Proof-of-Concept Integrated Work Zone Mapping Toolset

Testing Results

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Final Report – July 13, 2020

Prepared for:

FHWA-XXX-XX-XXX: V2X Work Zone Mapping Toolset

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16. Abstract The purpose of the Proof of Concept (POC) test is to verify the functionality and performance of the system which captures latitude, longitude and elevation of the work zone configuration, travel path and features. From this information we can accurately create a work zone map message in 3 different formats that can be shared with other Connected Vehicle systems. The key system engineering elements for the POC are documented in the companion document System Engineering and Testing Plan for Proof-of-Concept of Integrated Work Zone Mapping Toolset. That document summarizes system engineering architecture and requirements for the POC system as well as a demonstration and testing plan. That document is intended only as summary of key elements sufficient to support proof of concept testing.		
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Chapter 1. Introduction

1.1 Project Scope

Work zones are dynamic and change roadway characteristics frequently, affecting mobility and safety of traffic flow. Up-to-date information about dynamic conditions occurring on roads – such as construction events – is needed by both the traveling public, and by connected and automated vehicles (CAVs) to navigate work zones safely and efficiently. The objective of Task 6 of the V2X Mapping Project is to develop, test and demonstrate a proof of concept (POC) system for efficiently capturing a digital map of a work zone and its features, including lane closures and workers present in the work zone. These data are combined with other work zone configuration data to form a work zone map message that is published to disseminate to infrastructure owners and operators (IOO) traveler information systems, third-party traveler information systems, and ADS such as the FHWA CARMA vehicle. The work zone map message is to be published in WZDx V2 [1], SAE J2945/4 RSM (XML) [4], and SAE J2945/4 RSM (binary) [4] formats.

1.2 Purpose of this Test

The purpose of the Proof of Concept (POC) test is to verify the functionality and performance of the system which captures latitude, longitude and elevation of the work zone configuration, travel path and features. From this information we can accurately create a work zone map message in three different formats that can be shared with other Connected Vehicle systems.

The key system engineering elements for the POC are documented in the companion document System Engineering and Testing Plan for POC of Integrated Work Zone Mapping Toolset. That document summarizes system engineering architecture and requirements for the POC system as well as a testing plan. That document is intended only as summary of key elements sufficient to support POC testing. The interfaces of the POC system are described in the other companion document, the Interface Control Document (ICD) for POC of Integrated Work Zone Mapping Toolset.

1.3 Summary of Testing Procedures and Results

The test for the POC work zone mapping tool consists of a single vehicle equipped with a Ublox GPS device connect to a computer running the Work Zone Data Collection application, with access to the Work Zone configuration creator and internet.

These tests were executed at the Archer test site in Wyoming. This test site contains a large oval shaped roadway approximately 1.6 km in diameter, and some additional service roads with 0.5 km straight and curved road sections. The test site is located about 12 km East of Cheyenne WY, at the Archer exit on Interstate 80. All testing was completed on July 24th, 2020.

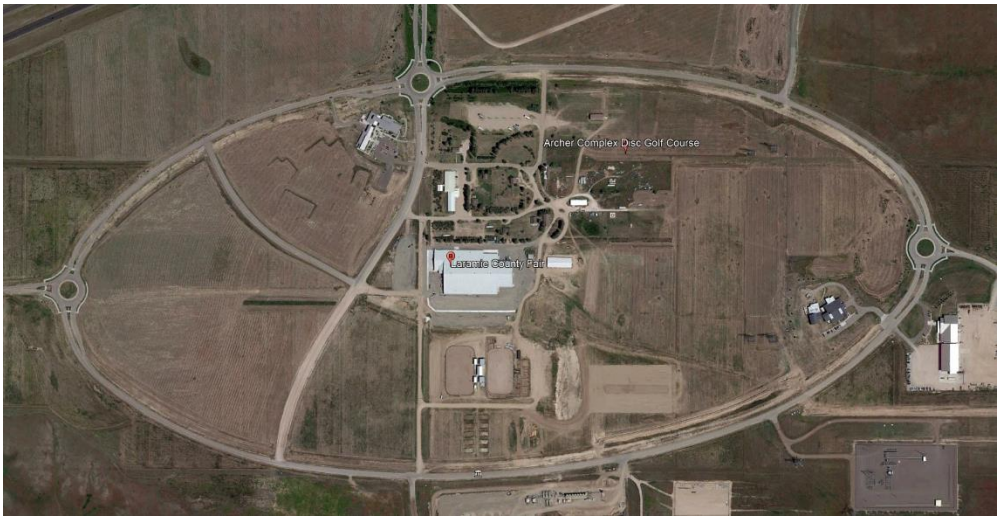


Figure 1. Archer Complex Testing location

The results from the tests are recorded in the results section of this document and organized by round of testing. The files created and generated by this tool include a configuration file (custom JSON), the path and features (CSV) file, RSM (UPER) message file, RSM (XML) file and WZDx (GeoJSON). Detailed information about each of these files are documented within the test case descriptions. The files generated from the testing as well as an Excel document used for calculations are located here: https://github.com/TonyEnglish/V2X-manual-data-collection/tree/master/Sample%20Files/Testing%20Data

Each step in the test plan in Table is performed 5 or 10 times. To pass the step, the pass/fail criteria must be met 5 out of the first 5 times or 9 out of first 10 times.

