

SPaT V2I Interface for Red Light Violation Warning System Requirements Specification

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Prepared by:

Cooperative Automated Transportation (CAT) Coalition - IOO/OEM Forum

Primary Author:

Ray Starr, Minnesota Department of Transportation

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1 Introduction

1.1 Background

Vehicle to Infrastructure (V2I) communications can improve traffic safety by enabling vehicles to utilize information from the roadside, such as from traffic signals, to support the driver in the driving task or to support automated driving systems. One V2I application that has progressed to a certain level of maturity in research and developmental testing is Red Light Violation Warning (RLVW).

Standards exist defining the communications technology and data messages between an equipped traffic signal and equipped vehicle to support RLVW. IEEE 802.11p defines Dedicated Short Range Communications (DSRC), based on WiFi standards. IEEE 1609 defines security and other aspects of communications. SAE J2735 defines Signal Phase and Timing (SPaT) and MAP messages that describe intersection geometry, traffic signal status, traffic signal state and traffic signal timing to a vehicle near an equipped intersection. Many of these standards have optional data elements and multiple allowed methods for conveying information. These options can result in different intersections being differently equipped to provide MAP and SPaT data in a manner that complies with the standards but is not interoperable. In order for RLVW to become widespread in production vehicles and traffic signals, it is important to apply the standards uniformly across North America.

The Crash Avoidance Metrics Partners LLC (CAMP) as part of the Infrastructure Owner Operator / Original Equipment Manufacturer (IOO/OEM) Forum of the Cooperative Automated Transportation (CAT) Coalition has performed field testing of RLVW at multiple intersections that are equipped to provide SPaT and MAP messages. As a result of this testing, CAMP has identified and documented verification requirements, test procedures, unexpected results, and inconsistencies in the application of the standard. Documentation of these findings is distributed across many individual documents identified in the Referenced Documents section of this System Requirements Specification (SRS). None of the individual documents provides a comprehensive view of the requirements that have evolved for supporting RLVW.

1.2 Purpose

The purpose of this SRS and its associated Concept of Operations (ConOps) is to consolidate the findings of the several IOO/OEM forum documents, discussions that have been held and additional observations into a more structured and comprehensive form for consideration in future standards or guidance creation efforts by others.

This SRS is focused on the SPaT V2I Interface for RLVW and is not an SRS for a complete SPaT infrastructure system at a specific intersection. Because of this focused purpose of the SRS, it does not address all of the requirements of the system, only those of the SPaT V2I Interface for RLVW. Other applications in addition to RLVW would entail additional requirements beyond those included in this SRS. The IOO implementing a SPaT enabled intersection may want to consider implementing other applications along with RLVW.

1.3 Document Overview

This SRS documents requirements for the SPaT V2I Interface for RLVW and provides design details for the message data elements used over the interface. The companion document to this SRS is the SPaT V2I Interface for Red Light Violation Warning Concept of Operations, which documents user needs that are the source of the requirements in this SRS.

2 SPaT V2I Interface for RLVW Requirements

The requirements in this SRS are traceable to the user needs identified in the SPaT V2I Interface for RLVW ConOps. Only requirements that apply to the SPaT V2I Interface and only to the RLVW application are included. Any additional functionality or data elements not included in these requirements are considered to be optional, and the SPaT Vehicle System is not guaranteed to be able to utilize them. Other SPaT V2I applications may need additional functionality and data elements beyond those required for RLVW in this SRS.

Each requirement has a title (informative, not normative), the actual requirement (normative), a reference to a need from the ConOps, optionally a reference to other documents and optionally one or more Notes.

SPaT V2I Interface for RLVW requirements are organized into the following categories:

- General Requirements
- MAP Requirements
- SPaT Requirements
- Location Correction Requirements
- Security Requirements

2.1 General Requirements

2.1.1 IEEE 802.11p

The SPaT Infrastructure System over-the-air interface shall conform to IEEE 802.11p for 5.9 GHz DSRC.

Need: ConOps 3.1 Standard Communications Technology

NOTE: The communications technology is subject to change contingent upon FCC rulings and OEM rollout announcements.

2.1.2 IEEE 1609

The SPaT Infrastructure System over-the-air interface shall conform to the IEEE 1609.x family of standards.

Need: ConOps 3.1 Standard Communications Technology

2.1.3 UPER Encoding

The SPaT Infrastructure System shall encode messages using Unaligned Packed Encoding Rules (UPER).

