Sharing Data between Mobile Devices, Connected Vehicles and Infrastructure

Task 6: Prototype Acceptance Test Plan

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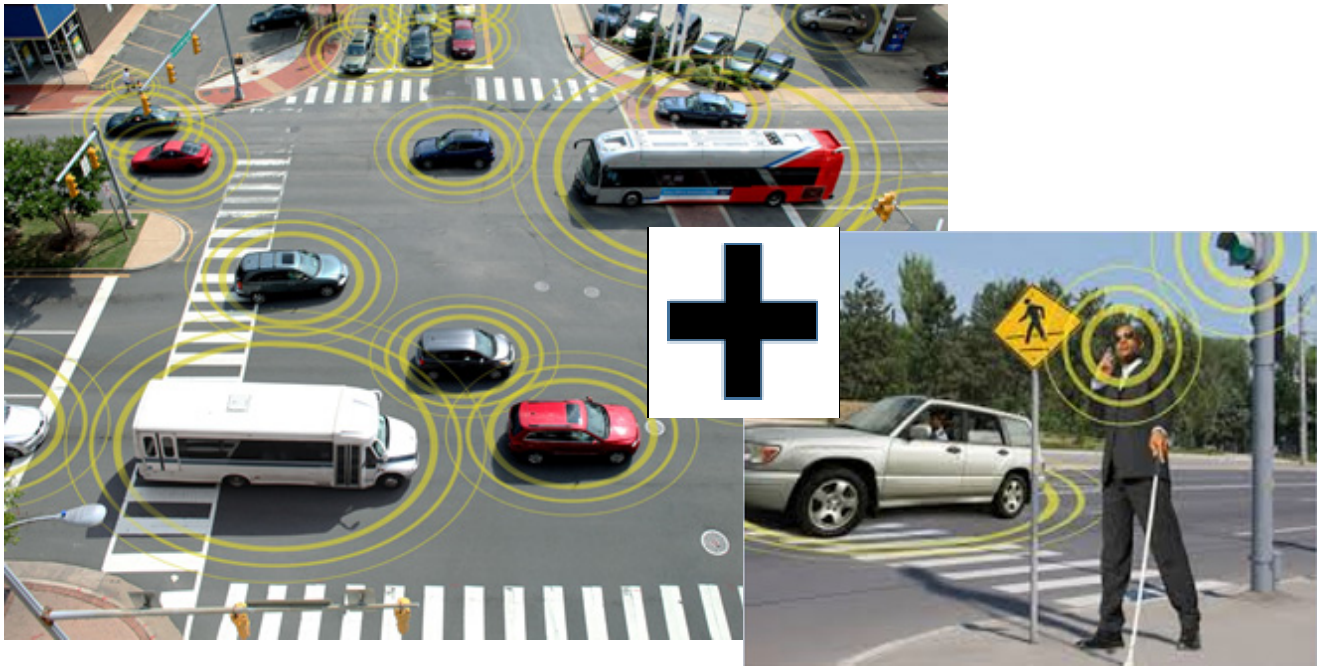

U.S. Department of Transportation
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15. Supplementary Notes

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16. Abstract

This Acceptance Test Plan (ATP) summarizes the results of the System Acceptance Testing that describe the operation of prototype, performance measures, the data that will be collected for validating the prototype, and test process for verifying that the system is functioning properly prior to the start of the Prototype Proof of Concept Field Test. In addition, the ATP verifies that the Prototype System for the *Sharing Data between Mobile Devices, Connected Vehicles and Infrastructure* project properly coordinates messages sent via Mobile Devices of pedestrians and vehicles in a connected vehicle environment.

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Revision History

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1	10/13/2016	Draft Release	
2	11/21/2016	Final Release addressing USDOT comments	All Chapters
3	12/21/2016	Final Release addressing 2nd round of USDOT comments	All Chapters

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Chapter 1 Scope

The purpose and vision of this experimental research task order is to enable the support in exchanging messages with pedestrian Mobile Devices within the public right of way, to enhance the safety and mobility of these pedestrian trips, and to enable the public agencies to improve how they manage traffic, which includes travelers using Mobile Devices.

This document contains the system's Acceptance Test Plan (ATP) and test procedures associated with the prototype proof of concept demonstration system to be developed as part of the *Sharing Data between Mobile Devices, Connected Vehicles and Infrastructure* (formerly called "Coordination of Mobile Devices for Connected Vehicle Applications") task order. This document has been written with the assumption that the reader possesses a general knowledge associated with the connected vehicle technologies and applications and the systems engineering process.

This document was developed based on the contents of the approved "Task 3: System Requirements Specifications (SysRS) for Coordination of Mobile Devices for Connected Vehicle Applications (Final from July 14, 2016)" document.

This ATP defines the tests to be conducted to demonstrate the success of the Prototype Proof-of-Concept Demonstration system. 'Success' is defined as the demonstration of anticipated functions and features in accordance with tests identified in the ATP. Corrective action will be taken to resolve any issues if a given function does not pass per the ATP. It is important to note that the performance of some functions is predicated on the availability of accurate inputs, and there is uncertainty regarding the ability of corrective action to resolve such issues. The ATP also describes the operation of prototype, the performance measures, the data that will be collected for validating the prototype, and test process for verifying that the system is functioning properly prior to the start of the Prototype Proof of Concept Field Test (formerly called the 'Small Scale' demonstration). In addition, the ATP verifies that the Prototype System for the *Sharing Data between Mobile Devices, Connected Vehicles and Infrastructure* task order properly coordinates messages sent via pedestrian's Mobile Devices and on-board units installed in vehicles within a connected vehicle environment.

