.3.3.4.1.4.1 is met.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				

Notes:
The intersection reference point is somewhat arbitrary. Unless the managing agency has defined where this point is supposed to be and it is measurable, verification for this requirement will be contingent upon the verification of requirement of 3.3.3.4.1.4.1

Table 97. Test Case 3.3.3.4.1.5

Requirement ID:	3.3.3.4.1.5	**Requirement Title:**	Default Lane Width
Description: A connected intersection shall provide the default lane width, in centimeters, for all lanes associated with the intersection.			
Design Detail: An intersection's default lane width is represented as laneWidth (DE_LaneWidth) and found under the data frame DF_IntersectionGeometry in MSG_MapData message in SAE J2735_202007. All lanes associated with the intersection are assumed to be the default lane width unless otherwise indicated (See 4.3.3.4.1.22, Node Lane Width). Lane widths are represented in centimeter units.			
Need ID:	2.4.3.4.1	**Need Title:**	Intersection Geometry
Description: A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop lines, crosswalks and landing geometry of the intersection.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x			x	
Evaluation Methodology: This requirement is verified by inspection of the laneWidth data element and is considered met if the laneWidth data element is present and in the correct range.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 98. Test Case 3.3.3.4.1.6

Requirement ID:	3.3.3.4.1.6	**Requirement Title:**	Lane Identifier
Description: A connected intersection shall assign a lane identifier unique within the intersection for each lane at the intersection, as defined by DE_LaneID in SAE J2735_202007.			
Design Detail: Each lane associated with an intersection is assigned a unique lane identifier within that intersection. The lane identifier is represented as laneID (DE_LaneId) and found under the data frame DF_GenericLane for intersections in MSG_MapData message in SAE J2735_202007. The CI Committee considered several schemes for assigning lane identifiers for an intersection, but how each lane is assigned an identifier is inconsequential to an application on an OBU/MU, although there is a preference that the assignment scheme be consistent. Schemes that have been used include assigning the first identifier for an approach to the leftmost lane and assigning odd numbers to ingress lanes and even numbers to egress lanes, which work very well for roundabouts.			
Need ID:	2.4.3.4.1	**Need Title:**	Intersection Geometry
Description: A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop lines, crosswalks and landing geometry of the intersection.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: This requirement is verified by inspection of the laneID data element in all genericLane data frames, and is considered met if all laneId values are unique and in the correct range.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes: Methods for assigning LaneIds will not be evaluated.x								

Table 99. Test Case 3.3.3.4.1.7

Requirement ID:	3.3.3.4.1.7	**Requirement Title:**	Center of Vehicle Lane Geometry
Description: A connected intersection shall describe the geometry of the center of each vehicle lane approaching (ingress), departing (egress) and internal to (storage) the intersection.			
Design Detail: Each lane associated with an intersection is represented by node points that are located along the centerline of the lane. Each node point consists of an XY offset from a preceding node point, or the intersection's reference point. For the connected intersections, absolute positions (i.e., latitude, longitude points) are not permitted. Read the guidance in Sections 4.3.3.4.1.11, First Node Point - Ingress Vehicle Lane Design Details to 4.3.3.4.1.23, Node Accuracy, for additional details. For a two-way road without lane striping and permitted parking, such as a residential street, it is recommended that two overlapping lanes be defined, one in each direction. Each lane should include the "parking" lane in case there are no parked cars to indicate that "area" where cars could be parked can be used for travel. Each lane should also include the area that a vehicle can normally travel, even if it overlaps with a travel lane in the opposite direction, as shown in Figure 21. In Figure 21, the width of lane 1 (an ingress lane) is from the sidewalk curb to a distance away from the opposite sidewalk curb, shown as a dashed line, to allow for parking on the opposite side. The width of lane 2 (an egress lane), is from the sidewalk curb on the right side to a distance away from the opposite sidewalk curb, also shown as a dashed line, to allow for parking on the opposite side. The area between the dashed lines represents an overlap of two lanes, lane 1 and lane 2. This overlapping of two lanes is represented by asserting bit 0 in sharedWith (DE_LaneSharing), which can be found under the data frame DF_LaneTypeAttributes in the MSG_MapData message in SAE J2735_202007, to indicate overlapping lanes. See 4.3.3.4.2.2, Lane Sharing			
Need ID:	2.4.3.4.1	**Need Title:**	Intersection Geometry
Description: A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop lines, crosswalks and landing geometry of the intersection.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x			x	
Evaluation Methodology: This requirement is verified by inspection of the MAP message data. The MAP message data is visualized and compared against a visual ground survey of lanes to ensure all lanes are accounted for and properly specified (ingress, egress).								
System Input(s):								

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:

Table 100. Test Case 3.3.3.4.1.8

Requirement ID:	3.3.3.4.1.8	**Requirement Title:**	Center of Crosswalk Lane Geometry
Description: A connected intersection shall describe the geometry of the center of each crosswalk lane at the intersection.			
Design Detail: Each crosswalk (lane) associated with an intersection is represented by node points that are located along the centerline of the crosswalk. Each node point consists of an XY offset from a preceding node point, or the intersection's reference point. For the connected intersections, absolute positions (i.e., latitude, longitude points) is not permitted. Read the guidance in Sections 4.3.3.4.1.13 to 4.3.3.4.1.16, 4.3.3.4.1.18, and 4.3.3.4.1.20 to 4.3.3.4.1.23, for additional details.			
Need ID:	2.4.3.4.1	**Need Title:**	Intersection Geometry
Description: A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop lines, crosswalks and landing geometry of the intersection.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x			x	
Evaluation Methodology: This requirement is verified by inspection of the MAP message data. The MAP message data is visualized and compared against a visual ground survey of crosswalks to ensure they are accounted for.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes: A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop lines, crosswalks and landing geometry of the intersection.								

Table 101. Test Case 3.3.3.4.1.9

Requirement ID:	3.3.3.4.1.9	**Requirement Title:**	Center of Pedestrian Landings Geometry
Description: A connected intersection shall describe the geometry of the center of each pedestrian landing at the intersection.			
Design Detail: Each pedestrian landing associated with an intersection is represented by node points that are located along the centerline of the landing. Each node point consists of an XY offset from a preceding node point, or the intersection's reference point. For the connected intersections, absolute positions (i.e., latitude, longitude points) is not permitted. Read the guidance in Sections 4.3.3.4.1.10, 4.3.3.4.1.13 to 4.3.3.4.1.16, and 4.3.3.4.1.19 to 4.3.3.4.1.23 for additional details.			
Need ID:	2.4.3.4.1	**Need Title:**	Intersection Geometry
Description: A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop lines, crosswalks and landing geometry of the intersection.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x			x	
Evaluation Methodology: This requirement is verified by inspection of the MAP message data. The MAP message data is visualized and compared against a visual ground survey of landings to ensure they are accounted for.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 102. Test Case 3.3.3.4.1.10

Requirement ID:	3.3.3.4.1.10	**Requirement Title:**	Lane Description
Description: A connected intersection shall describe the geometry of the center of each lane by identifying at least two node points that define at least one line segment depicting the center of the lane.			
Design Detail: See Sections 4.3.3.4.1.13 to 4.3.3.4.1.16 for additional guidance.			
Need ID:	2.4.3.4.1	**Need Title:**	Intersection Geometry
Description: A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop lines, crosswalks and landing geometry of the intersection.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x			x	
Evaluation Methodology: This requirement is verified by inspection of the MAP message data. This requirement is considered satisfied if there are two or more points defined for each lane.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 103. Test Case 3.3.3.4.1.11

Requirement ID:	3.3.3.4.1.11	**Requirement Title:**	Lane Description
Description: A connected intersection shall describe the geometry of the center of each lane by identifying at least two node points that define at least one line segment depicting the center of the lane.			
Design Detail: The first node point of an ingress vehicle lane is located at the upstream edge of the stop line. Consistent with the Connected Vehicle Pooled Fund Study's (CVPFS) Creation of a Guidance Document for MAP Preparation: • In the absence of a stop line, the first node point should be placed on the upstream edge of a crosswalk marking • In the absence of a stop line and crosswalk marking, the first node point should be placed, using engineering judgement, at the nearest point at the upstream edge of the intersection CTI 4501 v1.00 CI Implementation Guide Page 158 The reason for the location of the first node point for an ingress lane is that the RLVW application needs to know where the stop line is because if the vehicle crosses the stop line (or the crosswalk marking) while the light is red, the vehicle is technically in violation, which the RLVW application tries to prevent. The RLVW application therefore needs to determine the distance from the stop line and not the distance to a location past the stop line. If the vehicle passes the stop line and stops in the crosswalk or at the edge of the intersection box while the light is red, the vehicle could get ticketed, and the application design should not violate the law. Having the first node point at the location of the stop line also eliminates the need for an extra data element for the stop line location and reduces message size. Beyond the mapped lane (i.e., downstream of the first node point), the application may have a hysteresis type design, where the lane the vehicle matched itself to is still maintained for a certain distance after crossing the first node point of the lane. If the lane is bi-directional, such as a driveway, the first node point should follow the guidelines for the ingress direction, that is, located at the upstream edge of the stop line if present or the crosswalk marking. Figure 22 provides several examples of locations for the first node point of lanes associated with an intersection. The first node point for most ingress lanes at this intersection are either at the upstream edge of the stop line if exists, or at the upstream edge of the crosswalk marking. Similarly, the first node point for all the egress lanes is at the downstream edge of the crosswalk, where crosswalk markings exist. However, since there is no stop line or crosswalk for lanes 2, 4, 9, or 11, engineering judgement was used to place the first node point of those lanes			
Need ID:	2.4.3.4.1	**Need Title:**	Intersection Geometry
Description: A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop lines, crosswalks and landing geometry of the intersection.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x			x	
Evaluation Methodology: This requirement is verified by inspection of the MAP message data. This requirement is considered satisfied if there are two or more points defined for each lane.								

System Input(s):					
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**	
Notes:					

Table 104. Test Case 3.3.3.4.1.12

Requirement ID:	3.3.3.4.1.12	Requirement Title:	First Node Point - Egress Vehicle Lane
Description: A connected intersection shall describe the first node point at the downstream edge of the crosswalk for each egress vehicle lane, with each subsequent node being farther from the intersection.			
Design Detail: The first node point of an egress vehicle lane is located at the downstream edge of the crosswalk marking. Consistent with CVPFS's Creation of a Guidance Document for MAP Preparation: • In the absence of crosswalk markings, the first node point should be determined with engineering judgement to represent the point immediately outside the intersection and any path that pedestrians might use to cross the intersection (with or without crosswalk lines). For example, curbs or cross lanes of travel could be used as references to determine the boundary of the intersection. The reason for the location of the first node point for an egress lane is that the RLVW application needs to know if the vehicle can clear an intersection, defined as the downstream edge of the crosswalk marking of the lane the vehicle is leaving the intersection before the light turns red. If the vehicle cannot clear the intersection, the vehicle is is not meeting the design goal of this CI guidance, which the RLVW application tries to prevent. The RLVW application therefore needs to determine the distance from the stop line of the ingress lane to the downstream edge of the crosswalk marking of the egress lane. If the vehicle does not clear the crosswalk marking while the light is red, the vehicle would not meet the design goal of clearing the intersection." If a vehicle lane is reversible, the lane should be defined as two separate (revocable) lanes. So, when traveling in the ingress direction, the location of the first node point should follow the guidelines for an ingress lane, and when traveling in the egress direction, the first node point should follow the guidelines for an egress lane. If the lane is bi-directional, such as a driveway, the first node point should follow the guidelines for the ingress direction, that is, located at the upstream edge of the stop line if present or the crosswalk marking. If there is no stop line or crosswalk marking, engineering judgement should be used. See Figure 22 for several examples of locations for the first node point of egress lanes associated with an intersection. Notes on egress lanes. A RLVW application only needs one point to indicate the location of the egress lane. So, an egress lane can be described with two node points 1 centimeter apart. Based on this, the minimum length of the egress lane is 1 centimeter, represented by the first node point and a second node point 1 centimeter downstream. For the purposes of RLVW application, there is no need to extend the egress lane beyond 1 centimeter.			
Need ID:	2.4.3.4.1	**Need Title:**	Intersection Geometry
Description: A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop lines, crosswalks and landing geometry of the intersection.			

