Connected Vehicle Pilot Deployment Program Phase 4

Test Cases – Wyoming (C-V2X Conversion)

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16. Abstract

The Wyoming Department of Transportation's (WYDOT) Connected Vehicle (CV) Pilot Deployment Program is intended to develop a suite of applications that utilize vehicle to infrastructure (V2I) and vehicle to vehicle (V2V) communication technology to reduce the impact of adverse weather on truck travel in the I-80 corridor. These applications support a flexible range of services from advisories, roadside alerts, parking notifications and dynamic travel guidance. Information from these applications are made available directly to the equipped fleets or through data connections to fleet management centers (who will then communicate it to their trucks using their own systems). The pilot will be conducted in three Phases. Phase I includes the planning for the CV pilot including the concept of operations development. Phase II is the design, development, and testing phase. Phase III includes a real-world demonstration of the applications developed as part of this pilot.

This document presents the test plan for Phase 4 LTE-V2X. The test cases for Phase 4 focus on the functional changes since the testing of Phase 3, the replacement of the Dedicated Short-Range Communications (DSRC) layer with the Cellular Vehicle to Everything (LTE-V2X) communication layer.

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1 Introduction

1.1 Overview

The test cases listed in this document are part of Phase 4 of the WYDOT Connected Vehicle (CV) Pilot Deployment Program and will be executed at selected sections of the I-80 corridor in Wyoming and the test area around Archer Wyoming just east of Cheyenne. The test cases focus on the functional changes since the testing of Phase 3, the replacement of the Dedicated Short-Range Communications (DSRC) layer with the Cellular Vehicle to Everything (LTE-V2X) communication layer.

1.2 Objectives

The primary objective of the testing is to ensure interoperability and reliability of the LTE-V2X communication layer, specifically.

- Verify communication between onboard units (OBUs), i.e., vehicle-to-vehicle (V2V) communication.
- Verify communication between road-side units (RSUs) and OBUs i.e., infrastructure-to-vehicle (I2V) and vehicle-to-infrastructure (V2I) communication.
- Verify On Board Unit's (OBU) and Roadside Unit's (RSU) conformance to various LTE-V2X standards including 3GPP Release 14 specifications and SAE J3161. It may be noted that the standard conformance testing is only performed at a application level and is not to be conducted at the protocol level.
- IPv4 over Wi-Fi communication from OBUs.
- Traveler Information Messages (TIM) broadcast via satellite in addition to the broadcast via RSUs.

The interoperability testing based on standards other than the LTE-V2X is not an objective of this test effort. The out-of-scope standards include IEEE 1609, SAE J2735, SAE J2945, NTCIP 1218, and CTI 4001 as the functionalities specified in these standards have already been verified during Phase 3 testing. All testing will be conducted with certificates from ISS for 1609.2.

1.3 References

The following documents were used in the creation of this test plan.

- Connected Vehicle Pilot Deployment Program Phase 4 System Requirements Specification (SyRS) – WYDOT for LTE-V2X Conversion
- Connected Vehicle Pilot Deployment Program Phase 4 Concept of Operations (ConOps) – ICF/Wyoming
- Test Plan for Connected Vehicle (CV) Pilots Phase 2 Interoperability Testing
- ITS / V2X Testing (https://www.its.dot.gov/research_areas/emerging_tech/htm/ITS_V2X_Testing.htm)

2 Test Devices and Tools

2.1 WYDOT Test Devices

The test cases focus on demonstrating interoperability between the different CV devices. Table 1 lists the primary CV devices that will be under test during this trial.

Table 1. WYDOT Test Equipment

Device	Vendor	Quantity
OBU	Commsignia	10
RSU	Commsignia	70

2.2 Data Collection and Storage

Vehicle data including safety message data, any application-related data, vehicle, and road condition data are stored locally and transmitted to the WYDOT data warehouse. RSU data, i.e., the data collected by RSUs, is immediately forwarded to the WYDOT data warehouse. More details on the data warehouse are available in the Connected Vehicle Pilot Deployment Program Phase 4 System Requirements Specification (SyRS) – WYDOT for LTE-V2X Conversion document.

3 Feature Coverage

3.1 Features to Be Tested

The following features will be tested directly.

- LTE-V2X communication between OBUs
- LTE-V2X communication between OBUs and RSUs
- Reliability of V2V, V2I, and I2V messages over LTE-V2X
- Speed based LTE-V2X configuration profiles.
- Log files upload from OBUs over Wi-Fi
- TIM broadcast via satellite

Although the focus of testing will be the LTE-V2X interface, other Intelligent Transport Systems (ITS) functions will also get tested indirectly in this end-to-end field environment; and these functions include.

- Safety Applications
- Situational Awareness Applications
- Traveler Information Messages (TIM)
- RSU - TMC communications
- Security of various interfaces including V2V, I2V, V2I, and RSU- Transportation Management Center (TMC)
- SCMS Operation

3.2 Features not to be Tested

The LTE-V2X features, mainly low-level protocol aspects, that will not be tested along with the rationale for not testing are captured in the Table 2.

Table 2. LTE-V2X Features not to be Tested.