Need: ConOps 3.1 Standard Communications Technology

2.1.4 Time Accuracy

For messages that include time, the SPaT Infrastructure System shall provide time that is accurate to within 10 milliseconds (ms) of Coordinated Universal Time (UTC).

Need: ConOps 3.4 Common Time Reference

Reference: CCIs 2.1.1 Time accuracy and synchronization

2.1.5 Every Lane

The SPaT Infrastructure System shall broadcast messages such that they can be received by DSRC on-board units in each lane approaching the intersection.

Need: ConOps 3.8 Coverage

2.1.6 300 M Coverage

The SPaT Infrastructure System shall broadcast messages with no more than 10% packet data loss to a distance of at least 300 meters upstream of the stop bar for each approaching lane.

Need: ConOps 3.8 Coverage

2.2 MAP Requirements

2.2.1 SAE J2735

The SPaT Infrastructure System shall broadcast MAP messages that conform to SAE J2735.

Need: ConOps 3.2 Standard Messages

2.2.2 Channel 172

The SPaT Infrastructure System shall broadcast MAP messages on DSRC channel 172.

Need: ConOps 3.1 Standard Communications Technology

2.2.3 PSID 0x82

The SPaT Infrastructure System shall broadcast MAP messages using PSID 0x82.

Need: ConOps 3.1 Standard Communications Technology

2.2.4 1Hz Frequency

The SPaT Infrastructure System shall broadcast MAP messages periodically at 1 HZ.

Need: ConOps 3.9 Timeliness

2.2.5 Message Revision Counter Increment

The SPaT Infrastructure System shall increment a message counter for a MAP message whenever any data element in the message except the time stamp changes.

Need: ConOps 3.6 Message Revision

2.2.5.1 Message Revision Counter Not Increment

The SPaT Infrastructure System shall not increment a message counter for a MAP message if no data element in the message except the time stamp changes.

Need: ConOps 3.6 Message Revision

2.2.6 Intersection Geometry

The SPaT Infrastructure System shall provide the intersection geometry for one or more intersections.

Need: ConOps 3.12 Intersection Geometry

2.2.7 Intersection Reference Identifier

The SPaT Infrastructure system shall provide an intersection reference identifier unique within North America for each SPaT enabled intersection included in the MAP message.

Need: ConOps 3.11 Unique Intersection Identification

2.2.7.1 Road Regulator Identifier

The SPaT Infrastructure system shall provide an intersection reference identifier that includes a road regulator identifier unique within North America.

Need: ConOps 3.11 Unique Intersection Identification

NOTE: A system to uniquely assign road regulator IDs in North America has not yet been developed. Until such a system is developed, an IOO should use a road regulator ID of zero, which the ID for testing purposes. The IOO will need to coordinate with other IOOs in the nearby geographic area of the SPaT enable intersection to ensure that the same intersection ID is not duplicated between nearby intersections.

2.2.7.2 Intersection Identifier

The SPaT Infrastructure system shall provide an intersection reference identifier that includes an intersection identifier unique within the road regulator identifier.

Need: ConOps 3.11 Unique Intersection Identification

2.2.8 Intersection Revision Counter Increment

The SPaT Infrastructure System shall increment a message counter for the intersection description within a MAP message whenever any data element in the intersection description changes.

Need: ConOps 3.6 Message Revision

NOTE: 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 would happen when a different intersection description in the MAP message changes but not this intersection description.

2.2.8.1 Intersection Revision Counter Not Increment

The SPaT Infrastructure System shall not increment a message counter for an intersection description within a MAP message if no data element in the intersection description changes.

Need: ConOps 3.6 Message Revision

2.2.9 Intersection Reference Point

The SPaT Infrastructure System shall provide an intersection reference point that includes latitude and longitude and that is within the latitude and longitude range of all the lane node points associated with the intersection.

Need: ConOps 3.12 Intersection Geometry

NOTE: It is customary but not required to use the center of the intersection as the reference point. For example, a traffic signal pole with a known location at the intersection could be the reference point.

2.2.9.1 Reference Point Precision

The SPaT Infrastructure System shall provide an intersection reference point that includes latitude and longitude with a minimum of six significant decimal places for better than 0.11132 meter accuracy.