It needs to be noted that the test plan and associated test procedures were developed for those system requirements that are shown in the last column ("EPS Req") within the requirements tables of the Final SysRS document.

1.1 Background

The United States Department of Transportation (U.S. DOT) has conducted significant research on the use, benefits, and operational issues associated with using dedicated short-range communications (DSRC) and Cellular Devices in both vehicular and infrastructure-based communications. Specifically, the benefits are intended to improve the safety, mobility and environmental impact on our surface transportation system. When the concept of connected vehicle environment first emerged, DSRC was conceived as an enabler for the mobility-impaired and other travelers with unique needs. However, the unprecedented adoption of smartphones and similar devices in the general population has

necessitated a renewed analysis of its role in the broader connected vehicle environment. To date, less research has been conducted on implementation pathways, policy and institutional impediments, as well as the feasibility of deployment of low-latency wireless communications on Mobile Devices in concert with the current cellular and Wi-Fi communications protocols. In particular, key questions and issues exist related to the expected impact that personal Mobile Devices (e.g., tablets, smartphones, etc.), that are also equipped with DSRC technology, will have on channel utilization and error-rates in the connected vehicle environment. If saturation is reached, it will likely degrade the anticipated benefits of connected vehicle safety applications by requiring more processing of radio messages than can be performed in low-latency required situations. It is with these considerations that this research is being initiated, the objectives of which are:

1. Examine the feasibility and benefits of utilizing non-DSRC communication mechanisms for the transmission of probe and safety messages.
2. Develop and test modifications to the existing probe and safety messages to make them applicable for Mobile Devices.
3. Create and demonstrate potential methods for coordinating messages and communications related to safety and mobility between Mobile Devices, vehicles, and infrastructure.

Importantly, the scope of this document and the system described herein is limited to an experimental system that will be used to design, test, and demonstrate new communication messages and message types as well as explore the effectiveness and potential mechanisms for coordinating these messages across multiple Mobile Devices, vehicles, and roadside infrastructure. This is intended as a research project and therefore does not seek to identify, define, summarize, or propose a system suitable for immediate wide-scale deployment.

1.2 Document Identification

This document is the Prototype Acceptance Test Plan deliverable of the *Sharing Data between Mobile Devices, Connected Vehicles and Infrastructure* task order, which is being conducted by Battelle Memorial Institute for the Federal Highway Administration (FHWA) under Contract Number DTFH61-12-D-00046. This document defines the test plan and test procedures for testing the Experimental Prototype System.

1.3 Document Overview

The ATP describes tests that will be performed during the Prototype Proof of Concept Test. These tests will verify the operation of prototype, performance measures, the data that will be collected for validating the prototype, and test process for verifying that the system is functioning properly prior to the start of the Prototype Proof of Concept Demonstration held at the Turner Fairbank Highway Research Center (TFHRC). This document further elaborates and is consistent with the Systems Architecture and Design document deliverable in Task 4.

The remainder of this document consists of the following sections and content:

- Chapter 2 (Referenced Documents) describes any external documentation referenced throughout this document.
- Chapter 3 (Prototype Acceptance Test Objectives) describes the purpose and outcomes of the Prototype Acceptance Test Plan.

- Chapter 4 (Prototype System Testing Approach) provides an overview of the approach used for the system testing.
- Chapter 5 (Acceptance Test Plan) details a series of tests to be performed to validate the system components meet the requirements. In addition, it describes the testing environment, the roles and responsibilities as well as the resources used for testing.
- Appendix A contains Requirements Traceability Matrix linking the system requirements defined in the SysRS for Coordination of Mobile Devices for Connected Vehicle Applications (Final from July 14, 2016)" document (FHWA-JPO-16-423) with the test procedures defined in Chapter 5 of this document.
- Appendix B contains Requirements Traceability Matrix for those requirements that were identified in the SysRq document but are not part of the Prototype System requirements.
- Appendix C contains Acronyms and Abbreviations.
- Appendix D contains Terms and Definitions.

1.4 Intended Audience

The primary audience for this document is U.S. DOT staff and other identified stakeholders who are leading or are interested in understanding the impact of safety and mobility messages from Mobile Devices within the envisioned connected vehicle environment where DSRC, Cellular, Wi-Fi, Bluetooth and other communication protocols are utilized by both vehicles and Mobile Devices. Additional audiences include the system developers, engineers, and any others who will assist in the development of a fully deployed Connected Vehicle environment.

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Chapter 2 Referenced Documents

This research is sponsored by the U.S. Department of Transportation as part of on-going research related to the connected vehicle program. As such, there are a number of reports, presentations, and documents on the various aspects of the connected vehicle program that can be found at http://www.its.dot.gov/research_archive.htm. The findings, schematics, results, and conclusions in these documents were routinely consulted and are incorporated in this document. Specific references in the following sections pertain only to documents and works that are not included in this public document repository.