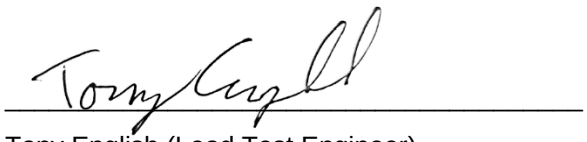
1.4 Document Organization

This Test Report document is organized into three chapters

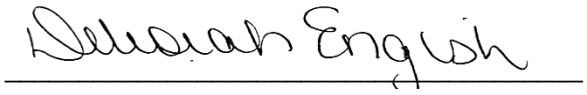
1. Introduction
2. Approval
3. Test Procedure and Test Cases

Chapter 2. Approval

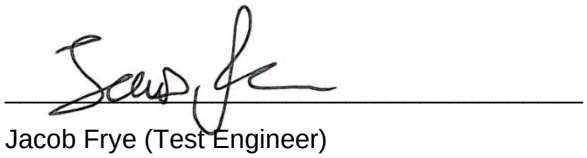
The following signatures indicate that this test result reported in this document have been reviewed and approved by:



Tony English (Lead Test Engineer) — 7/28/2020 Date



Debbie English (Test Engineer) — 7/28/2020 Date



Jacob Frye (Test Engineer) — 7/28/2020 Date

Chapter 3. Test Procedure and Test Cases

This chapter describes the testing and procedures to run each test. For each test, the steps and procedures are listed out by test name.

3.1 Table WZ Mapping Toolset Test Case Summary

Table 1 lists the steps for the test case summary.

Table 1. WZ Mapping Toolset Test Case Summary

Step	Activity	Action	Expected Result	Testing Requirements Verified
Initialize and prepare for Testing				
1	Initialize Back Office Folders	Empty Back Office File Folders including • WZ Config {JSON} & WZ Map {RSM(XML)}, {RSM(binary)}, WZ Path & Features, and {WZDx} (Unzipped) File Folder • Verified WZ Map {RSM(XML)}, {RSM(binary)}, and {WZDx} File Folder	File folder inspection shows file folders are empty	
2	Initialize Laptop Application and Folders	Initialize Laptop Work Zone Data Collection Application. Empty Laptop File Folders including: • WZ Config {JSON} & WZ Path & Features {CSV} File Folder	• Application open and ready for input File folder inspection shows file folders are empty	

Step	Activity	Action	Expected Result	Testing Requirements Verified
		• WZ Config {JSON} & WZ Map {RSM(XML)}, {RSM(binary)}, WZ Path & Features, and {WZDx} File Folder (Zipped) File Folder		
3	Prepare Testing WZ track	Set up Testing WZ including Cone Placement for • Begin of WZ • Begin of Lane Closure • Begin of Workers Present • End of Workers Present • End of Lane Closure • End of WZ Independently measure Lat/Long of work zone features within +/- 2m accuracy of • Begin of WZ • Begin of Lane Closure • Begin of Workers Present • End of Workers Present • End of Lane Closure • End of WZ	Testing WZ is setup, measured, and ready for testing.	PRD-01, PRD-02, PRD-03, PRD-04, PRD-05, PRD-06
Conduct Testing				

Step	Activity	Action	Expected Result	Testing Requirements Verified
4	Verifies TMC Configuration Creator	• Test Engineer opens TMC Configuration Creator page and enters each parameter. • Upon completion, WZ Config {JSON} file is saved and published to Azure cloud storage and downloaded to designated file folder. • Test Engineer opens and displays WZ Config file using file inspection tool. • Test engineer shows that WZ configuration parameters are correct.	• Testing of Configuration Creator, including the following fields: ○ Work Zone Description ○ Number of lanes ○ Vehicle Path Data Lane ○ Average Lane Width ○ Normal speed (before work zone) ○ Work Zone Speed without workers ○ Work Zone speed with workers ○ Work Zone Type ○ Start Date and Time ○ End Date and Time ○ Days of the Week in operation ○ GPS location (latitude / longitude) for the beginning and end of work zone • Entry of additional WZDx information: ○ Beginning Cross Street ○ Ending Cross Street ○ Event Status ○ Road Direction ○ Accuracies – Beginning, Ending, Start Date and End Date ○ Work Types ○ Lane restrictions ○ Lane Types ○ Issuing Organization	PRT-01, PRT-02, PRT-03, PRT-04, PRT-06, PRT-07

Step	Activity	Action	Expected Result	Testing Requirements Verified
			○ WZ Location Method ○ LRS Type ○ Location Verify Method ○ Data Feed Frequency Update ○ Contact Name ○ Contact Email	
5	Setup Laptop and WZ Path Application in Vehicle	• Test engineer sets up laptop in vehicle, connecting GPS antenna and power as needed. • Test engineer initiates WZDC application and verifies application is receiving valid GPS coordinates. • Test engineer loads configuration file into WZDC application and verifies it has loaded the configuration file. • Test engineer presses “Begin Data Collection” and verifies the application is ready to capture data.	WZDC application and vehicle are ready for data collection.	PRW-01, PRW-02, PRW-03, PRW-04 PRT-02, PRT-03, PRT-04
6	Confirm track is clear and all equipment and participants are ready to safely conduct testing.	• Driver confirms Testing WZ track is clear and testing is ready to proceed. • Driver starts vehicle. • Driver confirms all parties are ready to begin and all participants agree testing can be performed safely.	Track and all participants are ready for data collection and ready for vehicle to traverse the Testing WZ.	
Vehicle Path Data Collection				

Step	Activity	Action	Expected Result	Testing Requirements Verified
7	Driver traverses testing WZ path	• Driver begins traversing the specified path adjacent to the work zone, accelerating to and holding 15 mph, adhering to the middle of the lane as much as practical. • Driver continues to end of Testing WZ and stops vehicle.	Vehicle containing testing participants traverses the Testing WZ.	
8	Test Engineer captures WZ path and features while traversing WZ path	While traversing the specified path adjacent to the work zone, the test engineer shows that the application automatically completes the following steps: • Data collection begins • Reference point is marked • Data collection ends While traversing the specified path adjacent to the work zone, the test engineer toggles the WZDC Vehicle Path Data Acquisition application controls when perpendicular to each of the following: • Begin of Lane Closure • Begin of Workers Present • End of Workers Present • End of Lane Closure	• Data collection begins ~50m before the Begin of WZ marker • Reference point is marked when roughly perpendicular to Begin of WZ • Data collection ends when roughly perpendicular to End of WZ WZ Vehicle Path Data Acquisition Application captures path and feature lat/long data.	PRW-05, PRW-07, PRW-08, PRW-09, PRW-11
Data and Map Message Assessment				
9	Inspection of WZ Path & Features file	Upon completion of the WZ Testing run	• WZ Path & Features File located in the specified laptop folder.	PRW-06, PRW-10, PRW-12