Need: ConOps 3.12 Intersection Geometry

Reference: CCIs 2.1.3 Approach to node point latitude/longitude Representation

NOTE: The SAE J2735 standard calls for expressing the latitude and longitude in 1/10 micro degrees.

2.2.10 Lane Width

The SPaT Infrastructure System shall provide the width of the lanes at the intersection.

Need: ConOps 3.12 Intersection Geometry

2.2.11 Lane Identifier

The SPaT Infrastructure System shall provide a lane identifier unique within the intersection for each lane.

Need: ConOps 3.12 Intersection Geometry

2.2.12 Direction of Travel

The SPaT Infrastructure System shall identify each direction of travel allowed for each lane.

Need: ConOps 3.13 Lane Attributes

2.2.13 Revocable Lanes

At intersections having lanes with useage that is different at different times, such as lanes that by time of day are reversible, have turn restrictions, or have parking restrictions, the SPaT Infrastructure System shall define in the MAP message separate lanes for each variation of useage and designate each as a revocable lane.

Need: ConOps 3.17 Enabled Lanes

2.2.14 Lane Maneuvers

The SPaT Infrastructure System shall identify for each lane each maneuver that is allowed for that lane at the stop bar for ingress lanes and at the downstream point for egress lanes.

Need: ConOps 3.14 Allowed Maneuvers

NOTE: Since the maneuvers identified for the lane are the maneuvers allowed at the stop bar, a through lane will not show an allowed turning maneuver that will use a separate turn lane that begins downstream of where the through lane begins, even though turning traffic will be using the through lane until they reach the beginning of the turn lane.

NOTE: This contradicts CCI 2.1.6 Configuration of turn lanes which suggests breaking the through lane at the start of the turn and showing a connection to the turn lane and to the remainder of the downstream through lane. Breaking the through lane at the start of the turn lane is not the common practice, and so was not adopted in this SRS.

2.2.15 Center of Lane Geometry

The SPaT Infrastructure System shall describe the geometry of the center of each lane approaching (ingress) and departing (egress) the intersection.

Need: ConOps 3.12 Intersection Geometry

2.2.15.1 At Least 2 Nodes

The SPaT Infrastructure System shall describe the geometry of the center of the lane by identifying at least two node points that define at least one line segment depicting the center of the lane.

Need: ConOps 3.12 Intersection Geometry

2.2.15.2 First Node at Stop Bar

The SPaT Infrastructure System shall describe the first node point at the stop bar of the lane, with each subsequent node being farther from the intersection.

Need: ConOps 3.12 Intersection Geometry

2.2.15.3 At Least 300 M

The SPaT Infrastructure System shall describe ingress lanes from the stop bar to a minimum of 300 meters upstream of the stop bar.

Need: ConOps 3.8 Coverage

2.2.15.4 Density of Nodes

When describing a lane with a horizontal curve, the SPaT Infrastructure System shall include enough nodes such that the distance between the actual curved lane center line and the straight line connecting nodes shall not be more than 0.5 meters.

Need: ConOps 3.12 Intersection Geometry

2.2.15.5 Nodes by Offset

The SPaT Infrastructure System shall describe the location of the stop bar node by providing an X (east-west) and a Y (north-south) offset from the intersection reference point.

Need: ConOps 3.5 Compact Messages

NOTE: Although the SAE J2735 standard allows defining lane node points by latitude and longitude or by offset, providing it only by offset simplifies the processing the SPaT Vehicle

System must do to understand the MAP message. Using offsets also results in a more compact MAP message size.

2.2.15.6 Offset from Previous Node

The SPaT Infrastructure System shall describe the location of nodes subsequent to the stop bar node by providing an X (east-west) and a Y (north-south) offset from the previous node point.

Need: ConOps 3.5 Compact Messages

NOTE: Although the SAE J2735 standard allows defining lane node points by latitude and longitude or by offset, providing it only by offset simplifies the processing the SPaT Vehicle System must do to understand the MAP message. Using offsets also results in a more compact MAP message size.

2.2.15.7 Node XY 32 bit

The SPaT Infrastructure System shall describe the X and Y offsets of node points using a 16 bit representation of each offset, 32 bits per node.

Need: ConOps 3.12 Intersection Geometry

Reference: CCIs 2.1.3 Approach to node point latitude/longitude Representation

NOTE: Although the SAE J2735 standard provides options for multiple offset representations with fewer bits, using a single representation simplifies the processing the SPaT Vehicle System must do to understand the MAP message. Requiring this single representation trades a more compact MAP message size for simplified processing of the MAP message.