Feature	Rationale for Not Testing
RF emission characteristics of LTE-V2X devices	Covered by LTE-V2X Testing
RF propagation characteristics of 5.9 GHz	Covered by LTE-V2X Testing
Interference from adjacent Wi-Fi channels	Covered by LTE-V2X Testing
Interference with DSRC	Covered by LTE-V2X Testing
Loss of GPS handling by devices	Covered by LTE-V2X Testing
Congestion Handling at the LTE-V2X layer	Test equipment for generating load is not available
Priority Handling at the LTE-V2X layer	PPPP and CBR-based actions are too complex for field testing
IPv6 Transmission	IPv6 over PC5 is not supported by the devices
Public safety vehicles (transmission at higher power and priority)	Public safety vehicles are not available for testing
Segmentation of large messages by LTE-V2X	Need large MAP messages to trigger segmentation and it is not available for WYDOT testing
One-shot transmission	SPS packet collision is too complex to be tested in the field
RSRP exclusion threshold	RSRP exclusion threshold is too complex to be tested in the field
Channel and Data Rate	Number of subchannels and MCS selection is too complex to be tested in the field
3GPP PDCP/RLC/MAC protocol settings	3GPP protocol analyzers are not available for the field testing

The non-LTE-V2X features that will not be tested either directly or indirectly along with the rationale for not testing are captured in Table 3.

Table 3. Non-LTE-V2X Features not to be Tested.

Feature	Rationale for not Testing
MAP Transmissions from RSUs	MAP not available for WYDOT testing
Connected Intersections	Connected Intersections are not available at WYDOT
Handling of certificate revocation list (CRL)	This feature will be tested separately
Handling of misbehavior reporting	This feature will be tested separately
Applications behavior	Already tested during Phase 3
Privacy of vehicles from being tracked	Already tested during Phase 3

4 Risks and Contingencies

Table 4 identifies the high-level risks and contingencies identified with conducting the tests.

Table 4. Risks and Contingencies.

Risk	Likelihood	Severity	Contingency
Logs from Devices	Low	Medium	A few test cases require examining LTE-V2X, IEEE, and SAE message logs from OBUs and RSUs. These test cases will get blocked if the devices do not support this functionality.
Device Configuration	Low	Low	A few test cases require the support to view and modify the OBU's and RSU's configurations. These test cases will get partially blocked if the devices do not support this functionality.
GPS Accuracy	Medium	Medium	If sufficient GPS accuracy cannot be achieved (either through GPS satellite coverage or EMI interference) the V2V safety applications will not generate the proper warnings.

5 Test Cases

This chapter describes tests covering V2V, V2I, and I2V messages over LTE-V2X and satellite interfaces. Besides verification of the basic LTE-V2X communication, the tests will also verify operation of ITS functions of both infrastructure and in-vehicle applications. Table 5 is a high-level summary of the test cases, providing a summary and orientation for the reader.

Table 5. Test Cases Summary.

Test Case ID	Test Case Title	Test Case Objective	Test Case Input (Driving Scenario)	Test Case Expected Result (Pass/Fail Criterion)
WV2VMCT-1	Vehicle BSM Reception	* Verify V2V communication of BSMs	* Host vehicle and remote vehicle start 600 m apart and then approach to within 300 m	* BSM received by test vehicles while 300 m apart. Verified by log inspection. * BSM received in each vehicle from counterpart vehicle. Verified by inspection of logs.
WV2VMCT-2	Speed-based LTE-V2X Configuration Profiles	* Verify that OBUs use different LTE-V2X Configuration Profiles based on the vehicle's speed.	* Host and remote vehicles travelling below 120 kmph * Host and remote vehicles travelling above 120 kmph	* BSM received in each vehicle from the other vehicle regardless of speed. Verified by log inspection.
WV2IMCT-1	Stationary Log File Offload	* Verify V2I communication for log file offload	* Host vehicle approaches download RSU then stops and remains stationary at > 50 m from RSU	* Log files are offloaded through the RSU, processed by the ODE and stored by Data Warehouse. Verified by inspection of logs.
WFCW-1	FCW Stopped Vehicle	* Verify V2V communication of BSMs. * Verify V2I communication of log files. * FCW application issues a warning in time for driver to avoid forward collision.	* Host vehicle approaches stopped remote vehicle at 35 mph. * After receiving warnings, host vehicle slows to stop behind remote vehicle or veers to clear adjacent lane.	* FCW application issues a warning in time for driver to take action to avoid collision. Verified visually and by inspection of logs.