Step	Activity	Action	Expected Result	Testing Requirements Verified
		• Test engineer verifies that the WZ Path & Features {CSV} file is located in the designated laptop file folder. • Test engineer opens and displays WZ Path & Features {CSV)} file using file inspection tool. • Test engineer shows that WZ path and features lat/long are collected. (accuracy is verified in Step 10)	Inspection of the WZ Path & Features file verifies that WZ path and features parameters were collected and stored in a CSV file.	
10	Verify WZDC message builder. Inspect WZ Map {RSM(XML)} File.	• Test engineer verifies that the WZ Map {RSM(XML)} File is in the designated laptop folder. • Test Engineer opens and inspects WZ Map {RSM(XML)} File using file inspection tool. • Test engineer verifies that WZ map path and features lat/long are captured. Test engineer analyzes results and shows that WZ map features (and lane tapers) lat/long are within specified tolerances.	• WZ Map {RSM(XML)} file is located in the specified laptop folder. • Inspection verifies that WZ map path and features lat/long were collected and stored in an RSM(XML) file. Analysis verifies that WZ map features (and lane tapers) lat/long are within acceptable tolerances.	PRW-13, PRW-13.1, PRW-13.2, PRW-13.3, PRW-14, PRW-17
11	Verify RSM(XML)->WZDx Translator. Verify RSM(XML)-> {RSM(binary)} Translator.	• Test engineer verifies that the WZ Map {WZDx} file is located in the designated laptop file folder. • Test engineer verifies that the WZ Map {RSM(binary)} file is located in the designated laptop file folder. • Test Engineer opens and displays WZ Map {WZDx} File using file inspection tool.	• WZ Map {WZDx and RSM (binary)} files are located in the specified laptop folder. Inspection verifies that WZ path and features parameters were collected and stored in WZDx file.	PRW-15, PRW-16,

Step	Activity	Action	Expected Result	Testing Requirements Verified
		Test engineer shows that WZ path and features parameters are consistent with WZ Map {RSM(XML)} file.		
12	Verify work zone data ZIP archive contents.	• Test engineer verifies that the ZIP archive is located in the specified laptop directory. • Test engineer unzips local zip file and shows that all of the files are present	Inspection shows that WZ Config, WZ Path & Features, WZ Map {RSM(XML)}, {RSM(binary)} & {WZDx} are present in the local unzipped archive.	PRW-18
13	Trigger WZDC tool to upload files to Back Office.	• Test engineer presses “Upload” on the WZDC application and verifies that the application displays a success message. • Test engineer verifies that the ZIP archive is located in cloud storage. • Test engineer verifies that messages and files are organized in cloud storage.	Inspection shows that WZ Config, WZ Path & Features, WZ Map {RSM(XML)}, {RSM(binary)} & {WZDx} are uploaded and stored in the designated Back Office File folder (unzipped).	PRW-19, PRW-20 PRT-10, PRT-11
14	Verify TMC Website Visualizer.	• Test engineer activates the TMC Visualization and Verification application and loads the work zone. • Test Engineer displays the WZ Map {RSM(XML)} & {WZDx} files to the independently measured lat/long and to the satellite map of the Testing WZ. • Test Engineer verifies that the WZ Map {RSM(XML)} & {WZDx} files correctly depict • Begin of WZ • Begin of Lane Closure • Begin of Workers Present • End of Workers Present • End of Lane Closure	Inspection confirms that verified WZ Map {RSM(XML)} & {WZDx} are stored in the designated Back Office File folder, ready for download by others.	PRT-12, PRT-13, PRT-13.1, PRT-13.2, PRT-13.3, PRT-13.4, PRT-13.5, PRT-14, PRT-14.1, PRT-14.2, PRT-15, PRT-16

Step	Activity	Action	Expected Result	Testing Requirements Verified
		• End of WZ • Test Engineer verifies approval feature of application and storage of files in designated Back Office File Folder. • Test Engineer opens, displays and confirms transfer of each of the WZ Map Files using file inspection tool.		
15	Verify availability of WZ Map {RSM(XML)} and WZ Map {WZDx} Files Third party traveler information services and for CARMA systems.	• Test Engineer inspects file folders and shows WZ Map {RSM(XML)}, {RSM(binary)}, and {WZDx} Files are available for access by simulated Third party traveler information services and for CARMA systems. • Test Engineer downloads all 3 messages and verifies the contents of the download ZIP archive using a file inspection tool	Downloaded ZIP archive contains all 3 messages	PRT-17

3.2 Step 1 Initialize Back Office Folders Results

Table 2 describes the step to initialize the back office folders.

Table 2. Step 1 - Initialize Back office folders

Step #	Rep	Step 1	Test Engineer Verification and Remarks
Activity		Initialize Back Office Folders	
Test Case Completion Date		11 June 2020	
Results	Rep 1	Azure cloud storage folders emptied	Performed and confirmed by: DE, JF

Step #	Rep	Step 1	Test Engineer Verification and Remarks
Notes	Rep 1	None.	
Summary		All Azure cloud storage folders emptied.	
Requirements Verified			
Pass/Fail Assessment		• Pass	Performed and confirmed by: DE, JF

3.3 Step 2 Initialize Laptop Application and Folders Results

Table 3 describes the step to initialize the laptop application and folders.