2.2.15.8 Node Accuracy

The SPaT Infrastructure System shall describe the offsets of the node position with an accuracy within 0.5 meters of the actual location of the node.

Need: ConOps 3.12 Intersection Geometry

NOTE: The SAE J2735 standard calls for expressing the node offset for a 16 bit offset in centimeters.

2.2.16 Computed Lanes

The SPaT Vehicle System shall receive and process computed center of lane geometries described as the offset, angle and scale from another lane that was described using nodes.

Need: ConOps 3.5 Compact Messages

NOTE: The SPaT Infrastructure System does not have to use computed lanes, but the SPaT Vehicle System has to be able to receive them. Some intersections may only be able to fit everything into the MAP message by using computed lanes, since they result in a more compact MAP message size.

2.2.17 Lane Connections

The SPaT Infrastructure System shall identify each possible connection between each ingress and an egress lane.

Need: ConOps 3.15 Connections Between Lanes

2.2.18 Connection Egress Lane

For each connection between an ingress lane and an egress lane, the SPaT Infrastructure System shall identify the egress lane that the ingress lane connects to.

Need: ConOps 3.15 Connections Between Lanes

2.2.19 Remote Intersection Reference Identifier

If a lane connects to a lane defined for an adjacent SPaT enabled intersection, the SPaT Infrastructure System shall provide the intersection reference identifier of the remote intersection.

Need: ConOps 3.12 Intersection Geometry

Reference: CCI 2.1.8 Linking egress lanes to ingress lanes of downstream intersections

NOTE: Showing a connection in the MAP message between an egress lane and an ingress lane of an adjacent intersection allows the SPaT Vehicle System to know the intersection reference ID of the next intersection it will encounter. This can aid the SPaT Vehicle System in situations where it may be in range of broadcasts from multiple SPaT enabled intersections.

2.2.20 Connection Maneuvers

For each connection between an ingress lane and an egress lane, the SPaT Infrastructure System shall identify the maneuver the connection allows.

Need: ConOps 3.15 Connections Between Lanes

2.2.21 Connection Signal Group

For each connection between an ingress lane and an egress lane, the SPaT Infrastructure System shall identify the SPaT signal group that provides traffic signal control for that movement.

Need: ConOps 3.15 Connections Between Lanes

2.2.22 MAP Quality Assurance

If the MAP message currently being broadcast and the MAP message previously broadcast have the same revision number, the SPaT Infrastructure System shall verify that they are identical except for any time stamp.

Need: ConOps 3.10 Quality Assurance

2.2.22.1 MAP Problem

If the SPaT Infrastructure System determines that the MAP message other than any time stamp has changed from the previous MAP message while having the same revision number, the SPaT Infrastructure System shall indicate in the intersection status portion of the SPaT message that no valid map is available and shall stop broadcasting the MAP message.

Need: ConOps 3.10 Quality Assurance

2.2.22.2 MAP Revisions

The SPaT Infrastructure System shall not broadcast a MAP message with a different revision number from the previously broadcast MAP message without human verification that the change is intentional.

Need: ConOps 3.10 Quality Assurance

2.3 SPaT Requirements

2.3.1 SAE J2735

The SPaT Infrastructure System shall broadcast SPaT messages that conform to SAE J2735.

Need: ConOps 3.2 Standard Messages

2.3.2 Channel 172

The SPaT Infrastructure System shall broadcast SPaT messages on DSRC channel 172.

Need: ConOps 3.1 Standard Communications Technology

2.3.3 PSID 0x82

The SPaT Infrastructure System shall broadcast SPaT messages using PSID 0x82.

Need: ConOps 3.1 Standard Communications Technology

2.3.4 10 Hz Frequency

The SPaT Infrastructure System shall broadcast SPaT messages periodically at 10 HZ.

Need: ConOps 3.9 Timeliness

2.3.5 100 ms Latency

The SPaT Infrastructure System shall provide SPaT information that reflects the actual state of the intersection within a latency of 100 ms.

Need: ConOps 3.9 Timeliness

Reference: CCIs 2.2.2 Signal State Frequency of Output from the signal controller

2.3.6 Message Time Stamp

The SPaT Infrastructure System shall provide a timestamp indicating the minute of the year when the SPaT message was created.