Test Case ID	Test Case Title	Test Case Objective	Test Case Input (Driving Scenario)	Test Case Expected Result (Pass/Fail Criterion)
WFCW-2	FCW Stopped Vehicle Message Prioritization	* Verify V2V communication of BSMs. * Verify I2V communication of TIMs. * FCW application issues a warning in time for the driver to avoid forward collision. FCW should override TIM display. * FCW takes precedence over TIM display.	* Host vehicle drives into TIM geofence and confirm TIM display. * Host vehicle approaches stopped remote vehicle at 35 mph. * After receiving warnings, host vehicle slows to stop behind remote vehicle or veers to clear adjacent lane.	* FCW application issues a warning in time for driver to take action to avoid collision. Verified visually and by inspection of logs. * TIM received and displayed in vehicle within the specified geofence. Verified visually and by inspection of logs.
WFCW-3	FCW Slow Moving Vehicle	* Verify V2V communication of BSMs. * FCW application issues warning when approaching a slow-moving remote vehicle in time for driver to avoid forward collision.	* Host vehicle traveling at 35 mph approaches remote vehicle traveling at 15 mph.	* FCW issues a warning when there is a slow-moving vehicle in the same lane of travel in time for the driver to take action to avoid collision. Verified visually and by inspection of logs.
WI2VSA-1	Message Display in Travel Lanes and Perpendicular to Travel Lanes LTE-V2X I2V Message Communication	* Verify I2V TIM is parsed correctly, and message begins and ends display within 1 second of crossing geofence boundary. * Verify no message is displayed when crossing geofence outside of message direction.	* Host vehicle drives by RSU broadcasting TIM * Host vehicle driving in travel lanes in message direction. * Host vehicle driving on roadway perpendicular to message direction	* Message displays within 1 second of crossing geofence boundary. Verified visually and by inspection of logs. * Message not displayed on perpendicular route. Verified visually and by inspection of logs.
WI2VSA-2	Message Display in Travel Lanes and Opposing Travel Lanes Satellite I2V Message Communication	* Verify I2V TIM is received and parsed correctly, and message begins and ends display within 1 second of crossing geofence boundary. * Verify no message is displayed when traveling in opposing lanes outside of message direction.	* Host vehicle operating 5 minutes prior to driving into TIM geofence * Host vehicle driving in travel lanes in message direction. * Host vehicle driving in travel lanes opposite message direction	* Message displays within 1 second of crossing geofence boundary. Verified visually and by inspection of logs. * Message not displayed on opposing lanes route. Verified

Test Case ID	Test Case Title	Test Case Objective	Test Case Input (Driving Scenario)	Test Case Expected Result (Pass/Fail Criterion)
				visually and by inspection of logs.
WI2VSA-3	Simultaneous LTE-V2X and Satellite I2V Message Communication	* Verify I2V TIM is received and parsed correctly, and message begins and ends display within 1 second of crossing geofence boundary. * Verify no message is displayed when traveling in opposing lanes outside of message direction.	* Host vehicle operating 5 minutes prior to driving into TIM geofence * Host vehicle drives by RSU broadcasting TIM * Host vehicle driving in travel lanes in message direction. * Host vehicle driving in travel lanes opposite message direction	* Message displays within 1 second of crossing geofence boundary. Verified visually and by inspection of logs. * Message not displayed on opposing lanes route. Verified visually and by inspection of logs.
WI2VSA-4	Message Display Start and Stop Time	* Verify geofence implementation and I2V TIM start and stop time functionality. * Verify GPS location and time accuracy supports accurate display of I2V Messages.	* Host vehicle driving in travel lanes in "message direction". Vehicle enters geofence 20 seconds before start time. * Host vehicle driving in travel lanes in "message direction". Vehicle enters geofence 20 seconds before end time.	* Message begins display within 1 second of specified start date and time (while inside the geofence). Verified visually and by inspection of logs. * Message ends display within 1 second of specified end date and time (while inside the geofence). Verified visually and by inspection of logs.

5.1 WV2VMCT-1 Vehicle BSM Reception

5.1.1 Test Objective

Verify end-to-end communication of BSMs and V2V BSM communication range. This test should confirm that the OBU correctly receives and processes BSM from a remote vehicle OBU at the expected LTE-V2X communication range.

5.1.2 Test Description

5.1.2.1 Verify Readiness

1. Host and Remote vehicles have Commsignia OBUs installed with antenna and HMI, configured according to the WYDOT CV Pilot Commsignia OBU Provisioning Guide v1.0. The OBUs must be set up to support all communications with production SCMS.
2. Identify a rest location on the test track where vehicles can drive to before and after a test run.
3. Identify two endpoints of a drive test path that are at least 600 meters apart. The two vehicles will start the test drive at opposite ends of the path.
4. Identify remote offload location where vehicles can drive to offload log files upon completion of the driving test.

5.1.2.2 Test Start Up

1. Drive host and remote vehicles to rest location on the test track.
2. Power up each OBU in the host and remote vehicles. Confirm that the OBUs are operating and connected to their associated HMI. The HMI display should appear as a map with the vehicle marker at the current vehicle geographic location.

5.1.2.3 Track Test Procedure

1. Drive host and remote vehicles to opposite endpoints of the predefined drive test path.
2. Start the host vehicle driving towards the remote vehicle along the predefined drive test path.
3. Remote vehicle can remain stationary at its start position or drive along the predefined drive test path towards the host vehicle start position.
4. Neither vehicle should exceed 35 mph while driving towards each other along the approach path.
5. Both vehicles stop once they have approached within 10 meters of one another or as soon as they have passed each other going in opposite directions.
6. After safely stopping both vehicles, drivers should manually record the times associated with the drive test sequence.
7. The host and remote vehicles then return to the previously defined drive path endpoint locations to repeat the test.
8. After final test repetition, both the remote and host vehicles drive to offload location and confirm that generated log files are offloaded.

5.1.3 Pass/Fail Criteria

- Fifty percent of BSMs are received and processed by each vehicle from the opposite vehicle while the vehicles are at least 280 meters apart and less than 320 meters apart.

5.2 WV2VMCT-2 Speed-based LTE-V2X Configuration Profiles

5.2.1 Test Objective

The objective of this test is to verify that OBUs use different LTE-V2X Configuration Profiles based on the vehicle's speed.