Verification Method	Demonstration	Test	Analyze	Inspection	Other			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x			x	

Evaluation Methodology:
This requirement is verified by inspection of the MAP message data. The MAP message egress lane data is visualized (numbering sequential points or joining sequential points with a line) and compared against a visual

ground survey of lanes to ensure lanes move away from the intersection.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**	

Notes:

Table 105. Test Case 3.3.3.4.1.13

Requirement ID:	3.3.3.4.1.13	**Requirement Title:**	Node Offset from Intersection Reference Point
Description: A connected intersection shall describe the location of first node point of a lane by providing an X (east-west) and a Y (north-south) offset, in centimeters, from the intersection reference point.			
Design Detail: The first node point of all lanes at or associated with an intersection is described as a node offset from the intersection's reference point. Node offsets consists of an X value, followed by a Y value and all are in 1-centimeter units. As indicated by SAE J2735_202007, the offset is positive to the east (X) and to the north (Y). The node offset is represented as a choice of different data frames (node-XY1, nodeXY-2, node-XY3, node-XY4, node-XY5, or node-XY6, represented by DF_Node_XY_20b, DF_Node_XY_22b, DF_Node_XY_24b, DF_Node_XY_26b, DF_Node_XY_28b, and DF_Node_XY_32b, respectively) and can be found under the data frame DF_NodeOffsetPointXY in the MSG_MapData message in SAE J2735_202007. The difference between the choices are the sizes of the offset data to be transmitted. Table 12 summarizes the differences between the choices, including the range of offsets supported for each choice CTI 4501 v1.00 CI Implementation Guide Page 160 and the number of bits required to transmit the choice. Note the number of bits required are for the Xoffset and the Y-offset combined and each the same value. The guidance is to use the smallest data frame if possible if there is a MAP message size issue, even if one lane uses different data frames (e.g., node-XY2 and node-XY4) to represent the node offsets for the same lane. It is recommended that Universal Transverse Mercator (UTM) coordinates NOT be used because it introduces a rotation. As shown in Figure 23, node offsets to the east are denoted by X offset and node offsets to the north by Y offset. For Figure 23, the first node point for lane id 5 and lane id 8 are the following: CTI 4501 v1.00 CI Implementation Guide Page 161 {"laneID":5,"laneAttributes":{…},"nodeList":{"nodes":[{"delta":{"node-XY3":{"x":900,"y":-1080}}},{"delta":{…}}]}},{"laneID":8,"laneAttributes":{…},"nodeList":{"nodes":[{"delta":{"nod e-XY2":{"x":360,"y":1000}}},{"delta":{…}}]}} Note that since the first node point for lane id 8 is within 10.23 meters of the intersection reference point for X- and Y- offsets (the range of node-XY2), node-XY2 is used to describe the location of the first offset node point lane 8. On the other hand, the first node point for lane id 5 is outside 10.23 meters for the Yoffset, so node-XY3 is used to describe the location of the first offset node point lane 5.			
Need ID:	2.4.3.4.1	**Need Title:**	Intersection Geometry
Description: A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop lines, crosswalks and landing geometry of the intersection.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: This requirement is verified by inspection of the MAP message data. An offset (from the intersection reference point) shall be used to specify the first point of each geometry. The smallest offset type to convey the offset information shall be used.								

System Input(s):					
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**	
Notes:					

Table 106. Test Case 3.3.3.4.1.14

Requirement ID:	3.3.3.4.1.14	**Requirement Title:**	Node Elevation Offset from Intersection Reference Point
Description: A connected intersection shall describe the elevation offset, in one centimeter units, of the first node point of a lane from the intersection reference point.			
Design Detail: The elevation of the first node point of all lanes at or associated with an intersection is described as an offset from the intersection's reference point, in one centimeter units. The elevation offset is represented as dElevation (DE_Offset-B10) and can be found under the data frame DF_NodeAttributeSetXY in the MSG_MapData message in SAE J2735_202007. If there is no change in elevation from the intersection reference point, this data element is not sent. A positive value indicates an increase in elevation from the intersection reference point. Figure 25 is an example of a first node point that is at a different elevation than the intersection reference point.			
Need ID:	2.4.3.4.1	**Need Title:**	Intersection Geometry
Description: A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop lines, crosswalks and landing geometry of the intersection.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: This requirement is verified by inspection of the MAP message data. An elevation offset (from the intersection reference point) shall be used to specify the first elevation point of each geometry. If the elevation does not change, this data element shall not be present.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 107. Test Case 3.3.3.4.1.15

Requirement ID:	3.3.3.4.1.15	**Requirement Title:**	Offset from Previous Node
Description: A connected intersection shall describe the location of a node subsequent to the first node point of a lane by providing an X (east-west) and a Y (north-south) offset, in centimeters, from the previous node point			
Design Detail: Each subsequent node point after the first node point of all lanes at or associated with an intersection is described as a node offset from the previous node point. Node offsets consists of an X value, followed by a Y value and all are in 1-centimeter units. As indicated by SAE J2735_202007, the offset is positive to the east (X) and to the north (Y). The node offset is represented as a choice of different data frames (node-XY1, nodeXY-2, node-XY3, node-XY4, node-XY5, or node-XY6, represented by DF_Node_XY_20b, DF_Node_XY_22b, DF_Node_XY_24b, DF_Node_XY_26b, DF_Node_XY_28b, and DF_Node_XY_32b, respectively) and can be found under the data frame DF_NodeOffsetPointXY in the MSG_MapData message in SAE J2735_202007. Table 12 in Section 4.3.3.4.1.13 describes the differences between the choices. The guidance is to use the smallest data frame if possible if there is a MAP message size issue, even if one lane uses different data frames (e.g., node-XY2 and node-XY4) to represent the offsets between node points for the same lane. Figure 24 builds on Figure 23 and shows additional node points for lanes at the intersection, including two turning bays at the same intersection. The light green lines indicate the centerline path for the vehicle in each lane. In Figure 24, only two node points are used to define lane ids 3, 5, 15, and 17. The node points that appear between the two end node points of each lane are only used to define the last node points for lane ids 1, 7, 13, and 19. Using JSON encoding, the node points for lane ids 1, 3, 5 and 7 are the following: {"laneID":1,"laneAttributes":{…},"nodeList":{"nodes":[{"delta":{"node-XY3":{"x":180,"y":-1080}}},{"delta":{"node-XY2":{"x":0,"y":-1020}}},{"delta":{"node-XY1":{"x":360,"y":-400}}}]}},{"laneID":3,"laneAttributes":{…},"nodeList":{"nodes":[{"delta":{"nodeXY3":{"x":540,"y":-1080}}},{"delta":{"node-XY3":{"x":0,"y":-1840}}}]}},{"laneID":5,"laneAttributes":{…},"nodeList":{"nodes":[{"delta":{"nodeXY3":{"x":900,"y":-1080}}},{"delta":{"node-XY3":{"x":0,"y":-1840}}}]}},"laneID":7,"laneAttributes":{…},"nodeList":{"nodes":[{"delta":{"nodeXY3":{"x":1260,"y":-1080}}},{"delta":{"node-XY2":{"x":0,"y":-960}}},{"delta":{"nodeXY1":{"x":-360,"y":-460}}}]}}			
Need ID:	2.4.3.4.1	**Need Title:**	Intersection Geometry
Description: A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop lines, crosswalks and landing geometry of the intersection.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
This requirement is verified by inspection of the MAP message data. An offset (from a previously-defined point) shall be used to specify subsequent points of each geometry. The smallest offset type to convey the offset information shall be used.

System Input(s):

Supported Sites	GDOT	ODOT	UDOT	Other	

Notes:

Table 108. Test Case 3.3.3.4.1.16

Requirement ID:	3.3.3.4.1.16	**Requirement Title:**	Elevation Offset from Previous Node
Description: A connected intersection shall describe the elevation offset, in one centimeter units, of a node from the previous node point for a lane.			
Design Detail: The elevation offset of a node point of a lane at or associated with an intersection from a previous node point is represented as dElevation (DE_Offset-B10) and can be found under the data frame DF_NodeAttributeSetXY in the MSG_MapData message in SAE J2735_202007, in 1-centimeter units. If there is no change in elevation from the previous node point, this data element is not sent. A positive value indicates an increase in elevation from the previous node point. Changes in elevation are assumed to be a linear taper between the node points (it is a straight line between the two node points). CTI 4501 v1.00 CI Implementation Guide Page 163 Note that SAE J2735_202007 states that changes to elevation offsets persist to subsequent nodes. Also see Section 4.3.3.4.1.20, Maximum Distance between Nodes, for additional notes about vertical curves. Figure 25 is a profile of a lane entering an intersection. The elevation of the first node point is located 20 centimeters higher than the elevation of the intersection reference point, and the second node point is also located 20 centimeters higher that the first node point. The third node point is at the same elevation as the second node point, while the fourth node point is 10 centimeters lower from the third node point. The node point representation for this lane could be (JSON encoding) the following: {"laneID":3,"laneAttributes":{…},"nodeList":{"nodes":[{"delta":{"node-XY3":{"x":540,"y":- 1080}},"attributes":{"dElevation":20}},{"delta":{"node-XY3":{"x":0,"y":-1420}},"attributes":{"dElevation":20}},{"delta":{"node-XY3":{"x":0,"y":- 1420}}},{"delta":{"node-XY1":{"x":0,"y":-700}},"attributes":{"dElevation":-10}}]}}			
Need ID:	2.4.3.4.1	**Need Title:**	Intersection Geometry
Description: A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop lines, crosswalks and landing geometry of the intersection.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: This requirement is verified by inspection of the MAP message data. An offset (from a previously-defined point) shall be used to specify subsequent points of each geometry. If the elevation does not change, this data element shall not be present.								
System Input(s):								

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:

Table 109. Test Case 3.3.3.4.1.17

Requirement ID:	3.3.3.4.1.17	**Requirement Title:**	Advanced Notification - Ingress Vehicle Lane
Description: A connected intersection shall describe node points of each ingress vehicle lane that extend a minimum distance upstream from the first node point of the lane 10 seconds at the 85th percentile speed or a speed equal to the posted or statutory speed limit plus 7 miles per hour (mph).			
Design Detail: The requirement this design detail traces to provide guidance on how far upstream should node points be provided for an ingress lane into an intersection. In addition: • Whenever possible, the length of the ingress lanes should provide at least 10 seconds of vehicle travel in the ingress lane before the stop line. This length may be computed by multiplying the speed in mph by 4.469 to receive distance in meters. The recommendation is to use the 85th percentile speed in the calculation or the speed limit plus 7 mph if the 85th percentile speed is not available. For 25 miles per hour, this is equivalent to an ingress lane 112 meters long. • Ingress lanes may or may not extend beyond the egress lanes of upstream intersections. This allows an OBU application to determine where a vehicle leaves the upstream intersection without having to process the ingress lane of the downstream intersection. • However, ingress lanes may NOT extend into the conflict area of an upstream intersection. The rationale for this constraint is a concern that extending an ingress lane into an upstream intersection may cause confusion. This driver confusion is demonstrated in the scenarios below. • It is recommended that if Intersection A in Figure 27 is within 10 seconds of vehicle travel in the ingress lane for Intersection B before the stop line; AND Intersection A is NOT a connected intersection, i.e., is not broadcasting MAP and SPaT messages, that the intersection geometry for Intersection A be included in the MAP message for Intersection B. Thus, Intersection B would broadcast a MAP message containing the intersection geometry for Intersections A and B. Including the adjoining non-CI intersection would allow the RLVW application to know not to provide warning/information before crossing the non-CI intersection. • If Intersection A in Figure 27 is within 10 seconds of vehicle travel in the ingress lane for Intersection B before the stop line; and Intersection A IS a connected intersection, then the intersection geometry for Intersection A MAY be included in the MAP message for Intersection B. This would allow an approaching vehicle to still receive information about Intersection A in case Intersection A stops broadcasting a MAP message for any reason. CTI 4501 v1.00 CI Implementation Guide Page 164 To demonstrate the driver confusion if the ingress lanes extend into or beyond an upstream intersection, two scenarios are presented below. The following pre-conditions are assumed: • Intersections A and B are signalized intersections • Speed limit is 45mph • Required MAP length (speed limit + 7mph) ≅ 230m from stop point • Distance between the intersection A and B is 150m • RF transmission range of RSU ≅ 500m In Scenario 1, Intersections A and B in Figure 26 are signalized Connected Intersections (CI) broadcasting required messages to support in-vehicle RLVW application. Figure 26 shows operation and vehicle movements through the intersections. When the approaching Connected Vehicle (CV) is at position 1, it is outside the broadcast range of RSU from intersection A, no messages are received. • When the CV reaches position 2, it is within the broadcast range of 500m from intersection A and starts receiving messages from the intersection. At this location, the CV is 270m away from the start of mapped lanes (map is up to 230m from the intersection). The in-vehicle RLVW application can determine its lane position when the CV is in within mapped area. At this time however, the reference point (from received MAP message) is known to establish relevance of approaching intersection by the application. • When the CV reaches position 3, it is within mapped lane definition for intersection A and within the broadcast range of intersection B. The CV now has messages from both intersections. • When the CV is at position 4, it is within defined map of intersections A and B • In this scenario, the in-vehicle RLVW application would perform as intended for intersection A (being the relevant intersection) followed by the intersection B after crossing the intersection A. It is assumed that both connected intersections are operational,			

and broadcast required messages for the RLVW application at the time of CV traveling through the corridor. • However, if Intersection A stops broadcasting MAP messages for any reason, such as an error condition, Scenario 2 below would occur. In Scenario 2, Intersection A and B in Figure 27 are signalized intersections; however, Intersection A is not a Connected Intersection (CI) or not broadcasting required messages for RLVW application. Intersection B is broadcasting required messages to support in-vehicle RLVW application. Figure 27 shows operation and vehicle movements through the intersections. CTI 4501 v1.00 CI Implementation Guide Page 165 Figure 27. Overlapping Ingress Lanes - Scenario 2. • When the approaching CV is upstream of position 3, the CV is outside the broadcast range of RSU from the intersection B and no messages are received by the CV. • When the CV is at the position 3, it is within the broadcast range of 500m from Intersection B. From the received MAP message, for next 270 meters, the CV has the reference point location of the Intersection B, but the CV is not yet within the defined lane level map node points (maximum 230m from the intersection) for the intersection to determine its lane position to associate with SPaT for RLVW application. The in-vehicle application, however, can establish the relevance of approaching intersection based on the reference point of the intersection from the MAP message. • When the CV is downstream of position 4, it is within mapped lane definition for the Intersection B for the in-vehicle application to determine its lane. • When the CV is between the downstream from position 4 and before the stop point of Intersection A marked as “Driver Confusion” zone, the CV is approaching intersection A. However, the intersection relevant to the in-vehicle application is intersection B. When the CV is in the driver confusion zone and the signal phase is red or about to turn red for intersection A, the RLVW will not warn the driver since the application warning is for intersection B and not A. This may confuse the CV operator since the operator is not aware of intersection A not a CI, thinking that the RLVW system is not working.