Table 3. Step 2 - Initialize Laptop application and folders

Step #	Rep	Step 2	Test Engineer Verification and Remarks
Activity		Initialize Laptop Application and Folders	
Test Case Completion Date		11 June 2020	
Results	Rep 1	• Application initialized and ready for input • Local output folders were empty of files	Performed and confirmed by: DE, JF
Notes	Rep 1	None	
Summary		Application initialized and local folders emptied.	
Requirements Verified			

Step #	Rep	Step 2	Test Engineer Verification and Remarks
Pass/Fail Assessment		• Pass	Performed and confirmed by: DE, JF

3.4 Step 3 Prepare Testing WZ Track

Table 4 describes the step to prepare the testing on the work zone track.

Table 4. Step 3 - Prepare testing WZ Track

Step #	Rep	Step 3	Test Engineer Verification and Remarks
Activity		Prepare Testing WZ track	
Test Case Completion Date		11 June 2020	
Results		• testing work zone constructed and measured using Google Maps. Locations are as follows: (lat, long) • Begin of WZ: (41.1469491, -104.655958) • Begin of Lane Closure: (41.147228, -104.651442) • Begin of Workers Present: (41.147951, -104.648074) • End of Workers Present: (41.149419, -104.645261) • End of Lane Closure: (41.149851, -104.644749) • End of WZ: (41.15042906, -104.644422)	Performed and confirmed by: DE, JF
Notes	Preliminary setup	Feature locations were set on intersections of cross streets. The locations of the features were determined using google maps and estimating the location of the feature in the center of the driven lane.	
Summary		Independent locations captured.	

Step #	Rep	Step 3	Test Engineer Verification and Remarks
Requirements Verified			
Pass/Fail Assessment		• Pass	Performed and confirmed by: DE, JF

3.5 Step 4 Verify TMC Configuration Creator Results

Table 5 describes the step to verify the TMC configuration creator results.

Table 5. Step 4 Verify TMC Configuration Creator Results

Step #	Rep	Step 4	Test Engineer Verification and Remarks
Activity		Verify TMC Configuration Creator	
Test Case Completion Date		11 June 2020	
Results	Rep 1	The following fields were entered into the configuration creator: • Work Zone Description: accuracy-test-1 • Number of lanes: 2 • Vehicle Path Data Lane: 2 • Average Lane Width: 3.6 • Normal speed: 25 • Work Zone Speed without workers: 20 • Work Zone speed with workers: 15 • Work Zone Type: maintenance • Start Date and Time: 2020-06-15T06:00:00Z • End Date and Time: 2020-06-20T11:59:00Z	Performed and confirmed by: DE, JF

Step #	Rep	Step 4	Test Engineer Verification and Remarks
		• Days of the Week in operation: Mon, Tue, Wed, Thurs, Fri • GPS location (latitude / longitude) for the beginning and end of work zone: • Begin: (41.146949089427, -104.655958174084) • End: (41.1504290591271, -104.644421993111) • Beginning Cross Street: HR Ranch Road • Ending Cross Street: Laramie County Public Works • Event Status: planned • Road Direction: eastbound • Accuracies – Beginning, Ending, Start Date and End Date: estimated • Work Types: maintenance (false) • Lane restrictions: • Lane Restriction • Lane Number: 1 • Restriction Type: no-trucks • Lane Restriction • Lane Number: 2 • Restriction Type: towing-prohibited • Lane Types: left-lane, right-lane • Issuing Organization: Neaera Consulting • WZ Location Method: channel-device-method • LRS Type: interpolative • Location Verify Method: GPS equipment accurate to 1 m • Data Feed Frequency Update: • Contact Name: Jacob Frye • Contact Email: jfrye@neaeraconsulting.com	

Step #	Rep	Step 4	Test Engineer Verification and Remarks
		All data was confirmed to be in configuration file	
Notes	Rep 1	None.	
Results	Rep 2	Exactly the same as Rep 1, except for: • Work Zone Description: accuracy-test-2 All data was confirmed to be in configuration file	Performed and confirmed by: DE, JF
Notes	Rep 2	None.	
Results	Rep 3	Exactly the same as Rep 1, except for: • Work Zone Description: accuracy-test-3 All data was confirmed to be in configuration file	Performed and confirmed by: DE, JF
Notes	Rep 3	None.	
Results	Rep 4	Exactly the same as Rep 1, except for: • Work Zone Description: accuracy-test-4 All data was confirmed to be in configuration file	Performed and confirmed by: DE, JF
Notes	Rep 4	None.	
Results	Rep 5	Exactly the same as Rep 1, except for: • Work Zone Description: accuracy-test-5 All data was confirmed to be in configuration file	Performed and confirmed by: DE, JF
Notes	Rep 5	None.	
Summary		All 5 configuration files created.	
Requirements Verified			

Step #	Rep	Step 4	Test Engineer Verification and Remarks
Pass/Fail Assessment		Pass	Performed and confirmed by: DE, JF

3.6 Step 5 Setup Laptop and WZ Path Application in Vehicle Results

Table 6 describes the step for setting up the laptop and the work zone in vehicle application.

Table 6. Step 5 - Setup laptop and WZ Path Application in vehicle

Step #	Rep	Step 5	Test Engineer Verification and Remarks
Activity		Setup Laptop and WZ Path Application in Vehicle	
Test Case Completion Date		11 June 2020	
Results	Rep 1	• Loaded configuration file accuracy-test-1 • GPS connection was verified • Data collection was initiated • Pass	Performed and confirmed by: DE, JF
Notes	Rep 1	None.	
Results	Rep 2	• Loaded configuration file accuracy-test-2 • GPS connection was verified • Data collection was initiated • Pass	Performed and confirmed by: DE, JF
Notes	Rep 2	None.	
Results	Rep 3	• Loaded configuration file accuracy-test-3 • GPS connection was verified • Data collection was initiated	Performed and confirmed by: DE, JF

Step #	Rep	Step 5	Test Engineer Verification and Remarks
		• Pass	
Notes	Rep 3	None.	
Results	Rep 4	• Loaded configuration file accuracy-test-4 • GPS connection was verified • Data collection was initiated • Pass	Performed and confirmed by: DE, JF
Notes	Rep 4	None.	
Results	Rep 5	• Loaded configuration file accuracy-test-5 • GPS connection was verified • Data collection was initiated • Pass	Performed and confirmed by: DE, JF
Notes	Rep 5	None.	
Summary		Configuration file loaded and application initialized correctly for 5/5 tests.	
Requirements Verified			
Pass/Fail Assessment		• Pass	Performed and confirmed by: DE, JF

3.7 Step 6 Confirm Track Clear and Participants Ready

Table 7 describes the step to confirm the track is clear and participants are read for the test.