2.1 Non-Government Publications

Institute of Electrical and Electronics Engineers (IEEE)

IEEE 829-2006	IEEE Standard for Software and System Test Documentation
IEEE 1016-2009	IEEE Standard for Information Technology – Systems Design – Software Design Description
IEEE 1609.3,.4,.5-2010	IEEE Family of Standards for Wireless Access in Vehicular Environments (WAVE) define an architecture and a complementary, standardized set of services and interfaces that collectively enable secure vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) wireless communications.
IEEE 802.11™-2012	IEEE Standard for Information technology--Telecommunications and information exchange between systems Local and metropolitan area networks--Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications.

Society of Automotive Engineers (SAE)

J2735:2016	Object Dedicated Short Range Communications (DSRC) Message Set Dictionary – published
J2945/1:2016	On-Board System Requirements for V2V Safety Communications– published
J2945.9 – draft	Performance Requirements for Safety Communications to Vulnerable Road Users

National Transportation Communications for ITS Protocol (NTCIP)

1201:2005 V02.27	Global Object Definitions
1202v03 – draft	Object Definitions for Actuated Traffic Signal Controllers (ASC) – version 03 will include data elements and messages that are coordinated with the SAE J2735 standard, but also data elements for addressing pedestrian and bicycle needs at signalized intersections.

Wi-Fi Alliance

Wi-Fi Peer-to-Peer Services Technical Specification Package v1.2
See (http://www.wi-fi.org/discover-wi-fi/wi-fi-direct) for more

Battelle Memorial Institute

FHWA-JPO-16-422	Task 3: Concept of Operations Document *(ConOps)* for Coordination of Mobile Devices for Connected Vehicle Applications (3rd Revised Report from July 13, 2016)
FHWA-JPO-16-423	Task 3: System Requirements Specifications *(SysRS)* for Coordination of Mobile Devices for Connected Vehicle Applications (Final from July 14, 2016)
FHWA-JPO-17-476	Task 4: System Architecture and Design Document *(SA/DD)* for Sharing Data between Mobile Devices, Connected Vehicles, and Infrastructure (Final Report from October 26, 2016)
FHWA-JPO-17-475	Task 5: Prototype Proof of Concept Field Demonstration Experimental / Field Demonstration Site Plan *(Demo Experimental / Site Plan)* for Sharing Data between Mobile Devices, Connected Vehicles, and Infrastructure (Final from October 6, 2016)

2.2 Order of Precedence

In the event of a conflict between the text of this document and the references cited herein, the inconsistencies should be brought to the attention of the project manager. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

Chapter 3 Prototype Acceptance Test Plan Objectives

The Prototype System for the *Sharing Data between Mobile Devices, Connected Vehicles and Infrastructure* task order centers on potentially expanding the connected vehicle environment by coordinating Mobile Devices of pedestrians with each other and with compatible on-board units deployed within vehicles. The Prototype System will include application software, which supports several new and SAE J2735:201509 defined types of messages:

- Personal Safety Message (PSM) – defined in SysRS.
- A variety of coordination messages (all new):
    - Personal Mobility Message (PMM),
    - PMM Response (PMM-RSP) message,
    - PMM Arrival (PMM-ARRIVE) message, and
    - PMM Cancel (PMM-CANCEL) message.
- Basic Safety Messages (BSM) – defined in SAE J2735:201509 (formatting and encoding).

These message types are defined and/or referenced within the Task 4: System Architecture and Design Document (SA/DD).

The main objective of the Prototype ATP is to verify that the Prototype System properly coordinates messages sent via Mobile Devices of pedestrians and other Mobile Devices as well as those devices deployed in vehicles in a connected vehicle environment. The test will execute the system such that all gaps, errors, or missing requirements are identified (if any). The Prototype ATP also describes the operation of the prototype system, the performance measures, and the data that will be collected for validating the prototype at a Battelle testing facility in Columbus, OH. Once the tests are performed, the test data is analyzed, and a test report has been developed and distributed, the system functionality will be demonstrated to project stakeholders at the Prototype Proof of Concept Demonstration at the TFHRC.

The Prototype ATP will test the message coordination prototype system that consists of several components, described in the Prototype System of Interest diagram introduced in the SA/DD and further refined in Figure 3-1 below. The diagram shows components performing certain functions and the communication interfaces between the components including desired communication media and the data exchange content. Within the diagram, a main instance of the Mobile Device is shown in the upper left, complete with all interfaces to/from the other major functional components. A second group of these same functionally-equivalent Mobile Devices is shown in the lower left and represents the additional Mobile Devices that interact in the system. The entire Prototype System centers on the Mobile Devices and their interaction with each other as well as with other components such as vehicles, roadside equipment (RSE), and cloud infrastructure. Vehicles include equipped vehicles, meaning those vehicles that support Dedicated Short Range Communications (DSRC) and, as a minimum, BSM message broadcasting, as well as unequipped vehicles meaning those vehicles that

do not have the capability to generate BSM messages to send messages over DSRC. The cloud infrastructure is used for relaying travel requests to a vehicle capable of transporting passengers. The RSE has three purposes:

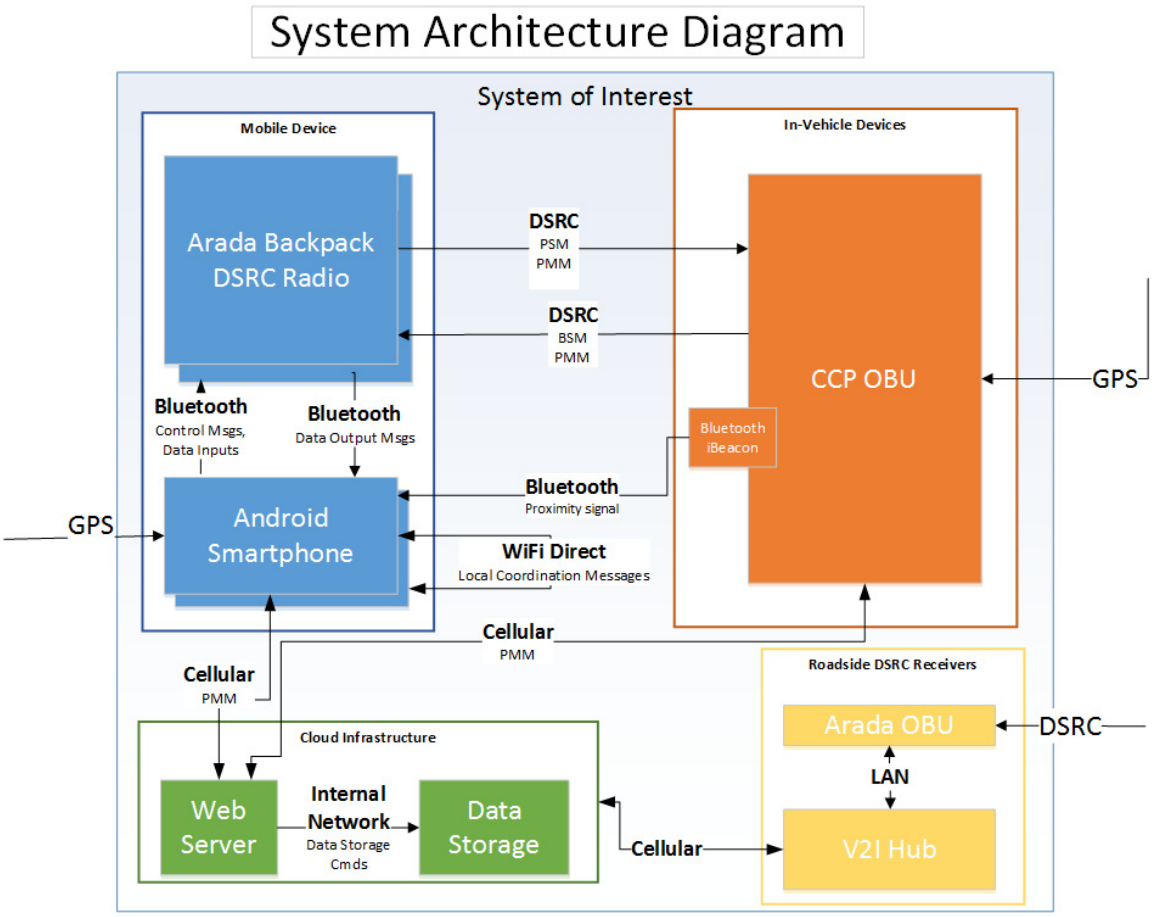
1. Sending Signal Phase and Timing (SPaT), Map Data (MAP) and other J2735-defined messages to pedestrians carrying Mobile Devices, and receiving PSMs.
2. Receiving PMMs sent over cellular and relaying this information to a Transit Management Center (TMC) or directly to a Transit Vehicle, and sending transit-related traveler information to Mobile Devices.
3. Capture all DSRC messages including timestamps of messages received, message types (BSM, PMM, PSM, etc.), and message contents.

The Prototype ATP will also outline and detail the experiments to be performed during testing of the system performance concepts and operational scenarios introduced in the ConOps. Experiments will not necessarily follow the order of events presented in the ConOps scenarios, but will capture the essence of those operational scenario-defined events and processes. The experiments used to test Functional requirements associated with the Prototype System include:

1. The ability of a mobile device to coordinate travel between itself and a passenger-transporting vehicle via DSRC.
2. The ability of a mobile device to coordinate travel between itself and another mobile device via Wi-Fi Direct.
3. The ability of a non-DSRC equipped mobile device to communicate PMMs to a dispatch center using a Roadside Unit (RSU) as a protocol translator. For the purposes of the Prototype System, all Mobile Devices will be capable of using Wi-Fi, DSRC, and cellular communications and will use these media to send PMMs.
4. The ability for a traveler to send a PMM from a location other than a designated pickup location (e.g. from home). However, for the purposes of the Prototype System, travelers must be at a designated pickup location when broadcasting a PMM.
5. The ability for a Transit Vehicle or taxi to send an arrival message to its passenger(s) when approaching the arrival location.
6. The ability of an Intersection RSU to coordinate pedestrian crossings at crosswalks.
7. The ability of an Intersection RSU to send BSMs, PSMs, and PMMs to a TMC or other agency for traffic monitoring purposes. For the purposes of the Prototype System, the Intersection RSU will only capture and locally record BSMs, PSMs and PMMs.

The ATP is intended to demonstrate that the Prototype System will be able to function in a controlled environment system at TFHRC. Results from the ATP will be captured, analyzed, and evaluated within the ATP Summary Report.

Furthermore, the ATP Summary Report is expected to provide guidance to Prototype Field Demonstration (Task 9), which will be performed in a larger setting in Columbus, OH. A slightly modified ATP will be created for use with the Prototype Field Demonstration to demonstrate that the Prototype System will also be able to function in an operational environment.



Note: CCP refers to Common Computing Platform.