Need: ConOps 3.7 Message Time Stamp

2.3.7 Intersection State

The SPaT Infrastructure System shall provide the intersection state for one or more intersections.

Need: ConOps 3.18 Intersection Status

2.3.8 Intersection Reference Identifier

The SPaT Infrastructure System 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.

Need: ConOps 3.11 Unique Intersection Identification

2.3.9 Revision Counter Increment

The SPaT Infrastructure System shall increment a message counter for a SPaT message whenever any data element in the message except the time stamp changes.

Need: ConOps 3.6 Message Revision

2.3.9.1 Revision Counter Not Increment

The SPaT Infrastructure System shall not increment a message counter for a SPaT message if no data element in the message except the time stamp changes.

Need: ConOps 3.6 Message Revision

2.3.10 Intersection Status

The SPaT Infrastructure System shall indicate the current overall status of the intersection.

Need: ConOps 3.18 Intersection Status

2.3.10.1 Manual Control

The SPaT Infrastructure System shall indicate whether or not manual control is enabled.

Need: ConOps 3.18 Intersection Status

2.3.10.2 Stop Time

The SPaT Infrastructure System shall indicate whether or not stop time is activated.

Need: ConOps 3.18 Intersection Status

2.3.10.3 Failure Flash

The SPaT Infrastructure System shall indicate whether or not the intersection is in flash mode due to failure or due to police panel flash.

Need: ConOps 3.18 Intersection Status

2.3.10.4 Preemption

The SPaT Infrastructure System shall indicate whether or not preemption is activated.

Need: ConOps 3.18 Intersection Status

2.3.10.5 Priority

The SPaT Infrastructure System shall indicate whether or not signal priority is activated.

Need: ConOps 3.18 Intersection Status

2.3.10.6 Fixed Time

The SPaT Infrastructure System shall indicate whether or not the traffic signal is operating in fixed time mode.

Need: ConOps 3.18 Intersection Status

2.3.10.7 Traffic Dependent Mode

The SPaT Infrastructure System shall indicate whether or not the traffic signal is operating in traffic dependent mode.

Need: ConOps 3.18 Intersection Status

2.3.10.8 Standby Mode

The SPaT Infrastructure System shall indicate whether or not the traffic signal is operating in standby mode with the controller partially switched off or partially amber flashing.

Need: ConOps 3.18 Intersection Status

2.3.10.9 Failure Mode

The SPaT Infrastructure System shall indicate whether or not the controller has a problem or failure in operation.

Need: ConOps 3.18 Intersection Status

2.3.10.10 Controller Off

The SPaT Infrastructure System shall indicate whether or not the controller is switched off.

Need: ConOps 3.18 Intersection Status

2.3.10.11 Recent MAP Update

The SPaT Infrastructure System shall indicate whether or not the intersection has had a recent MAP message update.

Need: ConOps 3.18 Intersection Status

2.3.10.12 New Lane IDs

The SPaT Infrastructure System shall indicate whether or not the intersection has had a recent change in MAP assigned lane IDs.

Need: ConOps 3.18 Intersection Status

2.3.10.13 No MAP Available

The SPaT Infrastructure System shall indicate when no valid MAP is available.

Need: ConOps 3.18 Intersection Status

2.3.10.14 No SPaT Available

The SPaT Infrastructure System shall indicate when no valid SPaT message is available.

Need: ConOps 3.18 Intersection Status

2.3.11 Intersection Time Stamp

The SPaT Infrastructure System shall provide a timestamp indicating the milliseconds within the current minute when the SPaT information was updated for each intersection within the SPaT message.

Need: ConOps 3.7 Message Time Stamp

2.3.12 Enabled Lanes

If the MAP message for the intersection includes lanes indicated as being revocable lanes, the SPaT Infrastructure System shall identify which revocable lanes are currently enabled.

Need: ConOps 3.17 Enabled Lanes

2.3.13 Movement State

The SPaT Infrastructure System shall provide the movement state for each signal group identified in the MAP message.

Need: ConOps 3.19 Movement State

2.3.13.1 Movement State Enumeration

The SPaT Infrastructure System shall enumerate the current interval state for the signal group as being unavailable, dark, stop then proceed, stop and remain, permissive movement allowed, protected movement allowed, permissive clearance, protected clearance, or caution conflicting traffic.