Table 7. Step 6 - Confirm track clear and participants are ready for test

Step #	Rep	Step 6	Test Engineer Verification and Remarks
Activity		Confirm track is clear and all equipment and participants are ready to safely conduct testing.	
Test Case Completion Date		11 June 2020	
Results	Rep 1	• Track inspected and participants ready • Pass	Performed and confirmed by: DE, JF
Notes	Rep 1	None.	
Results	Rep 2	• Track inspected and participants ready • Pass	Performed and confirmed by: DE, JF
Notes	Rep 2	None.	
Results	Rep 3	• Track inspected and participants ready • Pass	Performed and confirmed by: DE, JF
Notes	Rep 3	None.	
Results	Rep 4	• Track inspected and participants ready • Pass	Performed and confirmed by: DE, JF
Notes	Rep 4	None.	
Results	Rep 5	• Track inspected and participants ready • Pass	Performed and confirmed by: DE, JF
Notes	Rep 5	None.	
Summary		Track inspected for all 5 tests.	
Requirements Verified			

Step #	Rep	Step 6	Test Engineer Verification and Remarks
Pass/Fail Assessment		• Pass	Performed and confirmed by: DE, JF

3.8 Step 7 Driver Traverses Testing WZ Path

Table 8 describes the step for traversing through the testing work zone path.

Table 8. Step 7 - Driver traverses testing WZ path

Step #	Rep	Step 7	Test Engineer Verification and Remarks
Activity		Driver traverses testing WZ path	
Test Case Completion Date		11 June 2020	
Results	Rep 1	• Work zone was traversed. • Pass	Performed and confirmed by: DE, JF
Notes	Rep 1	• Speed was kept to ~15mph	
Results	Rep 2	• Work zone was traversed. • Pass	Performed and confirmed by: DE, JF
Notes	Rep 2	• Speed was between 20 and 25 mph	
Results	Rep 3	• Work zone was traversed. • Pass	Performed and confirmed by: DE, JF
Notes	Rep 3	• Near features, driven speed was 15 mph. Between features speed was 25 mph	
Results	Rep 4	• Work zone was traversed. • Pass	Performed and confirmed by: DE, JF

Step #	Rep	Step 7	Test Engineer Verification and Remarks
Notes	Rep 4	• Near features, driven speed was 15 mph. Between features speed was 25 mph	
Results	Rep 5	• Work zone was traversed. • Pass	Performed and confirmed by: DE, JF
Notes	Rep 5	• Near features, driven speed was 15 mph. Between features speed was 25 mph	
Summary		Work zone successfully traversed for 5/5 tests.	
Requirements Verified			
Pass/Fail Assessment		• Pass	Performed and confirmed by: DE, JF

3.9 Step 8 Test Engineer Captures WZ Features

Table 9 describes the step for capturing the work zone path features.

Table 9. Step 8 - Test Engineer Captures WZ Features

Step #	Rep	Step 8	Test Engineer Verification and Remarks
Activity		Test Engineer captures WZ path and features while traversing WZ path	
Test Case Completion Date		11 June 2020	
Results	Rep 1	The following work zone features were automatically marked: • Data collection began before Begin of WZ marker • Reference Point marked at Begin of WZ marker • Data collection terminated at End of WZ marker	Performed and confirmed by: DE, JF

Step #	Rep	Step 8	Test Engineer Verification and Remarks
		The following work zone features were manually marked at the closest approach to their respective markers: • Begin of Lane Closure • Begin of Workers Present • End of Workers Present • End of Lane Closure Analysis of results is in Step 10 (Section **3.11**).	
Notes	Rep 1	None.	
Results	Rep 2	Same as Rep 1	Performed and confirmed by: DE, JF
Notes	Rep 2	None.	
Results	Rep 3	Same as Rep 1	Performed and confirmed by: DE, JF
Notes	Rep 3	None.	
Results	Rep 4	Same as Rep 1	Performed and confirmed by: DE, JF
Notes	Rep 4	None.	
Results	Rep 5	Same as Rep 1	Performed and confirmed by: DE, JF
Notes	Rep 5	None.	
Summary		WZ features successfully marked for 5/5 tests.	
Requirements Verified			
Pass/Fail Assessment		• Pass	Performed and confirmed by: DE, JF

3.10 Step 9 Inspection of WZ Path and Features Results

Table 10 describes the step for inspecting the work zone path features.

Table 10. Step – 9 Inspection of WZ Path and feature results

Step #	Rep	Step 9	Test Engineer Verification and Remarks
Activity		Inspection of WZ Path & Features file	
Test Case Completion Date		11 June 2020	
Results	Rep 1	WZ Path and Features file (path-data—accuracy-test-1—Prairie Center Cir.csv) located in WZ_VehPathData directory WZ Path & Features file includes lat/long of the following features: • reference point: (41.14693775, -104.6559426) • start of lane 1 closure: (41.14721825, -104.6514053) • start of worker presence: (41.14794075, -104.6480925) • end of worker presence: (41.14943817, -104.6452377) • end of lane 1 closure: (41.14988025, -104.6447271) • end of data collection: (41.15044533, -104.6444045) Analysis of results is in Step 10 (Section **3.11**). Pass	Performed and confirmed by: DE, JF
Notes	Rep 1	None.	