Need ID:	2.4.3.4.1	**Need Title:**	Intersection Geometry

Description:
A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop lines, crosswalks and landing geometry of the intersection.

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				

Evaluation Methodology:
This requirement is verified by inspection of the MAP Message data. The cumulative distance along the line generated by all points (in the correct order) shall be greater than the distance (as a function of the speed limit) specified in the requirement.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**	

Notes:

Table 110. Test Case 3.3.3.4.1.18

Requirement ID:	3.3.3.4.1.18	**Requirement Title:**	End Nodes - Crosswalk Lane
Description: A connected intersection shall describe the first and last node point of a crosswalk lane at the edge of the curb.			
Design Detail: The end nodes of a crosswalk shall be at the edge of a sidewalk curb, or a pedestrian landing. No guidance is provided on which end is the first node since the crosswalk is bi-directional.			
Need ID:	2.4.3.4.1	**Need Title:**	Intersection Geometry
Description: A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop lines, crosswalks and landing geometry of the intersection.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x			x	
Evaluation Methodology: This requirement is verified by comparison of surveyed data against MAP message data. The ends of the centerline of the crosswalk shall correspond with the location of a curb or landing.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes: It may be difficult to have the center of a crosswalk located along a curb while accurately defining the width of the crosswalk throughout its entire length								

Table 111. Test Case 3.3.3.4.1.19

Requirement ID:	3.3.3.4.1.19	**Requirement Title:**	End Nodes - Pedestrian Landing
Description: A connected intersection shall describe the first and last node point of a pedestrian landing (essentially a sidewalk lane) at the edge of the curb, co-incident with the end nodes of the adjacent crosswalk lanes.			
Design Detail: The end nodes of a pedestrian landing shall be at the edge of the sidewalk curbs, or the crosswalk. No guidance is provided on which end is the first node since the pedestrian landing is bi-directional.			
Need ID:	2.4.3.4.1	**Need Title:**	Intersection Geometry
Description: A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop lines, crosswalks and landing geometry of the intersection.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x			x	
Evaluation Methodology: This requirement is verified by comparison of surveyed data against MAP message data. The end of the pedestrian landing shall correspond with the location of a curb and shall match the end point of the corresponding crosswalk.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes: Center of pedestrian landing is not always at the center of the end of the crosswalk								

Table 112. Test Case 3.3.3.4.1.20

Requirement ID:	3.3.3.4.1.20	**Requirement Title:**	Maximum Distance between Nodes
Description: When describing a lane with a horizontal curve, a connected intersection shall place the next node point within a distance such that the maximum distance between the actual centerline of a lane and a straight line between the two node points, does not exceed 0.5 meters. This concept is shown in Figure 13			
Design Detail: For roadways with horizontal curves, the OBU application needs a certain amount of accuracy for lanematching purposes. Based on calculations, the lateral accuracy of the nodes and the lane/road width must be less than 0.5 meters. To fulfill this requirement, the following formula provides the maximum distance between adjacent nodes based on the vertical curve: Distance between adjacent nodes [m] = 0.058 x { (radius of the curve [m]) - 40m } + 12.5m The curve geometry node points do not necessarily have to be placed equidistant to each other. Figure 28 provides some background information related to how the above formula was derived. CTI 4501 v1.00 CI Implementation Guide Page 166 Figure 28. Maximum Distance Between Node Points. Figure 29 is an analysis graph. The ideal distance between nodes is highlighted by a dash line in the graph. The bounded area of blue colored line and different colored square shows percentage error from ideal value. Figure 29. Radius of Curvature vs Distance Between Nodes. Table 13 contains a suggested range of distance between node points for a curved segment. Table 13. Radius of Curvature vs Distance Between Nodes Radius of Curvature (m) Distance (Range) Between Nodes (m) < 100 15 – 20 101 to 200 22 – 30 201 to 300 25 – 35 301 to 400 30 – 38 401 to 500 32 – 45 501 to 600 35 – 52 Vertical curve information is only needed for vehicle dynamics and for deceleration. A balance is needed when adding node points between the benefits of providing vertical curve information versus the cost of the increase in message size to provide that information. A general guideline is that additional node points are not needed when the changes in elevation are 20 centimeters or less between two consecutive node points (not cumulative). Recalling that changes in elevation are assumed to be a linear taper between the node points (it is a straight line between the two node points), be aware of sudden dips in elevation, such as illustrated in Figure 30. CTI 4501 v1.00 CI Implementation Guide Page 167 Figure 30. Vertical Curves. No additional guidance is provided at this time for the maximum distance between nodes based on vertical curves.			
Need ID:	2.4.3.4.1	**Need Title:**	Intersection Geometry
Description: A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop lines, crosswalks and landing geometry of the intersection.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x			x	
Evaluation Methodology: This requirement is verified by comparison of surveyed data against MAP message data. No point along a lane defined by MAP message data shall be greater than 0.5 meters away from any point along the centerline as computed from survey data.								

System Input(s):					
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**	
Notes:					

Table 113. Test Case 3.3.3.4.1.21

Requirement ID:	3.3.3.4.1.21	**Requirement Title:**	Maximum Number of Nodes
Description: A connected intersection shall describe the centerline of the path of a lane with no more than 63 node points.			
Design Detail: It is recommended to have as few node points as possible to describe a lane to minimize the size of the MAP message, while still fulfilling requirements described in Sections 3.3.3.4.1.7 to 3.3.3.4.1.23			
Need ID:	2.4.3.4.1	**Need Title:**	Intersection Geometry
Description: A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop lines, crosswalks and landing geometry of the intersection.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: This requirement is verified by inspection of the MAP message data. This requirement is considered satisfied if there are 63 or fewer points defined for each lane.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 114. Test Case 3.3.3.4.1.22

Requirement ID:	3.3.3.4.1.22	**Requirement Title:**	Node Lane Width
Description: If the width of a lane at a node point is different than the default lane width and the lane width at the preceding node, a connected intersection shall describe change in width of the lane, in centimeters, at the node position.			
Design Detail: The difference in the width of a lane at or associated with an intersection from the intersection's default lane width or from a previous node point is represented as dWidth (DE_Offset-B10) and can be found under the data frame DF_NodeAttributeSetXY in the MSG_MapData message in SAE J2735_202007, in one centimeter units. If there is no change in the lane width from the previous node point, this data element is not sent. If there is no change in the lane width at the first node point for the lane from the default lane width for the intersection, this data element is not sent. A positive value indicates an increase in the lane width from the previous node point. Changes in lane widths are assumed to be a linear taper between the node points. For example, Figure 31 is an intersection with a default lane width of 360 centimeters. However, at the first node point of lane number 5, the lane width is 720 centimeters to the second node point, tapers down to 360 centimeters at the third node point, then remains 360 centimeters in width. CTI 4501 v1.00 CI Implementation Guide Page 168 Figure 31. Lane Widths. The node points and lane widths for lane number 5 could be (JSON encoding): {"laneID":5,"laneAttributes":{…},"nodeList":{"nodes":[{"delta":{"node-XY3":{"x":1080,"y":-1080}},"attributes":{"dWidth":360}},{"delta":{"node-XY2":{"x":0,"y":-960}}},{"delta":{"nodeXY1":{"x":-180,"y":-460}},"attributes":{"dWidth":-360}},{"delta":{"node-XY1":{"x":0,"y":- 700}}}]}} See Figure 24 for an example on how to address tapering when a single lane becomes two lanes (or vice versa).			
Need ID:	2.4.3.4.1	**Need Title:**	Intersection Geometry
Description: A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop lines, crosswalks and landing geometry of the intersection.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
				x			x	
Evaluation Methodology: This requirement is verified by comparison of surveyed data against MAP message data. Even though the GK - sentence unfinished								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				

Notes: Validating this requirement is difficult, as the requirement does not specify the acceptable tolerance for the value of the lane width at a given point.

Table 115. Test Case 3.3.3.4.1.23

Requirement ID:	3.3.3.4.1.23	**Requirement Title:**	Node Accuracy
Description: A connected intersection shall describe the absolute node position with an accuracy within ± 0.2 meters of the actual location of the node.			
Design Detail: For a vehicle to determine what lane it is in, for the worst case of a vehicle driving along the edge line the total error cannot be more than half the vehicle width or 0.8 meters. GNSS without RTCM Corrections allows the vehicle to determine its position within 0.6 meters. This difference leaves a requirement for 0.2 meters node accuracy. If augmentation (e.g., RTCM Corrections) is provided, then ± 0.4/0.5 meters may be sufficient. The CVPFS' Creation of a Guidance Document for MAP Preparation document provides some guidance on how to check for node accuracy.			
Need ID:	• 2.4.3.4.1 • 2.4.3.4.7	**Need Title:**	• Intersection Geometry • Road Geometry Accuracy
Description: • A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop lines, crosswalks and landing geometry of the intersection. • A connected intersection needs to provide assurances that the road geometry data provided by the infrastructure is accurate and represents the roadway geometrics at the intersection within a defined tolerance. Inaccurate data reduces the effectiveness of the applications that use the data. NOTE: Enough accuracy is needed so the vehicle can determine which lane it is in, since different lanes may be controlled by different signal indications being in different states.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x			x	
Evaluation Methodology: This requirement is verified by comparison of surveyed data against MAP message data. Requirement is difficult to verify as node points defined in the MAP message are not directly verifiable (as they typically do not correspond to a particular roadway feature). This requirement is considered satisfied if each node point is less than 0.2 meters from the lane centerline computed using survey data.								
System Input(s):								

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:

Table 116. Test Case 3.3.3.4.2.1

Requirement ID:	3.3.3.4.2.1	**Requirement Title:**	Direction of Travel
Description: A connected intersection shall identify the allowable direction(s) of travel for a lane, as defined by DE_LaneDirection in SAE J2735_202007.			
Design Detail: The allowable direction(s) of travel for a lane is represented as directionalUse (DE_LaneDirection) and can be found under the data frame DF_LaneAttributes in the MSG_MapData message in SAE J2735_202007. DE_LaneDirection is a bit string. A value of 1 for Bit 0 indicates that the lane is an ingress lane (travel is from the last node point for a lane to the first node point of the same lane). A value of 1 for Bit 1 indicates that the lane is an egress lane (travel is from the first node point for a lane to the last node point of the same lane). A value of 0 for both Bit 0 and Bit 1 indicates no travel is allowed. A value of 1 for both Bit 0 and Bit 1 indicates travel in both directions are allowed, for example a pedestrian crosswalk. For reversible vehicle lanes, separate lane identifiers should be assigned - one for each direction of travel, AND each lane should be identified as revocable lane (See 4.3.3.4.6, Revocable Lanes).			
Need ID:	2.4.3.4.2	**Need Title:**	Lane Attributes
Description: A connected intersection needs to provide information about the allowed use of each lane at an intersection so an application on an OBU/MU can determine the current allowed usage of the lanes around its position and can provide appropriate warnings, information and guidance to the driver or VRU. Lane attributes provided include the direction of travel permitted in the lane and lane use restrictions.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x			x	
Evaluation Methodology: This requirement is verified by inspection of the MAP message data. The LaneDirection bitstring is visualized and compared against a visual ground survey of lanes to ensure the lane direction is properly specified for each lane per the design details.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 117. Test Case 3.3.3.4.2.2

Requirement ID:	3.3.3.4.2.2	**Requirement Title:**	Lane Sharing
Description: A connected intersection shall identify the allowed user types that are permitted to use the lane, as defined by DE_LaneSharing in SAE J2735_202007.			
Design Detail: A shared lane is a physical lane that can be shared by different types of travelers, each with a right to use the lane. A shared lane is represented by sharedWith (DE_LaneSharing) and can be found under the data frame DF_LaneAttributes in the MSG_MapData message in SAE J2735_202007. Common examples of shared lanes are tracked trolleys that share a vehicle lane, a bicycle lane that is shared with a vehicle lane, or a bicycle lane that is shared with a pedestrian pathway. For a connected intersection, how the lanes are coded in DE_LaneSharing depends on how the TSC infrastructure controls the different type of travelers. For example, in Figure 32, the far-left lane is defined as lane 1 and may be used by motorized vehicle and the tracked vehicles. There is no separate signalGroupID to control different types of vehicles in this lane. In this example, there is no need to map the same physical lane twice, because there are no separate signalGroupID assigned for motorized vehicles or tracked vehicles. So, the MAP message would assign Lane id 1 to this lane as a vehicle lane type (See 4.3.3.4.2.3, Lane Type Attributes). To indicate that the lane is treated as one for motorized vehicle and tracked vehicles, the multipleLanesTreatedAsOneLane bit is asserted to indicate "the lane object path and width details represents multiple lanes within it that are not further described;" and trackedVehicleTraffic bit is asserted to indicate "various modes and (the) type of traffic that may share this lane. The encoding for this example is as follows: Bit #: 0123456789 Asserted bit: 0100000010 CTI 4501 v1.00 CI Implementation Guide Page 170 Figure 32. Example Shared Lane. In Figure 33, the far-right lane is a shared lane with motorized vehicles and tracked vehicles. However, at the intersection, there are separate signal indications (signalGroupID) for the same shared lane, one for tracked vehicles and one for motorized vehicles. For motorized vehicles, the lane is identified as Lane 5 and has a separate signalGroupID (3), while for tracked vehicles, the lane is identified as Lane 7, but has its own signalGroupID just for tracked vehicles. In this example, Lane 5 and 7, the overlapping bit should be asserted because the lane does overlap with another defined lane (lane 5 overlaps lane 7) and are defined as separate lanes. The encoding for this example is as follows: Bit #: 0123456789 Asserted bit: 1000000010 Figure 33. Shared Lane - Example 2. As a third example, to indicate that the lane is overlapping and is also shared by taxi vehicle traffic which may stop the vehicle to pickup and drop-off customers, the overlappingLaneDescriptionProvided bit is asserted as: Bit #: 0123456789 Asserted bit: 1000010000			
Need ID:	2.4.3.4.2	**Need Title:**	Lane Attributes
Description: A connected intersection needs to provide information about the allowed use of each lane at an intersection so an application on an OBU/MU can determine the current allowed usage of the lanes around its position and can provide appropriate warnings, information and guidance to the driver or VRU. Lane attributes provided include the direction of travel permitted in the lane and lane use restrictions.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x			x	

Evaluation Methodology:
This requirement is verified by inspection of the MAP message data. The LaneSharing bitstring is visualized and compared against a visual ground survey of lanes to ensure modes are properly specified for each lane per the design details.