5.2.2 Test Description

5.2.2.1 Verify Readiness

1. Host and Remote vehicles have Commsignia OBUs installed with antenna and HMI, configured according to the WYDOT CV Pilot Commsignia OBU Provisioning Guide v1.0. The OBUs must be set up to support all communications with production SCMS.
2. Identify section of test track where vehicles can maintain the high speeds required for the test for at least two minutes of continuous driving time.
3. Identify a rest location on the test track where vehicles can drive to before and after a test run.
4. Identify remote offload location where vehicles can drive to offload log files upon completion of the driving test.
5. Confirm that the test team includes both a driver and recorder for both vehicles.
6. Provide a conference call to provide concurrent communication between all the driving test participants. This is necessary as the test vehicles are widely separated during the test sequence.

5.2.2.2 Test Start Up

1. Drive host and remote vehicles to rest location on the test track.
2. Power up the OBU in the host vehicle. Confirm that the OBU is operating and connected to its associated HMI. The HMI display should appear as a map with the vehicle marker at the current vehicle geographic location.

5.2.2.3 Track Test Procedure

1. Drive host and remote vehicles to beginning of the test section of roadway. The vehicles should travel down the test section together in-line, with the host vehicle trailing the remote vehicle.
2. Accelerate both vehicles to the initial test speed of 70 mph (113 km/hr). The host vehicle should trail the remote vehicle with a time separation of no more than 5 seconds. This will ensure the vehicles maintain less than 200 m separation.
3. Maintain the initial test speed for 2 minutes. The host vehicle recorder will be responsible for recording the start and end times of this initial speed drive.
4. After the initial speed drive, accelerate both vehicles to the secondary speed of 80 mph (129 km/hr). The host vehicle driver should maintain a 5 second separation time from the leading remote vehicle.

5. Maintain the secondary speed for 2 minutes. The host vehicle recorder will be responsible for recording the start and end times of this secondary speed drive.
6. After the secondary speed drive, both vehicles can leave the test track to a rest location where the drive sequence times can be manually recorded for this test sequence.
7. After final test repetition, both the remote and host vehicles drive to offload location and confirm that generated log files are offloaded.

5.2.3 Pass/Fail Criteria

- Each vehicle continues to receive BSM from other vehicles regardless of speed.
- If OBU logs include LTE-V2X information, it should show that the vehicles are using the correct MCS based on the vehicle speed as specified in SAE J3161.

5.3 WV2IMCT-1 Stationary Log File Offload

5.3.1 Test Objective

Verify end-to-end communication of log files and V2I communication range. This test should confirm that the OBU correctly offloads any collected log files when it approaches within LTE-V2X and Wi-Fi communication range of an RSU configured to support log file offload.

5.3.2 Test Description

5.3.2.1 Verify Readiness

1. Host vehicle has a Commsignia OBUs installed with antenna and HMI, configured according to the WYDOT CV Pilot Commsignia OBU Provisioning Guide v1.0. The OBU must be set up to support all communications with production SCMS.
2. Confirm that the designated log offload Commsignia RSU is installed and configured according to the WYDOT CV Pilot Commsignia RSU Provisioning Guide v1.2. The RSU must be set up to support all communication with production SCMS. Ensure this RSU is configured to support Log File offload.
8. Identify a stop location that is approximately 50 meters away from designated log offload RSU, where the host vehicle can approach, stop at, and safely remain stationary for 10 minutes.
9. Identify a rest location beyond the communication range of the log offload RSU where the vehicle can remain stationary while checks are executed on the OBU to confirm count of onboard log files.

5.3.2.2 Test Start Up

1. Power up the OBU in the host vehicle. Confirm that the OBU is operating and connected to its associated HMI. The HMI display should appear as a map with the vehicle marker at the current vehicle geographic location.
2. Confirm that the log offload RSU is operating and supports normal communication with the WYDOT CV environment.

5.3.2.3 Track Test Procedure

1. Build up a set of log files on the OBU by driving the host vehicle for a minimum of 30 minutes outside of communication range of any RSU configured for log offload.
2. After the log file build up period, drive the host vehicle to the predefined rest location where a check of the OBU can confirm the count of log files onboard.
3. Drive the host vehicle to the log offload site, approach the predefined stop location, and finally stop and remain stationary at the log offload stop location.
4. After stopping, keep the host vehicle running and check the OBU to determine if the onboard log files are offloading or have been offloaded.

5.3.3 Pass/Fail Criteria

- All log files built up on the OBU are offloaded when the host vehicle approaches and stops near (< 30 meters) the log offload RSU.
- Log files are received and processed by the ODE and stored in the data warehouse.

5.4 WFCW-1 - FCW Stopped Vehicle

5.4.1 Test Objective

Verify the FCW application issues an imminent FCW alert when there is an imminent threat of forward collision with a vehicle directly ahead in the same lane of travel and immediate action is required from the driver to avoid the collision.

5.4.2 Test Description

5.4.2.1 Verify Readiness

1. Host and Remote vehicles have Commsignia OBUs installed with antenna and HMI, configured according to the WYDOT CV Pilot Commsignia OBU Provisioning Guide v1.0. The OBUs must be set up to support all communications with production SCMS.
2. Confirm that the test track Commsignia RSU is installed and configured according to the WYDOT CV Pilot Commsignia RSU Provisioning Guide v1.2. The RSU must be set up to support all communication with production SCMS. Ensure this RSU is not configured to support Log File offload.
3. Identify a rest location on the test track where vehicles can drive to before and after a test run.
4. Identify specific test track location for remote vehicle to stop and be stationary. Identify the path that host vehicle will use to approach stationary remote vehicle. The approach path must start at least 600 meters from the stationary vehicle location.
5. Identify remote offload location where vehicles can drive to offload log files upon completion of the driving test.