Step #	Rep	Step 9	Test Engineer Verification and Remarks
Results	Rep 2	WZ Path and Features file (path-data—accuracy-test-2—Prairie Center Cir.csv) located in WZ_VehPathData directory WZ Path & Features file includes lat/long of the following features: • reference point: (41.14693417, -104.655925) • start of lane 1 closure: (41.14721033, -104.6514317) • start of worker presence: (41.14793767, -104.6480783) • end of worker presence: (41.14940933, -104.6452732) • end of lane 1 closure: (41.1498365, -104.644755) • end of data collection: (41.15043567, -104.644404) Analysis of results is in Step 10 (Section **3.11**). Pass	Performed and confirmed by: DE, JF
Notes	Rep 2	None.	
Results	Rep 3	WZ Path and Features file (path-data—accuracy-test-3—Prairie Center Cir.csv) located in WZ_VehPathData directory WZ Path & Features file includes lat/long of the following features: • reference point: (41.14694033, -104.6559437) • start of lane 1 closure: (41.14721383, -104.6514683) • start of worker presence: (41.14795267, -104.6480743) • end of worker presence: (41.14939183, -104.6453025) • end of lane 1 closure: (41.14981667, -104.6447728) • end of data collection: (41.15044817, -104.6443973)	Performed and confirmed by: DE, JF

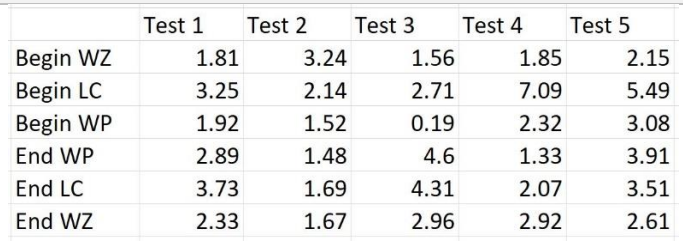
Step #	Rep	Step 9	Test Engineer Verification and Remarks
		Analysis of results is in Step 10 (Section **3.11**). pass	
Notes	Rep 3	None.	
Results	Rep 4	WZ Path and Features file (path-data—accuracy-test-4—Prairie Center Cir.csv) located in WZ_VehPathData directory WZ Path & Features file includes lat/long of the following features: • reference point: (41.14693833, -104.6559413) • start of lane 1 closure: (41.147207, -104.651522) • start of worker presence: (41.14794933, -104.6481017) • end of worker presence: (41.149408, -104.6452673) • end of lane 1 closure: (41.1498325, -104.6447458) • end of data collection: (41.15044333, -104.6443927) Analysis of results is in Step 10 (Section **3.11**). Pass	Performed and confirmed by: DE, JF
Notes	Rep 4	None.	
Results	Rep 5	WZ Path and Features file (path-data—accuracy-test-5—Prairie Center Cir.csv) located in WZ_VehPathData directory WZ Path & Features file includes lat/long of the following features:	

Step #	Rep	Step 9	Test Engineer Verification and Remarks
		• reference point: (41.14693917, -104.6559362) • start of lane 1 closure: (41.14721983, -104.6515067) • start of worker presence: (41.14794167, -104.6481087) • end of worker presence: (41.14939017, -104.6452877) • end of lane 1 closure: (41.14982, -104.644757) • end of data collection: (41.15044033, -104.6443947) Analysis of results is in Step 10 (Section **3.11**). Pass	
Notes	Rep 5	None.	
Summary		WZ Path and Feature Files found and locations extracted for 5/5 tests.	
Requirements Verified			
Pass/Fail Assessment		• Pass	Performed and confirmed by: DE, JF

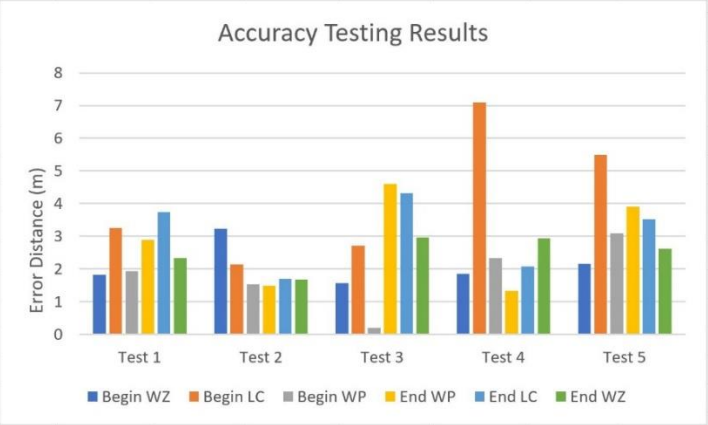
3.11 Step 10 Verify WZDC Message Builder and Inspect RSM Message

Table 11 describes the step for inspecting the RSM message.

Table 11. Step 10 - Verify WZDX message builder and inspect RSM message

Step #	Rep	Step 10	Test Engineer Verification and Remarks
Activity		Verify WZDC message builder. Inspect WZ Map {RSM(XML)} File.	
Test Case Completion Date		11 June 2020	
Results	Rep 1	Compiled in Summary	Performed and confirmed by: DE, JF
Notes	Rep 1	None.	
Results	Rep 2	Compiled in Summary	Performed and confirmed by: DE, JF
Notes	Rep 2	None.	
Results	Rep 3	Compiled in Summary	Performed and confirmed by: DE, JF
Notes	Rep 3	None.	
Results	Rep 4	Compiled in Summary	Performed and confirmed by: DE, JF
Notes	Rep 4	None.	
Results	Rep 5	Compiled in Summary	Performed and confirmed by: DE, JF
Notes	Rep 5	None.	
Summary		 **Figure 2. Distances between marked feature locations and independently measured feature locations (in meters).**	