System Input(s):

Supported Sites	GDOT	ODOT	UDOT	Other	

Notes:

Table 118. Test Case 3.3.3.4.2.3

Requirement ID:	3.3.3.4.2.3	**Requirement Title:**	Lane Type Attributes
Description: A connected intersection shall identify the attribute information specific to a given lane type, as defined by DE_LaneTypeAttributes in SAE J2735_202007. The types of lanes are vehicle lane, crosswalk, bike lane, sidewalk, medians and channels, striped lanes, tracked lanes (for trains and trolleys), and parking lanes.			
Design Detail: The lane type, and its attributes, of a lane associated with an intersection is represented by laneType (DE_LaneTypeAttributes) and can be found under the data frame DF_LaneAttributes in the MSG_MapData message in SAE J2735_202007. The Lane Type Attributes data frame is used to hold attribute information specific to a given lane type choice defined as the following: LaneTypeAttributes ::= CHOICE { vehicle crosswalk bikeLane sidewalk median striping trackedVehicle parking ... } Each defined lane type contains bit flags depending on its application. The attributes of a lane type are described in the following sections (Sections 4.3.3.4.2.4 to 4.3.3.4.2.8)			
Need ID:	2.4.3.4.2	**Need Title:**	Lane Attributes
Description: A connected intersection needs to provide information about the allowed use of each lane at an intersection so an application on an OBU/MU can determine the current allowed usage of the lanes around its position and can provide appropriate warnings, information and guidance to the driver or VRU. Lane attributes provided include the direction of travel permitted in the lane and lane use restrictions.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x			x	

Evaluation Methodology:
This requirement is verified by inspection of the MAP message data. The LaneTypeAttributes choice is visualized and compared against a visual ground survey of lanes to ensure the attribute is properly specified for each lane per the design details.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:

Table 119. Test Case 3.3.3.4.2.4

Requirement ID:	3.3.3.4.2.4	**Requirement Title:**	Lane Attributes - Vehicle
Description: A connected intersection shall indicate the applicable attributes for a vehicle lane, as defined by DE_LaneAttributes-Vehicle in SAE J2735_202007. Examples of attributes are if the lane is a revocable lane, and any lane restrictions (HOV, Taxi, private use, etc.).			
Design Detail: The attributes of a vehicle lane are described by vehicle (DE_LaneAttributes-Vehicle) and can be found under the data frame (DF_LaneTypeAttributes) in the MSG_MapData message in SAE J2735_202007. For example, to indicate a lane as a revocable vehicle lane but for HOV lane use only, the following bits are asserted: Bit #: 01234567 Asserted bit: 10100000			
Need ID:	2.4.3.4.2	**Need Title:**	Lane Attributes
Description: A connected intersection needs to provide information about the allowed use of each lane at an intersection so an application on an OBU/MU can determine the current allowed usage of the lanes around its position and can provide appropriate warnings, information and guidance to the driver or VRU. Lane attributes provided include the direction of travel permitted in the lane and lane use restrictions.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x			x	
Evaluation Methodology: This requirement is verified by inspection of the MAP message data. The LaneTypeAttributes bitstring is visualized and compared against a visual ground survey of vehicle lanes to ensure the attribute is properly specified for each lane per the design details.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 120. Test Case 3.3.3.4.2.5

Requirement ID:	3.3.3.4.2.5	**Requirement Title:**	Lane Attributes - Crosswalk
Description: A connected intersection shall indicate the applicable attributes for a crosswalk, as defined by DE_LaneAttributes-Crosswalk in SAE J2735_202007. Examples of attributes are if the lane is a revocable lane, and how the signal timing at the signalized intersection addresses travelers in the crosswalk lane.			
Design Detail: The attributes of a pedestrian crosswalk lane are described by crosswalk (DE_LaneAttributes-Crosswalk) and can be found under the data frame (DF_LaneTypeAttributes) in the MSG_MapData message in SAE J2735_202007. For example, to indicate a lane as a non-revocable crosswalk lane but the path allows bicycle traffic, the following bits are asserted: Bit #: 111111 0123456789012345 Asserted bit: 0010000000000000			
Need ID:	2.4.3.4.2	**Need Title:**	Lane Attributes
Description: A connected intersection needs to provide information about the allowed use of each lane at an intersection so an application on an OBU/MU can determine the current allowed usage of the lanes around its position and can provide appropriate warnings, information and guidance to the driver or VRU. Lane attributes provided include the direction of travel permitted in the lane and lane use restrictions.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x			x	
Evaluation Methodology: This requirement is verified by inspection of the MAP message data. The LaneTypeAttributes bitstring is visualized and compared against a visual ground survey of crosswalk lanes to ensure the attribute is properly specified for each lane per the design details.								
System Input(s):								

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**
Notes:				

Table 121. Test Case 3.3.3.4.2.6

Requirement ID:	3.3.3.4.2.6	**Requirement Title:**	Lane Attributes - Bicycle
Description: A connected intersection shall indicate the applicable attributes for a bicycle lane, as defined by DE_LaneAttributes-Bike in SAE J2735_202007. Examples of attributes are if the lane is a revocable lane, and how the signal timing at the signalized intersection addresses travelers in the bicycle lane.			
Design Detail: The attributes of a bicycle lane are described by bikeLane (DE_LaneAttributes-Bike) and can be found under the data frame (DF_LaneTypeAttributes) in the MSG_MapData message in SAE J2735_202007. For example, to indicate lane as bicycle lane (not revocable) and the path allows pedestrian traffic, following bit is asserted: Bit #: 111111 CTI 4501 v1.00 CI Implementation Guide Page 172 0123456789012345 Asserted bit: 0100000000000000			
Need ID:	2.4.3.4.2	**Need Title:**	Lane Attributes
Description: A connected intersection needs to provide information about the allowed use of each lane at an intersection so an application on an OBU/MU can determine the current allowed usage of the lanes around its position and can provide appropriate warnings, information and guidance to the driver or VRU. Lane attributes provided include the direction of travel permitted in the lane and lane use restrictions.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x			x	
Evaluation Methodology: This requirement is verified by inspection of the MAP message data. The LaneTypeAttributes bitstring is visualized and compared against a visual ground survey of bicycle lanes to ensure the attribute is properly specified for each lane per the design details.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 122. Test Case 3.3.3.4.2.7

Requirement ID:	3.3.3.4.2.7	**Requirement Title:**	Lane Attributes - Tracked Vehicles
Description: A connected intersection shall indicate the applicable attributes for a tracked vehicle lane, as defined by DE_LaneAttributes-TrackedVehicle in SAE J2735_202007. Examples of attributes are if the lane is a revocable lane, and the type of track (commuter rail, light rail, etc.).			
Design Detail: The attributes of a tracked vehicle lane are described by trackedVehicle (DE_LaneAttributesTrackedVehicle) and can be found under the data frame (DF_LaneTypeAttributes) in the MSG_MapData message in SAE J2735_202007. For example, to indicate the lane use restricted to certain vehicle types and restricted from public use, following bit is asserted: Bit #: 01234567 Asserted bit: 00000100			
Need ID:	2.4.3.4.2	**Need Title:**	Lane Attributes
Description: A connected intersection needs to provide information about the allowed use of each lane at an intersection so an application on an OBU/MU can determine the current allowed usage of the lanes around its position and can provide appropriate warnings, information and guidance to the driver or VRU. Lane attributes provided include the direction of travel permitted in the lane and lane use restrictions.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x			x	
Evaluation Methodology: This requirement is verified by inspection of the MAP message data. The LaneTypeAttributes bitstring is visualized and compared against a visual ground survey of tracked vehicle lanes to ensure the attribute is properly specified for each lane per the design details.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 123. Test Case 3.3.3.4.2.8

Requirement ID:	3.3.3.4.2.8	**Requirement Title:**	Lane Attributes - Parking
Description: A connected intersection shall indicate the applicable attributes for a parking lane, as defined by DE_LaneAttributes-Parking in SAE J2735_202007. Examples of attributes are if the lane is a revocable lane, and the type of parking (parallel, head in parking, do not park zone, private parking, etc.).			
Design Detail: The attributes of a parking lane are described by parking (DE_LaneAttributes-Parking) and can be found under the data frame (DF_LaneTypeAttributes) in the MSG_MapData message in SAE J2735_202007. For example, to indicate the revocable parking lane for head-in parking in use, following bits are asserted: Bit #: 111111 0123456789012345 Asserted bit: 1010000000000000			
Need ID:	2.4.3.4.2	**Need Title:**	Lane Attributes
Description: A connected intersection needs to provide information about the allowed use of each lane at an intersection so an application on an OBU/MU can determine the current allowed usage of the lanes around its position and can provide appropriate warnings, information and guidance to the driver or VRU. Lane attributes provided include the direction of travel permitted in the lane and lane use restrictions.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x			x	
Evaluation Methodology: This requirement is verified by inspection of the MAP message data. The LaneTypeAttributes bitstring is visualized and compared against a visual ground survey of parking lanes to ensure the attribute is properly specified for each lane per the design details.								
System Input(s):								

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**
Notes:				

Table 124. Test Case 3.3.3.4.3

Requirement ID:	3.3.3.4.3	**Requirement Title:**	Lane Maneuvers
Description: A connected intersection shall identify for a lane each maneuver that is allowed for that lane at the stop line for ingress lanes and at the first node point for the downstream lane, as defined by DE_AllowedManeuvers in SAE J2735_202007.			
Design Detail: The allowed lane maneuvers for a lane at an intersection is represented by maneuvers (DE_AllowedManeuvers) and can be found under the data frame (DF_GenericLane) in the MSG_MapData message in SAE J2735_202007. For example, to indicate a lane that allows straight, right turn on green and right turn on red, following bits are asserted: Bit #: 11 012345678901 Asserted bit: 101001000000			
Need ID:	2.4.3.4.3	**Need Title:**	Allowed Maneuvers
Description: A connected intersection needs to provide information about the allowed maneuvers of each lane at an intersection so the application on an OBU/MU can provide appropriate warnings, information and guidance to the driver or VRU. Allowed maneuvers define permitted turns from a lane, typically a vehicle lane, under different conditions.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x			x	
Evaluation Methodology: This requirement is verified by inspection of the MAP message data. The AllowedManeuvers bitstring is visualized and compared against a visual ground survey of lanes to ensure maneuvers are properly specified for each lane per the design details.								
System Input(s):								

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**
Notes: Unclear what is meant by 'first node point for the downstream lane'				

Table 125. Test Case 3.3.3.4.4.1

Requirement ID:	3.3.3.4.4.1	**Requirement Title:**	Lane Connections
Description: A connected intersection shall identify each permitted connection between a lane and each downstream lane at the intersection. NOTE: The downstream lane may be an egress or another ingress lane.			
Design Detail: A list of permitted connections between an ingress lane and each lane a traveler may connected to. This list is represented by connectsTo (DF_ConnectsToList) and can be found under the data frame (DF_GenericLane) in the MSG_MapData message in SAE J2735_202007. The DF_ConnectsToList data frame is used to provide a sequence of other defined lanes to which an ingress lane connects beyond its stop point. For example, to indicate connection between lanes, LaneID and allowed maneuvers are specified as follows (using JSON encoding): CTI 4501 v1.00 CI Implementation Guide Page 173 "connectsTo":[{"connectingLane":{"lane":10,"maneuver":"2400"},"signalGroup":4}] Where • “lane”: “10” indicates LaneID to which the current lane connects to pass the stop point • “maneuver”:”2400” indicates following bits are asserted to allow a right turn and a stop and then proceed when safe to turn right (Right Turn On Red Allowed) Bit #: 11 012345678901 Asserted bit: 001001000000 • "signalGroup":4 indicates the SPaT signal group that controls the movements for that connection			
Need ID:	2.4.3.4.4	**Need Title:**	Connections Between Lanes
Description: A connected intersection needs to provide information about the permitted connections between ingress lanes and egress lanes at an intersection so an application on an OBU/MU can determine what signal timing data from the infrastructure applies to it. The application uses this information to provide appropriate warnings, information and guidance to the driver or VRU. For example, this need ties a maneuver to a signal group so the application on an OBU can interpret what signal timing data applies.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x			x	
Evaluation Methodology: This requirement is verified by inspection of the MAP message data. The connection (ingress-to-ingress or ingress-to-egress) is visualized and compared against a visual ground survey of lanes to ensure the specified connections reflect ground truth conditions.								
System Input(s):								