Need: ConOps 3.19 Movement State

2.3.13.2 Flashing Yellow Arrow Permissive Movement

At an intersection that uses a flashing yellow arrow to control a permissive movement as part of a protected/permissive turn, the SPaT Infrastructure System shall enumerate the current interval state for the signal group as permissive movement allowed when the flashing yellow arrow is active.

Need: ConOps 3.19 Movement State

Reference: CClis 2.1.7 SPaT Message content related to flashing yellow arrows

2.3.13.3 Protected and Permissive Clearance

At an intersection where a yellow arrow sometimes follows a protected movement and sometimes follows a permissive movement, the SPaT Infrastructure System shall enumerate the current clearance interval state for the signal group as protected clearance or permissive clearance to correspond with the protected or permissive condition of the allowed movement preceding the clearance interval.

Need: ConOps 3.19 Movement State

Reference: CClis 2.1.7 SPaT Message content related to flashing yellow arrows

2.3.13.4 Resolve Protected Versus Permissive Movement

When an allowed movement controlled by a signal group is sometimes protected and sometimes a permitted, such as a protected/permissive left turn, the SPaT Infrastructure System shall determine whether the currently allowed movement is protected or permitted and shall enumerate the corresponding current state for the signal group.

Need: ConOps 3.19 Movement State

2.3.13.5 Ped Conflict Causes Permissive

When any allowed movement controlled by a signal group includes a maneuver in conflict with a pedestrian movement currently in a WALK or flashing DON'T WALK state, such as a

permissive right turn crossing a crosswalk having a WALK indication, the SPaT Infrastructure System shall enumerate the corresponding current allowed state for the signal group as permissive movement allowed.

Need: ConOps 3.19 Movement State

2.3.14 Time Change Details

The SPaT Infrastructure System shall provide time change details for each signal group identified in the MAP message.

Need: ConOps 3.20 Time Change Details

[Do we want the SPaT Infrastructure System to exclude time change details about the when the red signal will end?]

NOTE: Due to ambiguity in the SAE J2735 standard as to when start time refers to a past time or a future time, it is recommended to not provide the start time for an interval. NTCIP 1202v3 determined to not include an object for start time in that traffic signal controller communication standard for that reason.

NOTE: SPaT Data Needs SPaT Data Needs Item 2 indicates the need for providing likely end time. That document did not differentiate if this was needed for RLVW or only for other applications. Likely end time is not included in this SRS.

2.3.14.1 Minimum End Time

The SPaT Infrastructure System shall provide the soonest time that the current interval could end in the absence of unpredictable events such as preemption or priority calls.

Need: ConOps 3.20 Time Change Details

NOTE: The soonest time that a traffic dependent 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.

2.3.14.2 Resting in Green

If a traffic dependent green interval could end immediately upon a conflicting detector call, the SPaT Infrastructure System shall identify the soonest time that the current interval could end as being one tenth of a second from the current time.

Need: ConOps 3.20 Time Change Details

NOTE: SPaT Inconsistency c) b) i recommends setting the min end time to a fixed number during rest in green until the actual end time is known, and then providing the actual time. The recommendation was apparently based on experience at a location where the pedestrian indications rested in WALK. At that location once a conflicting call came, there was a fixed min end time based on the WALK clearance. However, many, if not most, signalized intersections do not rest in WALK, but in DON'T WALK. In that case, the green will terminate immediately (one tenth of a second) once a conflicting call comes. This SRS requires indicating the possibility of immediate change in the min end time when that is the configuration at an intersection.

2.3.14.3 Maximum End Time

For intervals that do not have a predetermined end time, the SPaT Infrastructure System shall provide the latest time that the current interval could end in the absence of unpredictable events such as preemption or priority calls.

Need: ConOps 3.20 Time Change Details

NOTE: The latest time that a traffic dependent green interval could end when there is a conflicting detector call may be constrained by the maximum green time setting or coordination force-offs.

2.3.14.4 No Maximum End Time

For intervals that have a predetermined time, such as the yellow interval or green intervals when running fixed time, the SPaT Infrastructure System shall not provide the latest time that the interval may change.

Need: ConOps 3.20 Time Change Details

NOTE: This is contrary to Test Procedure 3.1.5 Max Time at Change, which says that for intervals with a fixed time the max time at change will equal the min time at change.