5.4.2.2 Test Start Up

1. Drive host and remote vehicles to rest location on the test track.
2. Power up each OBU in the host and remote vehicles. Confirm that the OBUs are operating and connected to their associated HMI. The HMI display should appear as a map with the vehicle marker at the current vehicle geographic location.

5.4.2.3 Track Test Procedure

1. Drive host and remote vehicles to beginning of the forward collision approach path.
2. Drive the remote vehicle to the designated stationary position on the test track.
3. Once the remote vehicle is stopped at the stationary position, the host vehicle starts down the approach path towards the stationary remote vehicle. The host vehicle should follow the same approach path as the remote vehicle did when driving to the stationary position on the test track.
4. Accelerate the host vehicle to 35 miles per hour driving on the test track towards the stationary remote vehicle. The host driver should initially focus on achieving and maintaining the test speed of 35 mph.
5. As the host vehicle approaches the stationary remote vehicle the driver maintains vehicle speed and monitors the approach to the remote vehicle to ensure the host vehicle stops or avoids the remote vehicle before any collision.
6. During the approach to the remote vehicle, the host vehicle driver identifies any forward collision warnings issued to the driver.
7. After safely stopping behind the remote vehicle or avoiding the remote vehicle, the host vehicle driver should come to a complete stop and manually record the drive sequence times and any driver alerts received during the prior approach sequence.
8. The host and remote vehicles then return to the previously defined approach path start location to repeat the test.
9. After final test repetition, both the remote and host vehicles drive to offload location and confirm that generated log files are offloaded.

5.4.3 Pass/Fail Criteria

- The host vehicle OBU must issue an FCW in two sequential test repetitions or at least two out of three sequential test repetitions.
- The host vehicle OBU must issue the FCW at a time-to-collision close to the configured collision imminent time.

5.5 WFCW-2 - FCW Stopped Vehicle Message Prioritization

5.5.1 Test Objective

Verify the FCW application issues an imminent FCW alert when there is an imminent threat of forward collision with a vehicle directly ahead in the same lane of travel. Verify that FCW and I2V

situational awareness messages are correctly prioritized in a situation when they are being simultaneously displayed.

5.5.2 Test Description

5.5.2.1 Verify Readiness

1. Host and Remote vehicles have Commsignia OBUs installed with antenna and HMI, configured according to the WYDOT CV Pilot Commsignia OBU Provisioning Guide v1.0. The OBUs must be set up to support all communications with production SCMS.
2. Confirm that a test track Commsignia RSU is installed and configured according to the WYDOT CV Pilot Commsignia RSU Provisioning Guide v1.2. The RSU must be set up to support all communication with production SCMS. This RSU will be designated to broadcast the TIM required for the test.
3. Define a situational awareness TIM (e.g. snow TIM) with geofence boundary that starts at least 100 meters before the defined approach path and extends at least 100 meters past the defined stationary vehicle location.
4. Deposit the situational awareness TIM for broadcast on the designated TIM broadcast RSU.
5. Identify a rest location on the test track where vehicles can drive to before and after a test run.
6. Identify specific test track location for remote vehicle to stop and be stationary. Identify the path that the host vehicle will use to approach stationary remote vehicle. The approach path must start at least 1000 meters from stationary vehicle location to allow host vehicle time to receive TIM prior to a forward collision warning.
7. Provide a conference call to provide concurrent communication between all of the driving test participants. This is necessary as the test vehicles are widely separated during the test sequence, and well out of visual range of each other.
8. Identify remote offload location where vehicles can drive to offload log files upon completion of the driving test.

5.5.2.2 Test Start Up

1. Drive host and remote vehicles to rest location on the test track.
2. Power up each OBU in the host and remote vehicles. Confirm that the OBUs are operating and connected to their associated HMI. The HMI display should appear as a map with the vehicle marker at the current vehicle geographic location.
3. Drive the host vehicle by the designated RSU broadcasting the situational awareness TIM. Ensure the host vehicle OBU picked up the TIM by driving into the defined geofence for the TIM and confirming that the TIM is displayed in-vehicle. After the TIM display is confirmed, the host vehicle cannot reboot their OBU until completion of the test sequence (an OBU reboot would delete the received TIM from the OBU).

5.5.2.3 Track Test Procedure

1. Drive host and remote vehicles to beginning of the forward collision approach path.
2. Drive the remote vehicle to the designated stationary position on the test track.

3. Once the remote vehicle is stopped at the stationary position, the host vehicle starts down the approach path towards the stationary remote vehicle. The host vehicle should follow the same approach path as the remote vehicle did when driving to the stationary position on the test track.
4. Drive the host vehicle along the defined approach path towards the stationary vehicle location. Host driver should maintain a steady approach speed that must be at least 35 mph.
5. During the approach towards the stationary remote vehicle, the host vehicle driver identifies any advisory and warnings issued to the driver. The predefined situational awareness TIM should be the first advisory when the host vehicle starts into the defined approach path.
6. The host vehicle should continue in the same lane towards the stationary remote vehicle. As the host vehicle approaches the stopped remote vehicle, the host vehicle driver monitors the HMI and identifies any forward collision advisory and/or imminent forward collision warnings issued to the driver. The host vehicle driver brakes as necessary to ensure the host vehicle stops or avoids the remote vehicle before any collision.
7. After safely stopping behind the remote vehicle or avoiding the remote vehicle, the host vehicle driver should come to a complete stop and manually record the drive sequence times, any driver alerts received and the prioritization of those alerts during the prior approach sequence.
8. The host and remote vehicles then return to the previously defined approach path start location to repeat the test.
9. After final test repetition, both the remote and host vehicles drive to offload location and confirm that generated log files are offloaded.