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**
Notes:				

Table 126. Test Case 3.3.3.4.4.2

Requirement ID:	3.3.3.4.4.2	**Requirement Title:**	Connection Egress Lane
Description: For each permitted connection between an ingress lane and another lane, a connected intersection shall identify the other lane to which the ingress lane connects.			
Design Detail: The lane identifier of the egress lane from another lane at an intersection is represented by lane (DE_LaneID) and can be found under the data frame (DF_ConnectingLane) in the MSG_MapData message in SAE J2735_202007. An example of how an egress lane of a connection is represented lane is found in Section 4.3.3.4.4.1. Although SAE J2735_202007 allows the identifier of an egress lane to be the identifier of an ingress lane for a downstream intersection (See remoteIntersection (DF_IntersectionReferenceID) under the data frame (DF_Connection) in the MSG_MapData message, this is not recommended. By using the lane identifier of another intersection, the OBU application may need to process the MAP message for both intersections and assumes that the OBU receive the MAP message describing the downstream intersection. The guidance is to use the identifier of the egress lane at the intersection, then link the egress lane to the ingress lane of the downstream intersection if connection to the downstream intersection is desired. The egress lane can be defined by two node points 1 centimeter apart. See Section 4.3.3.4.1.12, First Node Point - Egress Vehicle Lane Design Details for additional guidance on egress lanes.			
Need ID:	2.4.3.4.4	**Need Title:**	Connections Between Lanes
Description: A connected intersection needs to provide information about the permitted connections between ingress lanes and egress lanes at an intersection so an application on an OBU/MU can determine what signal timing data from the infrastructure applies to it. The application uses this information to provide appropriate warnings, information and guidance to the driver or VRU. For example, this need ties a maneuver to a signal group so the application on an OBU can interpret what signal timing data applies.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: This requirement is verified by inspection of the MAP message data. This requirement is considered satisfied if the laneID data element (in the connectingLane data frame) is present for each specified connection.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				

Notes:

Table 127. Test Case 3.3.3.4.4.3

Requirement ID:	3.3.3.4.4.3	**Requirement Title:**	Connection Maneuvers
Description: For each permitted connection between an ingress lane and the downstream lane, a connected intersection shall identify the maneuver the connection allows. Examples of a maneuver include left turn, straight ahead, right turn on red, always yield, go after a full stop, etc.			
Design Detail: The permitted connection describes the type of maneuvers that are allowed to complete a connection between an ingress lane and an egress lane (or the next connection). The type of maneuver is represented as maneuver (DE_AllowedManeuvers) and can be found under the data frame (DF_ConnectingLane) in the MSG_MapData message in SAE J2735_202007. An example snippet of a MAP message (using JSON encoding) for a permitted connection between an ingress lane and an egress lane is found in Section 4.3.3.4.4.1.			
Need ID:	2.4.3.4.4	**Need Title:**	Connections Between Lanes
Description: A connected intersection needs to provide information about the permitted connections between ingress lanes and egress lanes at an intersection so an application on an OBU/MU can determine what signal timing data from the infrastructure applies to it. The application uses this information to provide appropriate warnings, information and guidance to the driver or VRU. For example, this need ties a maneuver to a signal group so the application on an OBU can interpret what signal timing data applies.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: This requirement is verified by inspection of the MAP message data. This requirement is considered satisfied if the allowedManeuvers bitstring data element (in the connectingLane data frame) is present for each specified connection.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 128. Test Case 3.3.3.4.4.4

Requirement ID:	3.3.3.4.4.4	Requirement Title:	Connection Signal Group
Description: For each permitted connection between an ingress lane and the downstream lane, a connected intersection shall identify the SPaT signal group that provides traffic signal control for that connection			
Design Detail: If a permitted connection is controlled by a traffic signal indication (head), then the permitted connection is tied to an identifier called the signal group. Each signal group represents a collection of connections (or movements) that may be in an active state (e.g., permissive movement allowed, or protected movement allowed) at the same time at the intersection. The signal group is represented as signalGroup (DE_SignalGroupID) and can be found under the data frame (DF_Connection) in the MSG_MapData message in SAE J2735_202007. An example of a representation of a signal group is found in Section 4.3.3.4.4.1. For every allowed connection defined for the intersection, there should be a corresponding signal group identifier for a movement state in the SPaT message, unless the connection is not controlled by the TSC CTI 4501 v1.00 CI Implementation Guide Page 174 infrastructure (See 4.3.3.3.3.1, Current Movement State for a Signal Group), in which case signalGroup data element is not sent.			
Need ID:	2.4.3.4.4	**Need Title:**	Connections Between Lanes
Description: A connected intersection needs to provide information about the permitted connections between ingress lanes and egress lanes at an intersection so an application on an OBU/MU can determine what signal timing data from the infrastructure applies to it. The application uses this information to provide appropriate warnings, information and guidance to the driver or VRU. For example, this need ties a maneuver to a signal group so the application on an OBU can interpret what signal timing data applies.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: This requirement is verified by inspection of the MAP message data. This requirement is considered satisfied if the signalGroup data element is present for each specified connection.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 129. Test Case 3.3.3.4.4.5

Requirement ID:	3.3.3.4.4.5	**Requirement Title:**	Include Only Permitted Connections
Description: A connected intersection shall only identify a connection between a lane and a downstream lane at the intersection if the movement represented by that connection is allowed at the intersection. If a permitted connection does not exist at an intersection, that connection is not included in the MAP message.			
Design Detail: Sending connections that are never permitted at an intersection can cause confusion and lead to errors. For example, an agency may have a convention that identifies four pedestrian crossings at every signalized intersection. However, if a signalized intersection only has three pedestrian crossings, the connected intersection only includes the connections for those three pedestrian crossings. If a connected intersection contains a connection that is permitted only under certain conditions, for example during a specific time of day or during special events, the ingress lane or downstream lane shall be defined as a revocable lane (See 3.3.3.4.6, Revocable Lanes). The connection would only apply if the revocable lane is currently enabled in the SPaT message. The SPaT message also indicates if the connection is in effect or not (by indicating the current movement state for the signal group associated with that connection.			
Need ID:	2.4.3.4.4	**Need Title:**	Connections Between Lanes
Description: A connected intersection needs to provide information about the permitted connections between ingress lanes and egress lanes at an intersection so an application on an OBU/MU can determine what signal timing data from the infrastructure applies to it. The application uses this information to provide appropriate warnings, information and guidance to the driver or VRU. For example, this need ties a maneuver to a signal group so the application on an OBU can interpret what signal timing data applies.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x			x	
Evaluation Methodology: This requirement is verified by inspection of the MAP message data. The connection (ingress-to-ingress or ingress-to-egress) is visualized and compared against a visual ground survey of lanes to ensure the specified connections reflect ground truth conditions.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 130. Test Case 3.3.3.4.5.1

Requirement ID:	3.3.3.4.5.1	**Requirement Title:**	Default Speed Limit
Description: A connected intersection shall provide the default posted or statutory maximum speed limit for general traffic, in units of 0.02 meters per second, for the intersection			
Design Detail: An intersection's default regulatory speed limits are represented as speedlimits (DF_SpeedLimitList) and found under the data frame DF_IntersectionGeometry in MSG_MapData message in SAE J2735_202007. All lanes associated with the intersection are assumed to use these default speed limits unless otherwise indicated. Up to nine types of default speed limits can be defined for the intersection, along with a speed measured in 0.02 meters per second. The type of speed limit is represented by DE_SpeedLimitType and speed is represented as DE_Velocity. Minimally, vehicleMaxSpeed is provided for DE_SpeedLimitType. For example, the following MAP message segment in JSON indicates maximum speed limit of 25 miles per hour in a school zone when children are present. The regulatory speed limit is specified using the speedLimits data frame containing type (DE_SpeedLimitType) and speed (DE_Velocity) in 0.02 meter/second units. …"intersections":[{"id":{"id":23},"revision":1,"refPoint":{"lat":425207879,"long":-830473419,"elevation":1890},"laneWidth":366,"speedLimits":{"type":"maxSpeedInSchool ZoneWhenChildrenArePresent","speed":559}…			
Need ID:	2.4.3.4.5	**Need Title:**	Approach Speed Limit Information
Description: A connected intersection needs to provide the posted or statutory speed limit, whichever is applicable, for each lane so an application in an OBU can provide advisories or warnings to a driver based on the speed limit.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: This requirement is verified by inspection of the MAP message data. The requirement is considered satisfied if there is at least one RegulatorySpeedLimit entry in the SpeedLimitList. SpeedLimitType and Velocity data elements shall both be specified. A minimum of one entry must indicate a value of 'vehicleMaxSpeed' for the SpeedLimitType. Note that if no additional speedLimitDetails are not provided under the laneDataAttribute data frame for a given lane, that the velocity shall match the speed limit for the given lane.								
System Input(s):								

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**
Notes:				

Table 131. Test Case 3.3.3.4.5.2

Requirement ID:	3.3.3.4.5.2	Requirement Title:	
Description: A connected intersection shall provide the posted or statutory speed limit, in units of 0.02 meters per second, for the			
Design Detail: If a lane has a speed limit that differs from the default speed limit for the intersection, the lane attribute data shall in (DF_SpeedLimitList) and found under the data frame DF_LaneDataAttribute in MSG_MapData message in SAE J2735_ speedlimits (DF_SpeedLimitList) is not sent. Up to nine types of default speed limits can be defined for the lane, along DE_SpeedLimitType and speed is represented as DE_Velocity. CTI 4501 v1.00 CI Implementation Guide Page 175 Any speed limit is first defined for the lane as ordered in the MAP message until a different speed limit is defined. For sub point, speedlimits (DF_SpeedLimitList) is not sent. For example, in Figure 34, the default speed limit for the intersecti first 50 meters from the stop bar, then 45 miles per hour upstream from that point. The maximum speed limit for lan encoding, the node points for lane ids 9, 10, 11 and 12 are the following: {"laneID":9,"laneAttributes":{…},"nodeList": {"attributes":{"data":[{"speedLimits":[{"speed":782,"type":"vehicleMaxSpeed"}]}]},{"delta":{ "nodeXY5":{"x":5000, MaxSpeed"}]}]}]}},{"laneID":10,"laneAttributes":{…},"nodeList":{"nodes":[{"delta":{"nodeXY3":{"x":- 1700,"y":180} XY4":{"x":- 3500,"y":0}}},{"attributes":{"data":[{"speedLimits":[{"speed":1008,"type":"vehicleMaxSpeed "}]}]}]},{"laneID":11,"laneAttributes":{…},"nodeList":{"nodes":[{"delta":{"nodeXY3":{"x":1800,"y":540}}},{"attribut MaxSpeed"}]}]},{"delta":{"nodeXY5":{"x":5000,"y":0}}},{"attributes":{"data":[{"speedLimits":[{"speed":1008,"type" MaxSpeed"}]}]}]},"laneID":12,"laneAttributes":{…},"nodeList":{"nodes":[{"delta":{"nodeXY3":{"x":- 1700,"y":180}} XY4":{"x":- 3500,"y":0}}},{"attributes":{"data":[{"speedLimits":[{"speed":1008,"type":"vehicleMaxSpeed "}]}]}]}}			
Need ID:	**2.4.3.4.5**	**Need Title:**	**Approach Speed Limit Informat**
Description: A connected intersection needs to provide the posted or statutory speed limit, whichever is applicable, for each lane			

Verification Method	Demonstration
Data Collection Type	Stationary
Evaluation Methodology: This requirement is only applicable for lanes that have a maximum speed limit that differs from the speed limit specif message data. The requirement is considered satisfied if there is at least one RegulatorySpeedLimit entry in the Spee must indicate a value of 'vehicleMaxSpeed' for the SpeedLimitType. The velocity shall match the speed limit for the g	
System Input(s):	

Supported Sites	GDOT	ODOT	UDOT	Other		
Notes:						