2.3.14.5 Unknown Maximum End Time

In a situation where the SPaT Infrastructure System cannot determine a latest end time, the SPaT Infrastructure System shall identify the latest end time as being undefined or unknown.

Need: ConOps 3.20 Time Change Details

2.3.15 SPaT Quality Assurance

The SPaT Infrastructure System shall verify that the SPaT message currently being broadcast is compatible with what the controller is commanding and with the physical indications being displayed at the intersection.

Need: ConOps 3.10 Quality Assurance

2.3.15.1 SPaT Problem

If the SPaT Infrastructure System determines that the SPaT message currently being broadcast is not compatible for more than 100 msec with what the controller is commanding or with the physical indications being displayed at the intersection, the SPaT Infrastructure System shall indicate in the intersection status portion of the SPaT message that no valid SPaT information is available and shall omit the movement state and timing from the SPaT message.

Need: ConOps 3.10 Quality Assurance

Reference: SPaT Data Needs SPaT Data Needs Items 5 & 6

2.3.15.2 SPaT Reset

After the SPaT Infrastructure System has set the intersection status to indicate no valid SPaT information that the SPaT message, the SPaT Infrastructure SPaT shall not begin again to broadcast movement state and timing without human verification that the SPaT message has been corrected.

Need: ConOps 3.10 Quality Assurance

2.4 Location Correction Requirements

2.4.1 Position Correction for Complex Intersections with Clear Sky

If the intersection has dedicated turn lanes for each left turn at the intersection and if the intersection has a clear view of positioning satellites, the SPaT Infrastructure System shall broadcast position correction messages.

Need: ConOps 3.16 Position Correction

NOTE: Previous work indicated that position correction is not needed at simple intersections where the approaching vehicle does not need to know the exact lane it is in and that position correction is not effective if there is not a clear view of the satellites.

2.4.1.1 SAE J2735

The SPaT Infrastructure System shall broadcast RTCM position correction message that conform to SAE J2735.

Need: ConOps 3.2 Standard Messages

2.4.1.2 Channel ?

The SPaT Infrastructure System shall broadcast RCTM messages on DSRC channel ?.

Need: ConOps 3.1 Standard Communications Technology

2.4.1.3 PSID 0x80

The SPaT Infrastructure System shall broadcast RTCM messages using PSID 0x80.

Need: ConOps 3.1 Standard Communications Technology

2.4.1.4 Message Type 1001

The SPaT Infrastructure System shall broadcast RTCM Correction messages containing the most recent RTCM version 3.0 10403 Message Type 1001 GPS L1 observation data periodically at 5 Hz.

2.4.1.5 Message Type 1005

The SPaT Infrastructure System shall broadcast RTCM Correction messages containing the most recent RTCM version 3.0 10403 Message Type 1005 Antenna Reference Point coordinates data periodically at 2 Hz.

Need: ConOps 3.9 Timeliness

2.5 Security Requirements

2.5.1 Security Certificates

The SPaT Infrastructure System shall sign each outgoing message with a valid security certificate.

Need: ConOps 3.3 Message Security

2.5.1.1 IEEE 1609

The SPaT Infrastructure System shall sign and validate DSRC messages using the IEEE 1609.2 security standard.

Need: ConOps 3.3 Message Security

2.5.1.2 Certificate Policy

The SPaT Infrastructure System shall utilize certificates that follow the certificate policy of the SCMS manager.

Need: ConOps 3.3 Message Security

2.5.1.3 SPaT Vehicle System Determines Trust

The SPaT Vehicle System shall determine whether to trust the security certificates it receives from the SPaT Infrastructure System.

Need: ConOps 3.3 Message Security

2.5.2 Certificates Unavailable

In the event that security certificates are unavailable, the SPaT Infrastructure System shall continue to broadcast messages and shall include a null [flag?] value in the security header in place of a valid security certificate.

Need: ConOps 3.3 Message Security

Reference: CCIs 2.1.3 Approach to node point latitude/longitude Representation

2.5.2.1 Use of Unsigned Messages

The SPaT Vehicle System shall determine whether to utilize messages from the SPaT Infrastructure System not having a security certificate.