Source: Battelle

Figure 3-1. Prototype System 'System Architecture' Diagram

Chapter 4 Prototype System Testing Approach

4.1 System Overview

The Prototype System for *Sharing Data between Mobile Devices, Connected Vehicles and Infrastructure* task order centers on potentially expanding the current connected vehicle environment by coordinating the Mobile Devices of pedestrians with other Mobile Devices and with on-board unit deployed within vehicles. The Prototype System will include application software, which supports several types of messages introduced in Chapter 3 and further detailed as follows.

1. The PSM is patterned after the BSM for vehicles. The BSM transmits a vehicle's position, speed, and heading, among other information. Surrounding vehicles use this information in various applications to increase safety by, for example, avoiding collisions. The PSM will provide similar information about the position of an individual carrying a mobile device. It will notify vehicles of the presence, for example, of a pedestrian in a crosswalk or of a runner in the street. Applications can be written for use within vehicles so that their drivers are aware of vulnerable road users (VRUs). The use of PSMs also has, for instance, the potential to reduce injuries in situations where drivers look left while they turn right on red and there are VRUs in the crosswalk. The PSM proposed in this project is virtually the same as the PSM message type defined in SAE J2735:2016, with the exception that the PSM used in this project will also identify whether a pedestrian is in a safe or unsafe zone. An "Unsafe Zone" is in a lane in which vehicle may travel including a roadway shoulder, a pedestrian crosswalk, or any area within one meter of the edge of the roadway. A "Safe Zone" is on a sidewalk or zone in which a vehicle must cross a physical obstacle to collide with pedestrian
2. Using Wi-Fi Direct with coordination messages will allow Mobile Devices to directly and efficiently communicate with each other at a "local level" to reduce the overall communication burden of the communications system in terms of the throughput on DSRC Radio links. These coordination messages will be used to temporarily "link" travelers together into ad-hoc travel groups so that only a single message, sent by the group leader (the first person to request a Transit Vehicle), needs to be transmitted to an infrastructure component or vehicle component rather than individual messages from every member of the group.
3. The PMM will enable new applications benefitting a variety of users. PMM messages representing a single or ad-hoc travel group ride/travel request will be sent to the vehicle via DSRC (if within range) or cellular (if outside of DSRC range). A PMM contains information about the traveler's (or travelers', if several within an ad-hoc travel group) destination and their requirements for travel schedule and/or other mobility issues similar to a traveler trip request message used in transit applications with the difference that the PMM would be applicable to any type of vehicle and, at the end, be truly multi-modal. A PMM will also contain information about the constraints on the traveler's trip such as requiring a Transit Vehicle with a wheelchair lift.

A vehicle having received a PMM and agreeing to pick up the passenger(s) will send a PMM response (PMM-RSP). Additionally, the responding vehicle will also send a PMM-ARRIVE message to let the traveler or the ad-hoc travel group know that the vehicle is in the vicinity allowing the traveler(s) to enter the vehicle. A PMM-CANCEL message is issued from a mobile device back to a vehicle if a traveler or ad-hoc travel group completely dissolves before the vehicle arrives, or if the traveler or ad-hoc travel group receives multiple PMM-RSP messages from different vehicles, in which case all but one PMM will be cancelled.

A series of demonstration tests have been developed within this document to support a variety of mobile device applications, which will explore how multiple communications technologies can be leveraged to increase traveler safety and improve the traveler experience. The applications are being developed to support the study of two (2) key topics with respect to the inclusion of Mobile Devices into the Connected Vehicle environment: traveler safety and traveler coordination.

Traveler safety addresses strategies to detect if a pedestrian is in a situation which is reasonably expected to be safe or if the location or circumstance of the pedestrian is inherently less safe. A pedestrian on the curb is generally in a safe place, whereas a pedestrian in the roadway is not. However, a passenger within a vehicle that is in the roadway inherits the protection of the vehicle's shell, and thus, is also deemed safe (if not on collision course with another vehicle). The demonstration tests will experiment with a variety of technologies and strategies to ascertain how best to determine the safety of the traveler's location.

Traveler coordination aims to address questions relating to the coordination of groups of travelers who have the same departure location, departure time, and destination locations, and consolidation of their travel request messages to reduce network congestion. If a group of travelers are at a transit stop, and all are utilizing ride-coordination technologies, then the degree of DSRC message traffic generated may adversely affect the system at that location. In situations where several individuals are coordinating with the same target (taxi, transit bus) and itinerary (pick-up location, pick-up time, and destination location), these messages may be consolidated and the load on the communications system be reduced.

4.2 Testing Overview

The ATP is conducted following the principles of systems engineering and the principles of IEEE 829-2008 (Standard for Software and System Test Documentation). Individual system components will be tested against their requirements. The objective of this series of demonstration tests is to verify that the Prototype System properly coordinates messages sent via Mobile Devices of pedestrians to other pedestrian's Mobile Devices and to on-board units within vehicles in the connected vehicle environment. This section outlines the testing approach and schedule that will be followed to test the system performance concepts and operational scenarios in accordance with the functional requirements of the Prototype System. The Test Cases introduced in Section 5.4 are system requirements-driven demonstration tests that will identify the functional requirements and outline test scenarios for the acceptance criteria. Each test case will be recorded and reported in the detailed format of the demonstration test summary report for further evaluation including metrics, event files, screen shots and other necessary files to document the results of the test procedures. Any discrepancies found during demonstration testing will be recorded. The demonstration test conductors will use a discrepancy recording tool that includes a description of the discrepancy, the requirements associated with the discrepancy, and the cause of the discrepancy. Discrepancies are reported based on the "Priority" levels, which are described as:

- Critical (1) – When testing cannot continue and has to be terminated. The software application or module associated with the test procedure cannot be used.
- Serious (2) – When the application is behaving in a manner that is different from the requirement causing a failure in the application function.
- Moderate (3) – When testing can continue and a workaround can be managed through the misbehaving functionality of the application.
- Cosmetic (4) – When a defect occurs that would affect only the non-functional aspects of the software elements.
- Recommendations (5) – When a suggestion for improving the application is presented.