Table 132. Test Case 3.3.3.4.6

Requirement ID:	3.3.3.4.6	Requirement Title:	Revocable Lanes
Description: At intersections having lanes with usage that is different at different times, such as lanes that by time of day are reversible, have turn restrictions, or have parking restrictions, a connected intersection shall define in the MAP message separate lanes for each variation of usage and designate each as a revocable lane			
Design Detail: A revocable lane is a lane that is "active" only during certain periods of time. How a revocable lane is represented is dependent on the lane type and its attributes, as represented by laneType (DE_LaneTypeAttributes) in the data frame DF_LaneAttributes (See Section 4.3.3.4.2.3). For example, • Lane attributes for a vehicle lane are represented by vehicle (DE_LaneAttributes-Vehicle) in the data frame DF_LaneTypeAttributes • Lane attributes for a crosswalk lane are represented by crosswalk (DE_LaneAttributesCrosswalk) in the data frame DF_LaneTypeAttributes • Lane attributes for a bicycle lane are represented by bikeLane (DE_LaneAttributes-Bike) in the data frame DF_LaneTypeAttributes • Lane attributes for a tracked vehicle lane are represented by trackedVehicle (DE_LaneAttributesTrackedVehicle) in the data frame DF_LaneTypeAttributes • Lane attributes for a parking lane are represented by parking (DE_LaneAttributes-Parking) in the data frame DF_LaneTypeAttributes Regardless of the lane type, a revocable lane is represented by a value of 1 for Bit 0 of the DE_LaneAttributes-xxxx, where xxxx is the type of lane. Whether the lane for an intersection is "active" or "enabled" is defined by the Enabled Lanes indication in the SPaT message for the same intersection (See Section 4.3.3.3.7, Enabled Lanes Indication).			
Need ID:	2.4.3.4.6	**Need Title:**	Revocable Lanes
Description: A connected intersection needs to identify lanes that are revocable. An IOO may define the same physical lane for different uses or with different restrictions depending on the time of day or on specific days. For example, a lane may be defined as an HOV lane during the morning rush hours, a reversible lane for special events (such as at an arena), and as a normal vehicle lane during all other times. NOTE: The SPaT message will then identify which revocable lane is currently is active			

Verification Method	Demonstration	Test	Analyze	Inspection	Other			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x			x	
Evaluation Methodology: This requirement is only applicable for lanes that vary in operation (i.e. have lane-specific MAP message attributes that may change during the course of normal intersection operations). This requirement is verified by inspection of the MAP message data. The RevocableLanes data are visualized and compared against a visual ground survey of lanes to ensure all intersection operational states are accounted for.								
System Input(s):								

Supported Sites	GDOT	ODOT	UDOT	Other

Notes:

Table 133. Test Case 3.3.3.4.7

Requirement ID:	3.3.3.4.7	Requirement Title:	MAP Message - Accuracy
Description: A connected intersection shall broadcast MAP messages that accurately reflect the physical location and dimensions of all travel lanes traversing the intersection within defined tolerances.			
Design Detail: No design details provided at this time.			
Need ID:	2.4.3.4.8	**Need Title:**	Signal Timing and Roadway Geometry Synchronization
Description: A connected intersection shall provide an intersection reference identifier for the SPaT message that matches the intersection reference identifier used in the MAP message for the same intersection. The intersection reference identifier consists of the road regulator identifier (See 3.3.3.3.1.2) and the intersection identifier (See 3.3.3.3.1.3)			

Verification Method	Demonstration	Test	Analyze	Inspection	Other			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x			x	
Evaluation Methodology: This requirement is verified by comparison of the road regulator identifier (See 3.3.3.3.1.2) and the intersection identifier (See 3.3.3.3.1.3) in both the SPaT and MAP messages broadcast from an intersection. Furthermore, the RSU is expected to be co-located with the reference point defined in the MAP message								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 134. Test Case 3.3.3.4.8.1

Requirement ID:	3.3.3.4.8.1	**Requirement Title:**	Matching Intersection Reference Identifier
Description: A connected intersection shall provide an intersection reference identifier for the SPaT message that matches the intersection reference identifier used in the MAP message for the same intersection. The intersection reference identifier consists of the road regulator identifier (See 3.3.3.3.1.2) and the intersection identifier (See 3.3.3.3.1.3)			
Design Detail: No design details provided at this time.			
Need ID:	2.4.3.4.8	**Need Title:**	Signal Timing and Roadway Geometry Synchronization
Description: A connected intersection needs to ensure that roadway geometry information being broadcast reflects the current operating state used to generate the signal timing data. The signal timing data and roadway geometry data cannot be viewed as independent, but BOTH need to reflect the actual usage. The signal timing data and the operating roadway geometry HAVE to be agreement. If an entity changes the design geometry environment, it may necessitate a change in the signal timing data			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
	x			x				
Evaluation Methodology: This requirement is verified by comparison of the road regulator identifier (See 3.3.3.3.1.2) and the intersection identifier (See 3.3.3.3.1.3) in both the SPaT and MAP messages broadcast from an intersection. Furthermore, the RSU is expected to be co-located with the reference point defined in the MAP message.								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

Table 135. Test Case 3.3.3.4.8.2

Requirement ID:	3.3.3.4.8.2	Requirement Title:	Matching SPaT and MAP Version
Description: The contents of the SPaT message broadcasted for an intersection shall be consistent/compatible with the MAP message broadcasted for the same intersection. For example, if the physical roadway geometry changes, the SPaT message may need to be updated to reflect those changes.			
Design Detail: The purpose of this requirement is that the contents of the SPaT message is consistent with the MAP message being broadcasted. An example of consistency includes that the SPaT message provides state and timing information for a left turn into a lane that is defined and allowed in the MAP message. The intent of requirement 3.3.3.4.8.2, mMatching SPaT and MAP Version is NOT that a connected intersection be able to "automatically" identify that the SPaT and MAP messages are consistent with each other. Rather, the intent of this requirement is that the IOO managing the connected intersection define policies and guidelines to prevent situations where SPaT and MAP message may conflict with each other. Polices and guidelines should address temporary situations, such as a temporary work zone; and permanent situations, such as permanent changes to the intersection configuration. For example, the traffic signal timing plan currently being implemented by a TSC infrastructure is designed for a specific geometric configuration. However, what happens during the following scenarios: • There are changes to the lane striping - should the connected intersection stop broadcasting the SPaT message and/or the MAP message while the striping work is underway? CTI 4501 v1.00 CI Implementation Guide Page 177 • What if the egress lane for a left-turn lane movement is temporarily closed for a construction - should the MAP allowing that left turn still be broadcasted? • After a re-striping project - should the SPaT and MAP message be checked and verified before the messages are broadcasted again? This is particularly important if the source of the SPaT and MAP messages are generated from different sources (e.g., a traffic engineering department for the SPaT message and a street construction department for the MAP message). Be aware that some OBUs may have the capability to store MAP information, so OBU applications may reference its stored copy of the MAP data even if the MAP message is not broadcasted by the connected intersection. This requirement is verified (tested) by inspection and/or demonstration. The method of verification can be decided by the IOO. Note: The standards can support different methods for verifying some form of consistency between the SPaT and MAP messages. For example, NTCIP 1202 v03A allows a traffic signal controller to verify against a checksum of the MAP message broadcasted before the SPaT data is generated. A SPaT message can also be tied to a specific version of a MAP message, e.g., the revision counter increment (See Section 4.3.3.2.2.3, MAP Message - Revision Counter Increment).			
Need ID:	2.4.3.4.8	**Need Title:**	Signal Timing and Roadway Geometry Synchronization
Description: A connected intersection needs to ensure that roadway geometry information being broadcast reflects the current operating state used to generate the signal timing data. The signal timing data and roadway geometry data cannot be viewed as independent, but BOTH need to reflect the actual usage. The signal timing data and the operating roadway geometry HAVE to be agreement. If an entity changes the design geometry environment, it may necessitate a change in the signal timing data			

Verification Method	Demonstration	Test	Analyze	Inspection	Other			
	Stationary	Driving	Video	pcap	Ground Truth	Test Tool	Survey	Other

Data Collection Type	x			x				

Evaluation Methodology:
See verification for 3.3.3.4 and 3.3.3.3.3.1

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**	

Notes:

Table 136. Test Case 3.3.3.5.1

Requirement ID:	3.3.3.5.1	**Requirement Title:**	Positioning Corrections
Description: An RSU shall broadcast Radio Technical Commission for Maritime Services (RTCM) corrections per RTCM10403.3, and with Multiple Signals Messages (MSM) 4. The messages consist of the following: a) Station location message numbers 1005 and 1006. b) The GNSS antenna and receiver location message 1033 (per the RTCM recommendation). c) The system parameter message 1013. NOTE: Vehicles may use other sources of correction or means for achieving the necessary precision.			
Design Detail: The SAE J2735_202007 RTCMcorrections message ASN.1 representation is as follows: RTCMcorrections ::= SEQUENCE { msgCnt MsgCount, rev RTCM-Revision, timestamp MinuteOfTheYear OPTIONAL, anchorPoint FullPositionVector OPTIONAL, rtcmHeader RTCMheader OPTIONAL, msgs RTCMmessageList, regional SEQUENCE (SIZE(1..4)) OF RegionalExtension {{REGION.RegRTCMcorrections}} OPTIONAL, … } A connected intersection shall increment msgCnt (DE_MsgCount) by 1 each time the RTCMmessageList contents change. Zero follows a value of 127. A connected intersection shall use a value of rtcmRev3 for rev (DE_RTCM_Revision) to indicate that RTCM corrections are per RTCM10403.3. The OPTIONAL MinuteOfTheYear field shall not be included in the RTCMcorrections message. The anchorPoint (DF_FullPositionVector) for a connection intersection shall include UTC, latitude, longitude, and elevation. UTC is the time at which the CI receives the corrections information included in RTCMmessage list from the reference station. The latitude, longitude, and elevation are at the location of the RTCM reference station antenna. All other fields in DF_FullPositionVector shall not be included. CTI 4501 v1.00 CI Implementation Guide Page 178 Note: The UTC timestamp within FullPositionVector is within +/- 10 ms of UTC as stated in the RSU Standard v01. If the RTCM corrections are being generated virtually from multiple sources, the latitude, longitude, and elevation is the location of the virtual reference (usually the RSU location at CI). Note: The location of the reference station may be used by the OBU to check the proximity of the reference station (source of the corrections). The UTC information may be used to check the age of the information. Both the time and location information may not be the same as the generation location and time information included in the security header of a signed RTCMcorrections message (i.e., it is likely different if the RSU is not the source of the corrections). The OPTIONAL RTCMheader field shall not be included in the RTCMcorrections message. Support for RTCM MSM 4 messages (station location message numbers 1005 and 1006, GNSS antenna and receiver location message 1033, system parameter message 1013) are mandatory and sufficient to support the RLVW application. An implementation may also provide MSM 5, 6, or 7 to support other corrections capabilities in addition to MSM 4. Implementations shall minimally support GPS and at least one of the following constellations: GLONASS, Galileo, QZSS, and BeiDou. A connected intersection shall include only one RTCM message received from the reference station in DF_RTCMmessageList. The RSU shall broadcast an RTCMcorrections message for each message received from the reference station. The regional (DF_RegionalExtension) field shall not be included in RTCMcorrections message			
Need ID:	2.4.3.5.1	**Need Title:**	Positioning Corrections
Description: A connected intersection needs to provide data in a standardized format that helps vehicles to achieve the required positioning and timing accuracy at intersections where this is needed. For example, position corrections data may provide information that allows an application on an OBU/MU to calculate its current position with enough accuracy to determine which lane it is in.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**	

Data Collection Type	Stationary	Driving	Video	pcap	Ground Truth	Test Tool	Survey	Other
	x			x				

Evaluation Methodology:
This requirement is verified through decoding the RTCMmessage data elements within the RTCM message. This requirement is considered satisfied if the following RTCM message types are observed from each broadcast location: 1005, 1006, 1033, 1013,

System Input(s):

Supported Sites	GDOT	ODOT	UDOT	Other	

Notes:

Table 137. Test Case 3.3.3.5.2.1

Requirement ID:	3.3.3.5.2.1	**Requirement Title:**	RSU Proximity
Description: The RTCM reference station providing correction messages shall be close enough to the RSU to provide adequate accuracy and latency. NOTE: The RSU may have integrated RTCM capabilities, or the RTCM could be generated by a nearby station. The RSU should broadcast a calculated RTK if it is far from a surveyed reference station			
Design Detail: This section specifies the maximum distance allowed between a real-time kinematic (RTK) reference station and an RSU at any connected intersection seeking to broadcast this reference station's differential GNSS corrections formatted according to the RTCMv3.3 standard1 (Note: the referenced link indicates v3.2, but the text is for v3.3). The varied range of the operational conditions seen by GNSS receivers across urban and rural environments2 and the unpredictability of atmospheric and space weather3 events affect the acceptable maximum distance. The following design requirements are recommended: • Any RTK reference station which is to be used as a source for the CI's SAE J2735_202007 RTCM Message shall be within 25 miles of the CI. This is based on engineering judgement, 1 RTCM 10403.3, Differential GNSS (Global Navigation Satellite Systems) – Radio Technical Commission for Maritime Services 2 Minimizing Errors during GNSS Data Collection - Video Library - NGS Training and Testing Center - National Geodetic Survey (noaa.gov) 3 Space Weather and GPS Systems | NOAA / NWS Space Weather Prediction Center CTI 4501 v1.00 CI Implementation Guide Page 179 combined with references4,5,6 which indicate 20 km is the maximum distance to base station where centimeter-level accuracy can be obtained. • The reference station shall be placed away from any sources of potential systematic errors, e.g., multi-path error; use the open sky definition in J2945/1 as a reference. • It is recommended that the location of the reference station be reviewed and/or be configured by a qualified subject matter expert. • It is recommended that the RTK reference station be located as close as possible to the connected intersection; the 25-mile requirement noted above is a maximum and locating the RTK reference station closer is preferred. The following must be noted as the distance between the reference station and its targeted receivers grows: • The underlying assumptions behind the RTK error correction equations physically limit the distance between the rover and reference station to approximately 25 miles. • Relative positioning error is induced between the position of the reference station and that of the receiving rover. This distance induced relative positioning error is manufacturer and installation dependent. • The availability of the relevant correction signals may be reduced due to differences in visible satellites between rovers and the reference station. • Transfer of RTCM correction data from the reference station to the RSU for SAE J2735_202007 encoding and broadcast may become more challenging and/or less reliable depending on the method of transport (LTE vs. Wire/Fiber vs. UHF radio modem). • Transfer of RTCM correction data and the integrity of the RTK reference station need to ensure the security of this information and need to be subject to the same security as the balance of the CV environment. It is important to note that the CI Committee also considered whether to recommend that GNSS position correction mechanisms other than RTK, such as precise point positioning (PPP) or other state-space representation (SSR) methods be broadcast by RSUs at connected intersections. The current state of the art SSR correction methods tend to use proprietary methods and message formats, proving to be even more challenging to validate than RTCM formatted correction messages. Their reported time to providing a receiver with a corrected solution under cold start conditions and following a system outage or rover disturbance also tends to be longer than conventional, single reference station-based, RTK correction methods. Finally, the business model of SSR correction providers leans on a per unit subscription model which would further increase the cost of deployment for IOOs. A single reference station within the requirement specified distance to any RSU can be used to provide RTK RTCM formatted corrections to many RSUs, only to be limited by the available communication bandwidth and the communication network			

architecture.