5.5.3 Pass/Fail Criteria

- The host vehicle OBU must issue an FCW in two sequential test repetitions or at least two out of three sequential test repetitions.
- The host vehicle OBU must issue the FCW at a time-to-collision close to the configured collision imminent time.
- The host vehicle OBU must display the predefined TIM during the approach prior to any FCW. The FCW display must be prioritized over the TIM display when the FCW occurs.

5.6 WFCW-3 – FCW Slow Moving Vehicle

5.6.1 Test Objective

Verify the FCW application issues an imminent FCW alert when there is an imminent threat of forward collision with a slow-moving vehicle directly ahead in the same lane of travel and immediate action is required from the driver to avoid the collision.

5.6.2 Test Description

5.6.2.1 Verify Readiness

1. Host and Remote vehicles have Commsignia OBUs installed with antenna and HMI, configured according to the WYDOT CV Pilot Commsignia OBU Provisioning Guide v1.0. The OBUs must be set up to support all communications with production SCMS.
2. Confirm that the test track Commsignia RSU is installed and configured according to the WYDOT CV Pilot Commsignia RSU Provisioning Guide v1.2. The RSU must be set up to support all communication with production SCMS. Ensure this RSU is not configured to support Log File offload.
3. Identify a rest location on the test track where vehicle can drive to before and after a test run.
4. Identify specific test track segment for remote vehicles to travel at a reduced speed and have a minimum of 600 meters trailing distance for the host vehicle to approach and catch up to the remote vehicle.
5. Identify remote offload location where vehicles can drive to offload log files upon completion of the driving test.

5.6.2.2 Test Start Up

1. Drive host and remote vehicles to rest location on the test track.
2. Power up each OBU in the host and remote vehicles. Confirm that the OBUs are operating and connected to their associated HMI. The HMI display should appear as a map with the vehicle marker at the current vehicle geographic location.

5.6.2.3 Track Test Procedure

1. Drive both the host and remote vehicle to the beginning of the designated test track segment where the test will be run.
2. First, the remote vehicle starts driving down the test segment. The remote vehicle drives at least 300 meters down the test track segment and then slows to the intercept speed of 15 mph. The remote vehicle then maintains the 15 mph speed until the test sequence is complete.
3. Once the remote vehicle is more than 300 meters down the test track segment and has slowed to the intercept speed, then start the host vehicle down the test track segment in pursuit of the remote vehicle. The host vehicle follows the same path that the remote vehicle did when driving down the test segment.
4. Accelerate the host vehicle up to 35 miles per hour driving on the test track segment in pursuit of the slow-moving remote vehicle. The host driver should initially focus on achieving and maintaining the test speed of 35 mph.
5. As the host vehicle approaches the slow-moving remote vehicle the driver maintains vehicle speed and monitors the approach to the remote vehicle, the driver ensures the host vehicle stops or avoids the remote vehicle before any collision.
6. During the approach to the remote vehicle, the host vehicle driver identifies any forward collision warnings issued to the driver.
7. Once the host vehicle has caught up to the remote vehicle and has slowed to match speed with the remote vehicle, this signals the end of this test sequence. The host vehicle driver

should come to a complete stop and record any driver alerts received during the prior approach sequence.

8. The host and remote vehicles then return to the previously defined approach path start location to repeat the test.
9. After final test repetition, both the remote and host vehicles drive to offload location and confirm that generated log files are offloaded.

5.6.3 Pass/Fail Criteria

- The host vehicle OBU must issue an FCW in two sequential test repetitions or at least two out of three sequential test repetitions.
- The host vehicle OBU must issue the FCW at a time-to-collision close to the configured collision imminent time.

5.7 WI2VSA-1 – Message Display LTE-V2X Communication

5.7.1 Test Objective

Verify that a TIM is received, parsed correctly, and displayed correctly in-vehicle per the defined type, timing, direction and geofence of the TIM. Confirm that a TIM can be transmitted to the vehicle OBU over LTE-V2X communication while operating at normal highway speeds.

5.7.2 Test Description

5.7.2.1 Verify Readiness

1. Host and Remote vehicles have Commsignia OBUs installed with antenna and HMI, configured according to the WYDOT CV Pilot Commsignia OBU Provisioning Guide v1.0. The OBUs must be set up to support all communications with production SCMS.
2. Confirm that the test track Commsignia RSU is installed and configured according to the WYDOT CV Pilot Commsignia RSU Provisioning Guide v1.2. The RSU must be set up to support all communication with production SCMS. This RSU will be designated to broadcast the TIM required for the test. Ensure this RSU is not configured to support Log File offload.
3. Define a situational awareness TIM (e.g. speed limit TIM) with a geofence along a defined roadway section of the test area. The start boundary of the TIM must start at least 1000 meters downstream from the RSU broadcasting the TIM.
4. Deposit the situational awareness TIM for broadcast on the designated TIM broadcast RSU. Ensure that the TIM is not available on the SDX so that the TIM is only broadcast from the RSU and is not broadcast from satellite.
5. Identify a rest location in the test area that is outside of the transmit range of the TIM broadcast RSU, where vehicles can drive to before and after a test run.
6. Confirm that the test team includes both a driver and recorder for the host vehicle.
7. Identify remote offload location where vehicles can drive to offload log files upon completion of the driving test.