	Test 1	Test 2	Test 3	Test 4	Test 5
Begin WZ	1.81	3.24	1.56	1.85	2.15
Begin LC	3.25	2.14	2.71	7.09	5.49
Begin WP	1.92	1.52	0.19	2.32	3.08
End WP	2.89	1.48	4.6	1.33	3.91
End LC	3.73	1.69	4.31	2.07	3.51
End WZ	2.33	1.67	2.96	2.92	2.61

Step #	Rep	Step 10	Test Engineer Verification and Remarks
		 **Figure 3 Plot of distances from Figure 2** • Testing results for all 5 test/repetitions. WZ = work zone, LC = lane closure, WP = worker presence • Excel document containing calculations (distance formula in VB Module) is located here: https://github.com/TonyEnglish/V2X-manual-data-collection/blob/master/Sample%20Files/Testing%20Data/gps_data_accuracy_tests.xlsm • The locations of the application-marked features were compared to the independently measured feature locations. The maximum error was 7.09m, less than the ±8 meter accuracy bound (PRW-16). • Interestingly, all the errors resulted from the locations being marked too early. • All distances between features were less than 8 meters, for 5/5 tests.	

Step #	Rep	Step 10	Test Engineer Verification and Remarks
Requirements Verified			
Pass/Fail Assessment		• Pass	Performed and confirmed by: DE, JF

3.12 Step 11 Verify WZDx and RSM(UPER) Translators

Table 12 describes the step to inspect WZDx and RSM(UPER) translator.

Table 12. Step 11 - Verify WZDx and RSM(UPER) Translators

Step	Rep	Step 11	Test Engineer Verification and Remarks
Activity		Verify RSM(XML)->WZDx Translator. Verify RSM(XML)-> {RSM(UPER)} Translator	
Test Case Completion Date		11 June 2020	
Results	Rep 1	• WZDx and RSM(UPER) files located in WZ_MapMsg directory • Pass	Performed and confirmed by: DE, JF
Notes	Rep 1	None.	
Results	Rep 2	• WZDx and RSM(UPER) files located in WZ_MapMsg directory • Pass	Performed and confirmed by: DE, JF
Notes	Rep 2	None.	
Results	Rep 3	• WZDx and RSM(UPER) files located in WZ_MapMsg directory • Pass	Performed and confirmed by: DE, JF

Step	Rep	Step 11	Test Engineer Verification and Remarks
Notes	Rep 3	None.	
Results	Rep 4	• WZDx and RSM(UPER) files located in WZ_MapMsg directory • Pass	Performed and confirmed by: DE, JF
Notes	Rep 4	None.	
Results	Rep 5	• WZDx and RSM(UPER) files located in WZ_MapMsg directory • Pass	Performed and confirmed by: DE, JF
Notes	Rep 5	None.	
Summary		WZDx and RSM(UPER) files automatically created for 5/5 tests.	
Requirements Verified			
Pass/Fail Assessment		Pass	Performed and confirmed by: DE, JF

3.13 Step 12 Verify ZIP Archive Contents

Table 13 describes the step for revise the ZIP archived contents.

Table 13. Step 12 - Verify ZIP archived contents

Step #	Rep	Step 12	Test Engineer Verification and Remarks
Activity		Verify work zone data ZIP archive contents.	
Test Case Completion Date		11 June 2020	

Step #	Rep	Step 12	Test Engineer Verification and Remarks
Results	Rep 1	• All 5 data files present in unzipped archive • Pass	Performed and confirmed by: DE, JF
Notes	Rep 1	None.	
Results	Rep 2	• All 5 data files present in unzipped archive • Pass	Performed and confirmed by: DE, JF
Notes	Rep 2	None.	
Results	Rep 3	• All 5 data files present in unzipped archive • Pass	Performed and confirmed by: DE, JF
Notes	Rep 3	None.	
Results	Rep 4	• All 5 data files present in unzipped archive • Pass	Performed and confirmed by: DE, JF
Notes	Rep 4	None.	
Results	Rep 5	• All 5 data files present in unzipped archive • Pass	Performed and confirmed by: DE, JF
Notes	Rep 5	None.	
Summary		ZIP archive correctly generated for 5/5 tests.	
Requirements Verified			
Pass/Fail Assessment		• Pass	Performed and confirmed by: DE, JF

3.14 Step 13 Trigger WZDC Upload

Table 14 describes the step for triggering the work zone DC upload.

Table 14. Step 13 - Trigger WZDC Upload

Step #	Rep	Step 13	Test Engineer Verification and Remarks
Activity		Trigger WZDC tool to upload files to Back Office.	
Test Case Completion Date		11 June 2020	
Results	Rep 1	• ZIP archive present in cloud storage container • All 5 data files organized into sub-folders in unzipped cloud storage container • Pass	Performed and confirmed by: DE, JF
Notes	Rep 1	None.	
Results	Rep 2	• ZIP archive present in cloud storage container • All 5 data files organized into sub-folders in unzipped cloud storage container • Pass	Performed and confirmed by: DE, JF
Notes	Rep 2	None.	
Results	Rep 3	• ZIP archive present in cloud storage container • All 5 data files organized into sub-folders in unzipped cloud storage container • Pass	Performed and confirmed by: DE, JF
Notes	Rep 3	None.	
Results	Rep 4	• ZIP archive present in cloud storage container • All 5 data files organized into sub-folders in unzipped cloud storage container • Pass	Performed and confirmed by: DE, JF
Notes	Rep 4	None.	
Results	Rep 5	• ZIP archive present in cloud storage container	Performed and confirmed by: DE, JF

Step #	Rep	Step 13	Test Engineer Verification and Remarks
		• All 5 data files organized into sub-folders in unzipped cloud storage container • Pass	
Notes	Rep 5	None.	
Summary		ZIP archive uploaded and automatically unzipped for 5/5 tests.	
Requirements Verified			
Pass/Fail Assessment		• Pass	Performed and confirmed by: DE, JF

3.15 Step 14 Test TMC Website Visualizer

Table 15 describes the step for testing the TMC website visualizer.