Need ID:	2.4.3.5.2	**Need Title:**	Real-Time Kinematic Corrections

Description:
When implementing Real-time Kinematic (RTK) positioning, all GNSS devices in the broader IOO system implementation need to use and broadcast a common RTCM corrections source as an RTCM broadcast, or the devices need to use a common (network-based, not broadcast) RTCM corrections source for their position correction.

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
								None

Evaluation Methodology:
This requirement is verified if there is at least one reference station within 25 miles of the test site, or a calculated value from multiple reference stations is used.

System Input(s):

Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**

Notes:
Is this outside the scope of message verification?

Table 138. Test Case 3.3.3.5.2.2

Requirement ID:	3.3.3.5.2.2	**Requirement Title:**	Minimum RTCM Corrections Broadcast Frequency
Description: An RSU shall broadcast RTCM corrections to OBUs with sufficient range and frequency for vehicles to enable lane matching at a minimum of 10 seconds at the 85th percentile speed or a speed equal to the posted or statutory speed limit plus 7 miles per hour (mph) before approaching vehicles would reach the stop line for each approaching lane.			
Design Detail: The design requirements are as follows: • MSM 4 correction broadcast rate (messages 1074, and 1084 and / or 1124) is tunable between 10 Hz (maximum rate) and 1 Hz (minimum rate). • Messages 1005 or 1006, and 1013 and 1033 are combined into one J2735 RTCMcorrections messages and sent no more frequently than once per second (1 Hz). 4 https://www.hindawi.com/journals/js/2019/3572605/ 5 https://www.ardusimple.com/rtk-explained/ 6 https://www.e-education.psu.edu/geog862/node/1845 CTI 4501 v1.00 CI Implementation Guide Page 180 The assumptions and calculations that led to the above design requirements are provided in Annex 0, RTCM Corrections Broadcast Rate Calculations			
Need ID:	2.4.3.5.2	**Need Title:**	Real-Time Kinematic Corrections
Description: When implementing Real-time Kinematic (RTK) positioning, all GNSS devices in the broader IOO system implementation need to use and broadcast a common RTCM corrections source as an RTCM broadcast, or the devices need to use a common (network-based, not broadcast) RTCM corrections source for their position correction.			

Verification Method	**Demonstration**	**Test**	**Analyze**	**Inspection**	**Other**			
Data Collection Type	**Stationary**	**Driving**	**Video**	**pcap**	**Ground Truth**	**Test Tool**	**Survey**	**Other**
		x		x				
Evaluation Methodology: See Appendix X - Message transmission range methodology. Max range must exceed distance specified in requirement (given 85th percentile speed or speed limit).								
System Input(s):								
Supported Sites	**GDOT**	**ODOT**	**UDOT**	**Other**				
Notes:								

9. Test Scenarios

Table 7 summarizes the test scenario information.

Note: This will be completed as the information becomes available.

Table 139. Test Scenarios

Function	Acceptance Test Scenario	Scenario Description	Test Case ID Reference	Requirement ID Reference

Source: WSP USA

10. Test Procedures

Table 8 summarizes the test procedure information.

Note: This will be completed as the information becomes available.

Table 140. Test Procedures

TEST CASE ID	Objective	Entrance Criteria	Procedure	Exit Criteria	Data Output

Source: WSP USA

Appendix A. Test Result Summary

This appendix contains some of the Microsoft Excel Tools utilized to capture and document test activities.

A.1 TEST RESULTS

Table 141 Is the Test Result Log utilized to record the results of each test.

Table 141: Test Result Log

Date	Name	Tester Role	Test Id	Test Objective	Run Number	Test Result (P/F)	Comment

Source: WSP USA

A.2 DEFECT TRACKER

The defect tracker will be used during testing to capture, track, monitor, and address anomalies observed during testing. For each entry, the development team will work to understand and reproduce (where possible) the defect, identify the root cause, summarize a response and log the activities taken to resolve the issue. As outlined in Section 6.5.9, the defect tracker helps with prioritizing defects based on severity level (critical to low) and maintains traceability to the test ID as well as status. The status field provides a simplified view of the various states a defect passes through as it moves toward resolution and closure.

A defect can have the following status values:

- **Opened** – indicates the defect has been logged and reported for correction.
- **Re-Opened** – indicates a defect was once closed and then re-opened for modification.
- **Closed** – indicates a defect was received, reviewed, and determined was not a defect (i.e., duplicate entry or a request for enhancement). In these cases, no corrective action is taken, and an explanation is provided by the development team while closing out the defect ticket.
- **Canceled** – indicates a scenario or test case where the defect derived was canceled and therefore, the defect is canceled by default.
- **Resolved** – indicates a defect has been successfully reviewed, verified, and a resolution was implemented to solve the problem along with the date the defect was corrected.

- **Returned** – indicates the defect was returned to the tester for additional information.
- **Deferred** – indicates the defect has been designated for correction for a later date.

In cases when a conflict arises between a design element that is tied to a requirement and a software product, the development manager will coordinate with the test manager to determine if a change to the system design and/or requirement is appropriate. The City of Columbus project manager will carefully review all requests to make a change that impacts the system design and requirements. All change requests will be captured within the change log tool.

Table 142 is a sample Defect Tracker that will be used for this project.

Table 142: Defect Tracker

Date	Defect No.	Defect Description	Severity	Defect Status	Test Id	Date Found	Assigned To	Resolution Description	Comments

Source: WSP USA

A.3 CHANGE REQUEST LOG

Table 143 is a sample Change Request Log for the CVE.

Table 143: Change Request Log

CR Id	Description	Justification	Defect Id	Requirement	Status

Source: WSP USA

A.4 TEST SUMMARY

Table 144 is sample Test Summary Report

Table 144: Test Summary Report

Date	Test Cases Planned	Test Cases Executed	Test Cases Passed	Test Cases Failed	Test Cases Deferred

Source: WSP USA

Table 13 is a sample Defect Matrix

Table 145: Defect Matrix

Defect Release	Open	Closed	Canceled	Resolved	Deferred

Source: WSP USA

A.5 TEST CASE STATUS

Table 146 is a sample Change Request Log.

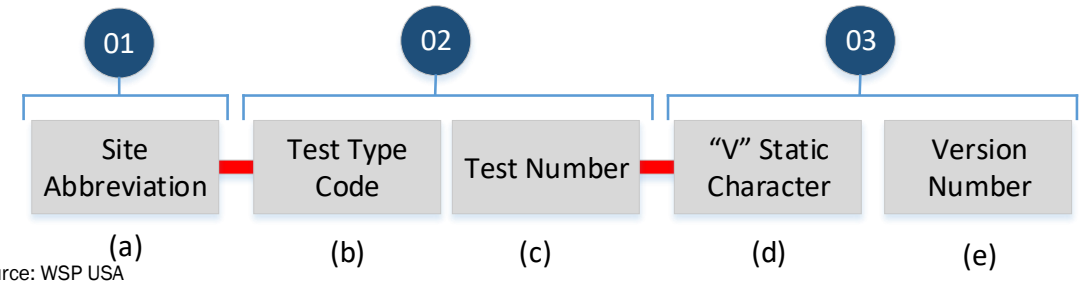
Table 146: Test Case Status

Test ID	Test Objective	No. of Test Runs	Expected Outcome	Status

Source: WSP USA

Appendix B. Numbering Convention

Each testing element contains a unique identifier for traceability and configuration management. Test cases and scenarios for all sites will follow the same convention, each representing an identifiable attribute of the traced metric. The convention is as follows:



Source: WSP USA

Figure 6: Numbering Convention

Table 147: Numbering Convention

Octet	Description	Data Type	Number of Characters or Digits
a. Site Abbreviation	The designated site abbreviation, GDOT, DRVOH, UDOT	String, upper case	Variable
b. Test Type Code	• FMT: Test Case for the Format Test • CNT: Test Case for the Content Test • RNG: Test Case for the Range Test • REL: Test Case for the Reliability Test • OEM: Test Scenario	String, upper case	3
c. Test Number	An integer incrementing by one, indicating the number of requirements established.	Integer	3
d. "V" Static Character	Static letter "V" represents the version for the particular test objective and procedure.	Character	1
e. Version Number	An integer incrementing by one, indicating the number of revisions made to the test element being traced.	Integer	2

Source: WSP USA

An example of a test case for the integration of could be GDOT-FMT001-V01.

- "GDOT" is the site abbreviation.
- "FMT001" is the test type code coupled with the three-digit test number.
- "V01" is the static "V" coupled with the two-digit version number.

Appendix C. Acronyms and Definitions

Appendix D. Test Corridor Site Details

D.1 SITE 1- GEORGIA DOT "THE RAY"

D.1.1 Description

Georgia DOT has offered an 18-mile stretch along I-85 and SR-403 in the state's southwest corner, close to the Georgia/Alabama border. Known as "The Ray," the region is an emerging testbed for advanced mobility and technology solutions. There are 6 signalized intersections and 6 freeway locations that have been equipped with dual-mode CV technology. For this project, the expectation is to use C-V2X.