As part of the demonstration test plan, Battelle will perform a dry-run at its software development facility in Columbus, Ohio and create a demonstration test summary report that entails the results of the ATP. This ATP dry-run report will be submitted at the end of the final software development and before prototype demonstration testing at TFHRC will be conducted.

The Prototype System and its components are described in the SA/DD. A brief synopsis is provided here for completeness and to clarity of the demonstration test summary.

- Mobile Device Subsystem
  - Smartphone (Google Nexus 5X)
  - DSRC Communications Hardware (Arada LocoMate™ ME OBU)
  - Mobile Device Experimental Applications (DEA) Software
- Transit Vehicle Subsystem
  - Battelle's Common Computing Platform (CCP) with hosted Cohda DSRC Radio
  - Vehicle Experimental Applications (VEA) plug-in running on Transportation Message eXchange (TMX) framework
  - Bluetooth Access Point (Estimote Beacon)
- RSU Subsystem
  - V2I Hub
  - Arada LocoMate™ RSU
- Cloud Service Subsystem
  - Computational Platform (Microsoft Windows Azure)

4.2.1 Schedule

The Prototype ATP testing to be conducted at the Battelle Laboratory is dependent on the timely completion of the agile development process, the acquisition and configuration of external devices to be tested and integration testing. Table includes the schedule of each test and the requirement.

Table 4-1. Prototype Proof of Concept ATP Testing Schedule

Activity	Expected Start Time	Expected Duration
Configure Hardware for ATP	11/18/2016	1 day
Integration Testing and bug fixes	11/21/2016	10 days
USDOT Approval of draft ATP	11/29/2016	
Declaring Prototype readiness (milestone)	12/06/16	
Installation and shakeout testing of Roadside Equipment	12/07/16	4 hours
Installation and shakeout testing of Vehicle Onboard Equipment	12/07/16	1 hours
Installation and shakeout testing of Mobile Devices	12/07/2016	4 hours
Run 1: ATP Test Case Execution		
5.4.1 PSM Test Cases	12/08/2016	4 hours
5.4.2 PMM Test Cases	12/08/2016	8 hours
5.4.3 BSM Test Cases	12/09/2016	1 hour
5.4.4 Ad-Hoc Travel Group Test Cases	12/09/2016	8 hours
5.4.5 Entering and Leaving Vehicle Test Case	12/12/2016	4 hours
5.4.6 Message Logging Test Cases	12/13/2016	2 hours
5.4.7 Safety Test Cases	12/13/2016	4 hours
5.4.8 SPaT and MAP Support	12/13/2016	2 hours
Identification of issues and fixes	12/08/2016	5 days
Run 2 readiness review – fixes done, built and installed	12/14/2016	
Run 2 Regression Testing	12/14/2016	4 hours
Run 2 Repeat Failed tests	12/14/2016	3 days
Execution of Scenario 1 and Monitoring of the data collected	12/19/16	3 hours
Execution of Scenario 2 and Monitoring of the data collected	12/19/16	3 hours
Execution of Scenario 3 and Monitoring of the data collected	12/19/16	4 hours

Source: Battelle

Chapter 5 Acceptance Test Plan

Battelle will conduct the ATP to verify if the prototype system is functioning properly as a pre-demonstration effort at the Battelle Software Development facility and support the post-demonstration effort at TFHRC. The demonstration to be executed will be the same at both locations – the difference being that the Battelle facility test will ensure that the prototype system is functioning in accordance to the SysRS document as well as the SA/DD, whereas the TFHRC demonstration test will be able to validate the prototype system readiness to FHWA staff and representatives.

5.1 Testing Environment

For both types of demonstration tests, the system hardware components that are part of the Prototype System are the same and include Mobile Devices, In-Vehicle Devices, Intersection RSE, and Cloud Infrastructure. Additional hardware may include laptops, cameras, and other required equipment to log test case scenarios. Each hardware component will communicate with other hardware components via DSRC Radio, Wi-Fi, Cellular or Bluetooth communication to transfer safety, mobility, coordination and RSU message types. Each type of hardware is further discussed in Section 5.3.

The system software applications that will be used during testing include the Mobile Device Experimental Application (MDEA), the Vehicle Experimental Application (VEA), and the RSU Experimental Application. These applications are developed for use in the Mobile Devices, the In-Vehicle Devices, and the RSU, respectively. Each piece of software that is developed will be used to support the system requirements specified in the SysRS document of Task 3 deliverable. The software components are further discussed in Section 5.3.

The servers, routers, switches, firewalls and other equipment resident in the test environment will use the access controls provided by the operating system running on them.