5.7.2.2 Test Start Up

1. Drive the host vehicle to rest location in the test area.
2. Power up the OBU in the host vehicle. Confirm that the OBU is operating and connected to its associated HMI. The HMI display should appear as a map with the vehicle marker at the current vehicle geographic location.

5.7.2.3 Track Test Procedure

1. Drive the host vehicle from the rest location along the test corridor past the TIM broadcast RSU and then through the defined TIM zone.
2. When driving through the defined TIM zone, the recorder monitors the HMI and notes times when the TIM displays and is removed.
3. After driving the full distance through the defined TIM zone, the host vehicle turns around and drives to the crossover path located within the defined TIM zone.
4. Drive the host vehicle along the crossover path and make one transit in each direction. The cross over path should be in a direction perpendicular to the primary direction mask of the TIM.
5. During the crossover transits, the recorder monitors the HMI and notes if the TIM is displayed.
6. After completing the crossover transits, drive the host vehicle back to the defined rest location. At the rest location the host vehicle OBU should be rebooted to erase the previously received TIM before starting a new repetition.

5.7.3 Pass/Fail Criteria

- TIM display appears within 1 second of entering TIM geofence boundary.
- TIM display removed within 1 second of exiting TIM geofence boundary.
- No TIM displayed when vehicle crosses TIM geofence boundary in a direction outside of the TIM defined direction mask.

5.8 WI2VSA-2 – Message Display Satellite Communication

5.8.1 Test Objective

Verify that a TIM is received, parsed correctly, and displayed correctly in-vehicle per the defined type, timing, direction and geofence of the TIM. Confirm that a TIM can be transmitted to the vehicle OBU over satellite communication.

5.8.2 Test Description

5.8.2.1 Verify Readiness

1. Host and Remote vehicles have Commsignia OBUs installed with antenna and HMI, configured according to the WYDOT CV Pilot Commsignia OBU Provisioning Guide v1.0. The OBUs must be set up to support all communications with production SCMS.
2. Confirm that the test track Commsignia RSU is installed and configured according to the WYDOT CV Pilot Commsignia RSU Provisioning Guide v1.2. The RSU must be set up to support all communication with production SCMS. Ensure this RSU is not configured to support Log File offload.
3. Define a situational awareness TIM (e.g., road construction TIM) with a geofence along a defined roadway section of the test area.
4. Deposit the situational awareness TIM for broadcast on the SDX. Ensure that the TIM is not deposited to any RSUs for broadcast, so that the TIM is only available from satellite broadcast.
5. Identify a rest location in the test area that is outside of defined TIM geofence, where vehicles can drive to before and after a test run.
6. Confirm that the test team includes both a driver and recorder for the host vehicle.
7. Identify remote offload location where vehicles can drive to offload log files upon completion of the driving test.

5.8.2.2 Test Start Up

1. Drive the host vehicle to the rest location in the test area.
2. Power up the OBU in the host vehicle. Confirm that the OBU is operating and connected to its associated HMI. The HMI display should appear as a map with the vehicle marker at the current vehicle geographic location.

5.8.2.3 Track Test Procedure

1. Ensure that the host vehicle is at the rest location with its OBU operating continuously for at least 5 minutes before beginning to drive through the defined TIM zone. This will ensure the OBU is operating for enough time to catch at least one satellite broadcast cycle.
2. Drive the host vehicle from the rest location through the defined TIM zone.
3. When driving through the defined TIM zone, the recorder monitors the HMI and notes times when the TIM displays and is removed.
4. After driving the full distance through the defined TIM zone, the host vehicle turns around and drives back to the rest location through the TIM zone in the opposite direction of the original traverse.
5. During the opposite direction transit, the recorder monitors the HMI and notes if the TIM is displayed.
6. After completing transit and return through the TIM zone, drive the host vehicle back to the defined rest location. At the rest location the host vehicle OBU should be rebooted to erase the previously received TIM before starting a new repetition.

5.8.3 Pass/Fail Criteria

- TIM display appears within 1 second of entering TIM geofence boundary.
- TIM display removed within 1 second of exiting TIM geofence boundary.
- No TIM displayed when vehicle traverses TIM geofence boundary in a direction outside of the TIM defined direction mask.

5.9 WI2VSA-3 – Message Display Simultaneous LTE-V2X and Satellite Communication

5.9.1 Test Objective

Verify that a unique TIM transmitted simultaneously over satellite and LTE-V2X is received, parsed correctly, and displayed correctly in-vehicle per the defined type, timing, direction and geofence of the TIM.

5.9.2 Test Description

5.9.2.1 Verify Readiness

1. Host and Remote vehicles have Commsignia OBUs installed with antenna and HMI, configured according to the WYDOT CV Pilot Commsignia OBU Provisioning Guide v1.0. The OBUs must be set up to support all communications with production SCMS.
2. Confirm that the test track Commsignia RSU is installed and configured according to the WYDOT CV Pilot Commsignia RSU Provisioning Guide v1.2. The RSU must be set up to support all communication with production SCMS. Ensure this RSU is not configured to support Log File offload.
3. Define a situational awareness TIM (e.g., road condition TIM) with a geofence along a defined roadway section of the test area.
4. Deposit the situational awareness TIM for broadcast on the SDX and deposit the TIM on the test track RSU so that the TIM is available from both LTE-V2X and satellite broadcast.
5. Identify a rest location in the test area that is outside of defined TIM geofence, where vehicles can drive to before and after a test run.
6. Confirm that the test team includes both a driver and recorder for the host vehicle.
7. Identify remote offload location where vehicles can drive to offload log files upon completion of the driving test.