D.1.2 Site Map

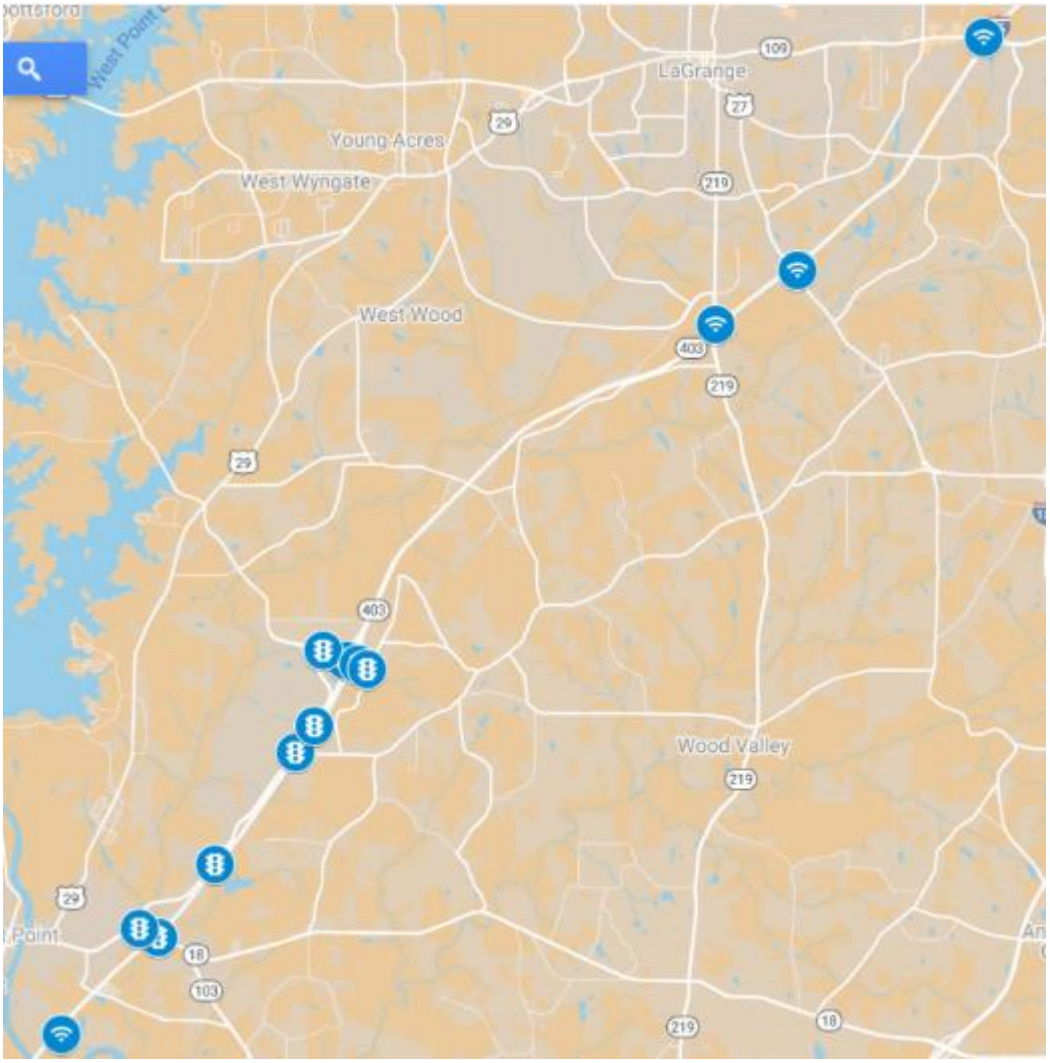


Figure 7. Georgia DOT "The Ray" Overview Map

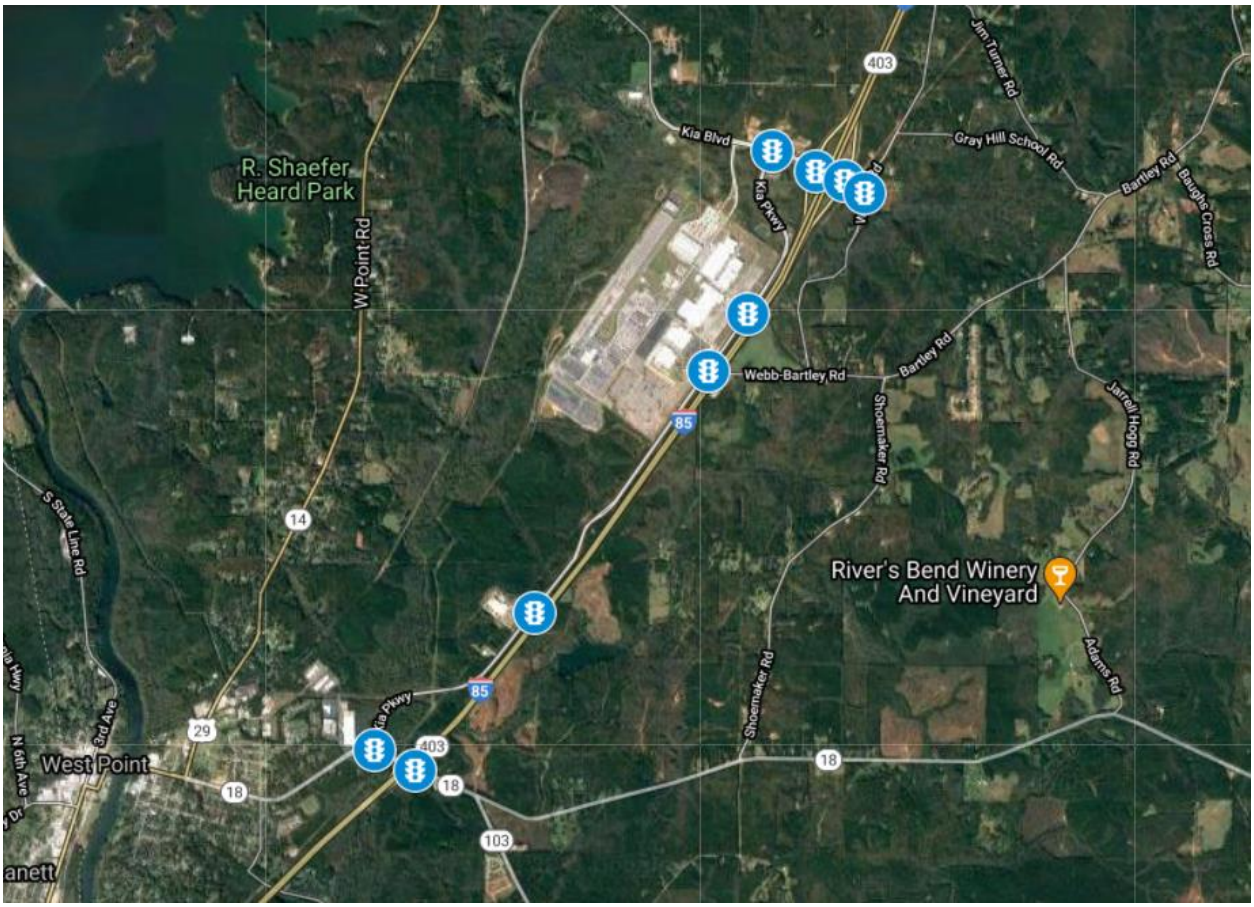


Figure 8. GDOT Signalized Locations

D.1.3 Hardware

Table 148. GDOT Hardware

Hardware	Vendor	Quantity
Signal Controller	Intelight	
Roadside Unit	Kapsch	
Position Correction		2

Source: WSP USA

D.1.4 Facilities

D.1.5 Schedule

D.1.6 Partners

Alan Davis will serve as the primary point of contact for testing at this site. Panasonic is the lead integrator and will assist with the test activities.

D.1.7 Site-Specific Test Cases

D.2 SITE 2 – DRIVE OHIO "CONNECTED MARYSVILLE"

D.2.1 Description

Drive Ohio has offered 6 signalized intersections that are part of the broader US 33 Smart Mobility Corridor. Specifically, six (6) signalized intersections located in Marysville, OH, at the intersection of US 33 and US 36. For this project, the expectation is to use DSRC.

D.2.2 Site Map

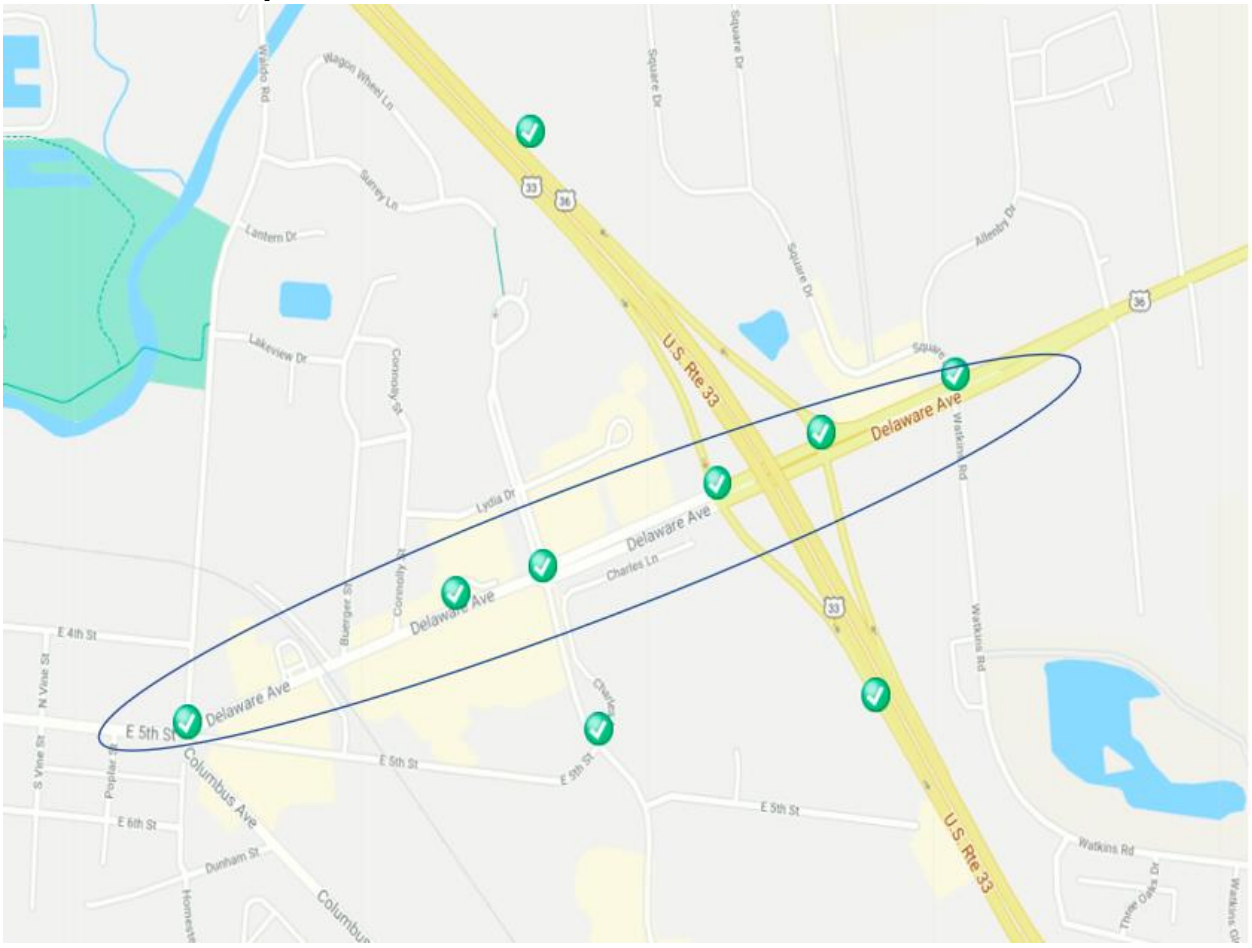


Figure 9. Drive Ohio Signalized Locations

D.2.3 Hardware

Table 149. Drive Ohio Hardware

Hardware	Vendor	Quantity
Signal Controller	Econolite Cobalt	6
Roadside Unit	Kapsch and Kapsch	3 ea.
Position Correction	Trimble	2

Source: WSP USA

D.2.4 Facilities

D.2.5 Schedule

D.2.6 Partners

Nick Hegemier at Drive Ohio will serve as the primary point of contact for testing at this site. MH Corbin is the lead integrator and will assist with the test activities. Honda is expecting to serve as the OEM.

D.2.7 Site-Specific Test Cases

D.3 SITE 3 – UTAH DOT "PARK CITY"

D.3.1 Description

The UDOT test site spans 8 intersections, along SR-224 between I-80 and Park City, equipped with Kapsch dual mode RSUs operating in C-V2X mode.

D.3.2 Site Map

Source: CAMP

D.3.3 Hardware

Table 150. UDOT Test Site Hardware

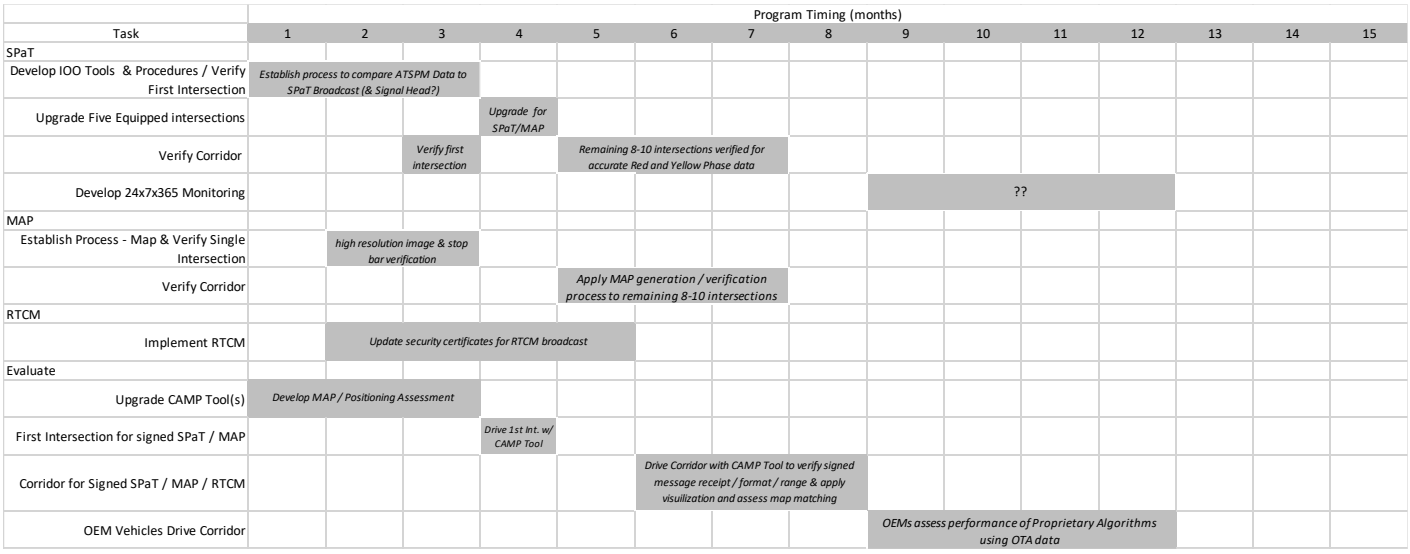
Hardware	Vendor	Quantity
Signal Controller		
Roadside Unit	Kapsch	8
Position Correction		

Source: WSP USA

D.3.4 Facilities

The project is in the field-testing phase; no bench facility will be provided.

D.3.5 Schedule



Source: CAMP

D.3.6 Partners

Blaine Leonard at UDOT will serve as the primary point of contact for the UDOT site. The UDOT team and their partners at CAMP are leading the testing efforts at this site.

D.3.7 Site-Specific Test Cases