5.1.1 Pre-Demonstration Test Environment

A full system prototype demonstration test plan and associated test procedures will be conducted in a controlled Battelle laboratory with adequate power, environmental controls, and other external components as well as in the field, if required. The test environment provides a setup of software and hardware on which each of the test cases will be performed. The setup consists of the physical setup and the software setup, which includes hardware and an operating system required to run the system successfully, respectively.

A Pre-Demonstration Test Summary Report will be prepared detailing the results from the software development and integration lab testing. This Summary Report will be provided to FHWA.

5.1.2 Demonstration Test Environment

After successful completion of the Pre-Demonstration Test and provision of the Pre-Demonstration Acceptance Test Summary Report, a demonstration of the full system prototype will be conducted at the TFHRC. It is assumed that adequate power, environmental controls, and other external components will be provided on-site. The test environment provides a setup of software and hardware on which the demonstration will be performed. The setup consists of the physical setup and the software setup, which includes hardware and an operating system required to run the system successfully, respectively.

5.2 Roles and Responsibilities

The testing procedures will be conducted by the Test Director, the Test Conductor, the Test Deliverable Lead, the Test Engineer, and the Test Support Personnel. All of these roles will be filled by Battelle employees. The Test Director and the Test Engineer roles will be filled by Battelle Staff that have been actively involved with the management, design, and development of the *Sharing Data between Mobile Devices, Connected Vehicles and Infrastructure* project. The Test Conductor, the Test Deliverable Lead and Test Support Personnel roles will be filled by Battelle staff that have experience working with connected vehicle systems. Table 5-1 identifies each role, a preliminary list of people who could fill each role, and the responsibility of the individuals filling each role.

Table 5-1. Roles and Responsibilities

Role		Description
Test Director	David Valentine	Supervises all test activities including planning, reviewing all test team deliverable, and managing all personnel within test team
Test Conductor	Sudhakar Nallamothu	Leads the execution of each specific test case by coordinating all actions between test Engineers and ensuring all data was collected
Test Deliverable Lead	Sudhakar Nallamothu	Manages assigned deliverable creation, managing the deliverable schedule, maintaining version control throughout the process, and managing the reviewing process
Test Engineers	Chris Toth, Margaret Hailemariam	Supports the creation of assigned test procedures, executing tests, collecting data during test, and analyzing test results
Test Support Personnel	Other Battelle staff	Support the success of the test procedure through various activities such as collecting logs and test data, monitoring external equipment, etc.

Source: Battelle

5.3 Resources

The resources that will be used to test the prototype proof of concept demonstration system include the hardware components, the software applications, and the physical requirements such that various methods of communication and messages are transmitted between elements in the system. The Prototype System, introduced in Chapter 3of this document, has several hardware components and can be broken into a first level decomposition as Mobile Devices, In-Vehicle Devices, Roadside Receivers, and the Cloud Infrastructure. Each Mobile Device, In-Vehicle Device, and Roadside Receiver will comprise an Android phone, a CCP and a DSRC Radio, respectively. The communication between the Mobile Device and the In-Vehicle Device over distances exceeding the limits of DSRC will be performed using the Cloud Infrastructure composed of a cellular network and the database backend. Again, the Prototype System also consists of software applications that execute the safety, mobility, coordination and intersection RSU messages and include the MDEA, VEA and the RSU Experimental Application.

5.3.1 Hardware Components

Mobile Devices are capable of broadcasting PSMs and PMMs to In-Vehicle devices via DSRC and cellular network. Mobile Devices can also use DSRC to broadcast PMMs to RSU, and the cellular network to send PMMs to the Cloud Infrastructure.

The standard Mobile Device used within the ATP is composed of an Android-based smartphone serving as the computational platform and a portable DSRC Radio. For purposes of this project, the Google Nexus 5X has been chosen to be used as a smartphone and the Arada LocoMate ME will be used as the DSRC Radio which is strapped to the smartphone (“backpack”) and connected via Bluetooth.

Similarly, for the purposes of the experiments performed in this project, In-Vehicle Device’s Cellular and DSRC communication will be handled by the CCP using the built-in DSRC Radio and cellular capabilities.

The RSU that will be used for testing and demonstration is the Arada LocoMate™ RSU, which is responsible for receiving messages transmitted via DSRC and storing them for logging purposes.

Furthermore, Connected Vehicles will also be used to test Mobile Devices’ ability to send and receive messages to and from In-Vehicle Devices, and to identify when a Mobile Device is in a Transit Vehicle as opposed to outside of the Transit Vehicle. For testing purposes, a Light-Duty vehicle carrying at least three (3) people will be used.

5.3.2 Software Components

The MDEA is an application installed on smartphones that allows a traveler to enter an origin and destination and coordinate travel with transit/taxi providers. It is capable of receiving input from the traveler through the mobile device interface. It is also capable of coordinating travel with other travelers and broadcasting PMMs via DSRC or the cellular network. Additionally, the Mobile Devices will be able to receive SPaT and MAP messages sent by RSUs.

The VEA is the vehicle-based counterpart to the MDEA. The VEA will be installed in a Taxi or Transit Vehicle and can receive input from the Taxi or Transit Bus Driver through the OBU. The VEA is also capable of receiving travel requests via DSRC or cellular, sending out BSMs via DSRC, and providing travel acceptance and location updates back to the group leader via DSCR or cellular.

The capabilities of both the MDEA and VEA are used to support two applications that comprise the pedestrian safety monitoring and travel coordination application.