Table 15. Step 14 - Test TMC Website Visualizer

Step #	Rep	Step 14	Test Engineer Verification and Remarks
Activity		Test TMC Website Visualizer	
Test Case Completion Date		11 June 2020	
Results	Rep 1	• Visualization of RSM shows all 6 WZ features • On publish, all 3 messages are located in the published cloud storage container. • Pass	Performed and confirmed by: DE, JF
Notes	Rep 1	None.	
Results	Rep 2	• Visualization of RSM shows all 6 WZ features	Performed and confirmed by: DE, JF

Step #	Rep	Step 14	Test Engineer Verification and Remarks
		• On publish, all 3 messages are located in the published cloud storage container. • Pass	
Notes	Rep 2	None.	
Results	Rep 3	• Visualization of RSM shows all 6 WZ features • On publish, all 3 messages are located in the published cloud storage container. • Pass	Performed and confirmed by: DE, JF
Notes	Rep 3	None.	
Results	Rep 4	• Visualization of RSM shows all 6 WZ features • On publish, all 3 messages are located in the published cloud storage container. • Pass	Performed and confirmed by: DE, JF
Notes	Rep 4	None.	
Results	Rep 5	• Visualization of RSM shows all 6 WZ features • On publish, all 3 messages are located in the published cloud storage container. • Pass	
Notes	Rep 5	None.	
Summary		Visualizations correctly generated and messages published for 5/5 tests.	
Requirements Verified			
Pass/Fail Assessment		• Pass	Performed and confirmed by: DE, JF

3.16 Step 15 Verify Availability of Published Messages

Table 16 describes the step to verify the availability of published messages.

Table 16. Step 15 - Verify availability of published messages

Step #	Rep	Step 15	Test Engineer Verification and Remarks
Activity		Verify availability of WZ Map {RSM(XML)} and WZ Map {WZDx} Files Third party traveler information services and for CARMA systems.	
Test Case Completion Date		11 June 2020	
Results	Rep 1	• All 3 messages present in downloaded ZIP archive • Pass	Performed and confirmed by: DE, JF
Notes	Rep 1	None.	
Results	Rep 2	• All 3 messages present in downloaded ZIP archive • Pass	Performed and confirmed by: DE, JF
Notes	Rep 2	None.	
Results	Rep 3	• All 3 messages present in downloaded ZIP archive • Pass	Performed and confirmed by: DE, JF
Notes	Rep 3	None.	
Results	Rep 4	• All 3 messages present in downloaded ZIP archive • Pass	Performed and confirmed by: DE, JF
Notes	Rep 4	None.	
Results	Rep 5	• All 3 messages present in downloaded ZIP archive • Pass	Performed and confirmed by: DE, JF
Notes	Rep 5	None.	

Step #	Rep	Step 15	Test Engineer Verification and Remarks
Summary		Messages successfully downloaded for 5/5 tests.	
Requirements Verified			
Pass/Fail Assessment		• Pass	Performed and confirmed by: DE, JF

Chapter 4. References

Table 17 lists the documents, sources, and tools referenced in this report.

Table 17. Referenced Documents, Sources, and Tools

#	Document (Title, source, version, date, location)
1	*Work Zone Data Exchange (WZDx) v2 Specification*, Federal Highway Administration (FHWA) and Intelligent Transportation Systems Joint Program Office (IT'S JPO), Jan 14, 2020. https://github.com/usdot-jpo-ode/jpo-wzdx/
2	Work Zone Data Initiative (WZDI), Federal Highway Administration (FHWA). https://collaboration.fhwa.dot.gov/wzmp/wzdi/Forms/AllItems.aspx
3	*Work Zone Event Data (WZED) – Data Dictionary Report,* Federal Highway Administration (FHWA), Version 3, Feb 28,2020. https://collaboration.fhwa.dot.gov/wzmp/Data%20DictionaryDocuments/Forms/AllItems.aspx
4	SAE J2945/4 – Road Safety Applications – UNPUBLISHED http://standards.sae.org/j2945/1_201603/
5	V2I Safety Applications, Connected Work Zone Software Toolchain User Guide CAMP LLC Vehicle to Infrastructure Consortium, *Version 1.1*, September 3, 2019. https://www.campllc.org/download-software-tools/
6	*Task 2 Technical Memo – Compiled Report*, Infrastructure and V2X Mapping Needs Assessment and Development Support Project, ICF Draft Report to Federal Highway Administration (FHWA),
7	*Task 3 Stakeholder Outreach Memo*, Infrastructure and V2X Mapping Needs Assessment and Development Support Project, ICF Draft Report to Federal Highway Administration (FHWA).
8	Design and Evaluation of a Connected Work Zone Hazard Detection and Communication System for Connected and Automated Vehicles (CAVs), Office of the Secretary of Transportation (OST), USDOT, Final Report, August 2019. https://www.vtti.vt.edu/utc/safe-d/wp-content/uploads/2019/10/03-050_FinalResearchReport_Final.pdf
9	*POC TMC Website*, Proof-of-Concept of Integrated Work Zone Mapping Toolset Project, Federal Highway Administration (FHWA).

	https://github.com/TonyEnglish/V2X-manual-data-collection
10	*POC Work Zone Data Collection Tool*, Proof-of-Concept of Integrated Work Zone Mapping Toolset Project, Federal Highway Administration (FHWA). https://github.com/TonyEnglish/V2X-manual-data-collection/tree/master/Work%20Zone%20Data%20Collection%20Tool
11	SAE J2945/1_201603 - On-Board System Requirements for V2V Safety Communications, SAE International, March 30, 2016. http://standards.sae.org/j2945/1_201603/
12	*V2X Hub*, Federal Highway Administration (FHWA). https://github.com/usdot-fhwa-OPS/V2X-Hub
13	Manual on Uniform Traffic Control Devices (USDOT). https://mutcd.fhwa.dot.gov/htm/2009/part6/part6c.htm

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