Need: ConOps 3.3 Message Security

3 Message Design

M = Mandatory O = Optional

3.1 MAP Message

MAP Data Elements		Applications:	J2735	RLVW
messageId=DE_DSRCmsgID			M	M
msgIssueRevision=DE_MsgCount			M	M
intersections=DF_IntersectionGeometryList			O	M
id=DF_IntersectionReferenceID			M	M
region=DE_RoadRegulatorID			O	M
id=DE_IntersectionID			M	M
revision=DE_MsgCount			M	M
refPoint=DF_Position3D			M	M
lat=DE_Latitude			M	M
long=DE_Longitude			M	M
laneWidth=DE_LaneWidth			O	M
laneSet=DF_LaneList			M	M
laneID=DE_LaneID			M	M
laneAttributes=DF_LaneAttributes			M	M
directionalUse=DE_LaneDirection			M	M
sharedWith=DE_LaneSharing			M	M
laneType=DF_LaneTypeAttributes			M	M
maneuvers=DE_AllowedManeuvers			O	M
nodeList=DF_NodeListXY			M	M
NodeSetXY=DF_NodeXY			M	M
delta=DF_NodeOffsetPointXY			M	M
node-XY6=DF_Node-XY-32b			M	M
x=DE_Offset_B16			M	M
y=DE_Offset_B16			M	M
ComputedLane = DF_Computed Lane			M	M
referenceLaneId=DE_LaneID			M	M
offsetXaxis			M	M
offsetYaxis			M	M
connectsTo=DF_ConnectsToList			O	M
connectingLane=DF_ConnectingLane			M	M
lane=DE_LaneID			M	M
maneuvers=DE_AllowedManeuver			O	M
remoteIntersection=DF_IntersectionReferenceID			O	M
signalGroup=DE_SignalGroupID			O	M

3.2 SPaT Message

SPaT Data E		Applications:	J2735	RLVW
messageId=DE_DSRC_MessageID			M	M
timeStamp=DE_MinuteOfTheYear			O	M
intersections=DF_IntersectionStateList			M	M
id=DF_IntersectionReferenceID			M	M
region=DE_RoadRegulatorID			O	M
id=DE_IntersectionID			M	M
revision=DE_MsgCount			M	M
status=DE_IntersectionStatusObject			M	M
timeStamp=DE_Dsecond			O	M
enabledLanes=DF_EnabledLaneList			O	M
states=DF_MovementList			M	M
signalGroup=DE_SignalGroupID			M	M
state-time-speed=DF_MovementEventList			M	M
eventState=DE_MovementPhaseState			M	M
timing=DF_TimeChangeDetails			O	M
minEndTime=DE_TimeMark			M	M
maxEndTime=DE_TimeMark			O	M

3.3 RTCM Message

[Place Holder]

4 Referenced Documents

[SAE J2735](#) – Surface Vehicle Standard J2735, MAR2016, Dedicated Short Range Communications (DSRC) Message Set Dictionary, Society of Automotive Engineers International

[SPaT Challenge Verification Document](#) – SPaT Challenge Verification Document, Version 1.2, Crash Avoidance Metrics Partners LLC (CAMP), October 30, 2017

[Test Procedure](#) - Test Procedure for Verifying SPaT and MAP Messages, Connected Signalized Intersections, Version 1.2, Crash Avoidance Metrics Partners LLC (CAMP), September 18, 2019

[CCIs](#) - Cooperative Automated Transportation, Clarifications for Consistent Implementations (CCIs) To Ensure National Interoperability, Connected Signalized Intersections, DRAFT Version 1.9.4, May 2019

[Enabling Connected Intersections](#) - Enabling Connected Intersections, Connected Intersection Communications with Production Vehicles, February 2020

SPaT Data Needs - Connected Signalized Intersections, SPaT Data Needs, Draft Version 6 – Updated following Dec 9, 2019 Discussion

SPaT Inconsistency – SPaT Inconsistency in Actuated Signalized Intersections [No reference information is provided in the document]

Additional Ambiguities - Additional ambiguities in Standard (J2735) [No reference information is provided in the document]

[SPaT Challenge Infrastructure System Model Concept of Operations](#) - SPaT Challenge Infrastructure System Model Concept of Operations, Draft Version 1.6, March 2018

[SPaT Challenge Infrastructure System Model Requirements](#) - SPaT Challenge Infrastructure System Model Requirements, Draft Version 1.1, March 2018

ConOps - SPaT V2I Interface for Red Light Violation Warning, Concept of Operations, Draft Version 20200409, Minnesota Department of Transportation, April 2020

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