5.9.2.2 Test Start Up

1. Drive the host vehicle to the rest location in the test area.
2. Power up the OBU in the host vehicle. Confirm that the OBU is operating and connected to its associated HMI. The HMI display should appear as a map with the vehicle marker at the current vehicle geographic location.

5.9.2.3 Track Test Procedure

1. Drive the host vehicle with its OBU operating within range of the RSU that is broadcasting the TIM. After the near pass of the RSU, drive the host vehicle to the rest location. Ensure that the host vehicle has its OBU operating continuously for at least 5 minutes before beginning to drive through the defined TIM zone. This time period will ensure the OBU is operating for enough time to catch at least one satellite broadcast cycle.
2. Drive the host vehicle from the rest location through the defined TIM zone.
3. When driving through the defined TIM zone, the recorder monitors the HMI and notes times when the TIM displays and is removed.
4. After driving the full distance through the defined TIM zone, the host vehicle turns around and drives back to the rest location through the TIM zone in the opposite direction of the original traverse.
5. During the opposite direction transit, the recorder monitors the HMI and notes if the TIM is displayed.
6. After completing transit and return through the TIM zone, drive the host vehicle back to the defined rest location. At the rest location the host vehicle OBU should be rebooted to erase the previously received TIM before starting a new repetition.

5.9.3 Pass/Fail Criteria

- TIM display appears within 1 second of entering TIM geofence boundary.
- TIM display removed within 1 second of exiting TIM geofence boundary.
- No TIM displayed when vehicle traverses TIM geofence boundary in a direction outside of the TIM defined direction mask.

5.10 WI2VSA-4 - Message Display Start and Stop Time

5.10.1 Test Objective

Verify that a TIM is received, parsed correctly, and displayed correctly in-vehicle per the defined type, timing, and geofence of the TIM.

5.10.2 Test Description

5.10.2.1 Verify Readiness

1. Host and Remote vehicles have Commsignia OBUs installed with antenna and HMI, configured according to the WYDOT CV Pilot Commsignia OBU Provisioning Guide v1.0. The OBUs must be set up to support all communications with production SCMS.
2. Confirm that the test track Commsignia RSU is installed and configured according to the WYDOT CV Pilot Commsignia RSU Provisioning Guide v1.2. The RSU must be set up to support all communication with production SCMS. This RSU will be designated to broadcast the TIM required for the test.
3. Define two different situational awareness TIMs (e.g. weather condition TIMs) with a common geofence along a defined roadway section of the test area. The start times of the two TIMs

must be defined at least 15 minutes apart but no more than 30 minutes apart. The duration of each TIM must be defined so that the stop times of the TIMs are at least 15 minutes apart and no more than 30 minutes apart. These defined start times and durations will allow a series of test runs to verify TIM start times followed by test runs to verify TIM end times.

4. Deposit the situational awareness TIMs for broadcast on the designated TIM broadcast RSU.
5. Identify a rest location in the test area that is outside of defined TIM geofence, where vehicles can drive to before and after a test run.
6. Confirm that the test team includes both a driver and recorder for the host vehicle.
7. Identify remote offload location where vehicles can drive to offload log files upon completion of the driving test.

5.10.2.2 Test Start Up

1. Drive the host vehicle to the rest location in the test area.
2. Power up the OBU in the host vehicle. Confirm that the OBU is operating and connected to its associated HMI. The HMI display should appear as a map with the vehicle marker at the current vehicle geographic location.
3. Drive the host vehicle, with its OBU operating, within range of the RSU that is broadcasting the TIM. After the near pass of the RSU, drive the host vehicle to the rest location.

5.10.2.3 Track Test Procedure

1. From the rest location drive the host vehicle into the TIM geofence. The host vehicle should enter the TIM geofence at least 30 seconds before the TIM start/end time. The goal is to ensure the vehicle is within the TIM geofence when the start/end time occurs.
2. When driving through the defined TIM zone, the recorder monitors the HMI and notes times when the TIMs are displayed and removed.
3. Drive the full distance through the defined TIM zone and confirm the removal of the TIM upon exiting the TIM geofence.
4. Drive the host vehicle back to the rest location and wait for the next drive run start per the predefined TIM start and end times.

5.10.3 Pass/Fail Criteria

- TIM display appears within 1 second of the predefined TIM start time.
- TIM display removed within 1 second of the predefined TIM end time.

Appendix A. Acronyms

Table 6 lists the acronyms used in this document.

Table 6. Acronyms

Acronym	Definition
BSM	Basic Safety Message
LTE-V2X	Cellular Vehicle to Everything (same as C-V2X)
CV	Connected Vehicle
DSRC	Dedicated Short Range Communications
FCW	Forward Collision Warning
GPS	Global Positioning System
I2V	Infrastructure to Vehicle
OBU	On-Board Unit
RSU	Roadside Unit
SAE	Society of Automotive Engineers
SCMS	Security Credential Management System
TIM	Traveler Information Message
TMC	Transportation Management Center
USDOT	United States Department of Transportation
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
WYDOT	Wyoming Department of Transportation

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