The RSU Experimental Application will be installed on the RSE, and is capable of storing all messages that are received via DSRC. The RSU Experimental Application is also capable of sending simulated SPaT and MAP messages via DSRC.

Lastly, Battelle will use a tablet-based application called the 'CV Inspector', whose purpose is the capture of DSRC data and to display it via a graphical user interface.

5.4 Acceptance Test Cases

This section identifies the Acceptance Test Cases for each of the functional requirements defined in the SysRS that have been identified for use within the Prototype Proof-of-Concept testing. These down-selected Prototype System requirements enable Mobile Devices to operate in the Connected Vehicle environment and are a larger set of system requirements than those required for use within the Prototype System Proof-of-Concept tests.

Test cases are precedents of the test procedures that include information on the type of test performed. They are the tests that will be performed to demonstrate the functionality of the high-level Prototype System. The tables that follow will include information on each demonstration test such as the Test Case ID, Test Case Name, Test Date, Test Location, Tester Name, and the Test Method/Configuration Comments to identify each test and run a Test Script.

Each test will be repeated a minimum of thirty (30) times to ensure representative results. Empirical data collected during testing will be used to assess the ability of the system to meet requirements, quantify performance measures, and evaluate the significance level associated with the ability of the system to meet performance measure targets. Final results and the implication of these results on the prototype field system will be presented and discussed in the Prototype Field Test Report.

Note: Acceptance Test Summary Report that will be submitted to FHWA after the successful completion of the ATP will document inspection, test artifacts and results from the analysis of data collected during ATP testing to demonstrate SysRS compliance. Data analysis will follow the procedures explained in Task5 – Field Demonstration Experimental Plan Document.

Unless otherwise specified, all tests are performed with MDEA Setting 'Send Psm Control' set to "UseAllRules".

5.4.1 Personal Safety Message

Test Case

Test Case ID	5.4.1.1
Test Case Name	PSM – Broadcasting PSM with Vehicle Within a Specified Radius (Transmit Timing)
Test Objective	• Verify the ability of the Mobile Device to broadcast PSMs via DSRC media in a configurable transmission interval in 0.1 second intervals • Verify the ability of the Mobile Device to transmit PSMs only when the Mobile Device determines a vehicle is within a specified radius of the mobile device
System Requirements	FR 1.01, FR 1.02, FR 1.08, SIR 1.01, SIR 1.02, SIR 1.03, SI 1.04, SIR 1.05, SIR 1.06, SIR 1.07, SIR 1.08, SIR 1.09, PR 1.03, PR 1.04, PR 5.01
Verification Method	Test
Test Date	By 12/08/2016
Test Location	Battelle Software Development Facility
Tester Name	
Test Method/ Configuration Comments	• DSRC capable hardware is connected to the mobile device and the MDEA application is installed • A pedestrian holding a mobile device is standing five (5) meters perpendicular to the edge of the roadway at the bus stop in a safe zone • DSRC capable hardware is installed on the Light-Duty vehicle and the VEA application is installed • The Light-Duty vehicle is stationed west of the crosswalk and moves east toward the pedestrian ○ From a stop, the Light-Duty vehicle must achieve a constant speed of 25 mph over a distance of approximately 600 feet • The test is repeated with the mobile device under test in various locations (in-hand, in-pocket, in-backpack) on the pedestrian • MDEA Setting ‘Send Psm Control’ should be set to “IgnoreSafeZoneRule”.

Test Script

Step	Test Action	Expected Results	Pass/Fail		Actual Results
			P	F	
1	The Light-Duty Vehicle accelerates up to twenty-five (25) mph.	None			
2	Vehicle maintains constant speed of twenty-five (25) mph.	None			
3	The Light-Duty Vehicle comes within 100 meters of the pedestrian.	Mobile Device begins broadcasting PSMs via DSRC. This is verified by inspection using CV Inspector. A detailed inspection is performed using data recorded on the MDEA data log.			
4	Inspect the PSM data recorded on the RSU log	Following data should have been logged: Location Speed Heading Number of Pedestrians Radius of Protection Path History (20 seconds) Path Prediction (5 seconds) Status (Safe/Unsafe)			
5	The Light-Duty Vehicle continues at a constant speed until it is more than 100 meters of the pedestrian	Mobile Device stops broadcasting PSMs. This is verified by inspection using CV Inspector. A detailed inspection is performed using data recorded on the MDEA data log.			
6	The Light-Duty Vehicle decelerates to a stop.	None.			

Test Case

Test Case ID	5.4.1.2
Test Case Name	PSM – Cease Broadcasting PSMs when In-Vehicle
Test Objective	• Verify the ability of the Mobile Device to cease broadcasting PSMs when it has detected that it has entered a vehicle
System Requirement	FR 1.03, PR 5.03
Verification Method	Test
Test Date	By 12/08/2016
Test Location	Battelle Software Development Facility
Tester Name	
Test Method/ Configuration Comments	• DSRC capable hardware is installed on the Light-Duty vehicle and the VEA application is installed • A Taxi starts from a location east of the Taxi Stop and approaches the taxi stop • A Light-Duty vehicle approaches the Taxi Stop from the west • DSRC capable hardware is connected to the mobile device and the MDEA application is installed • A pedestrian holding a mobile device is positioned at the taxi stop • A Tablet running CV Inspector application to verify that the mobile device broadcasting DSRC messages is positioned at the taxi stop • MDEA Setting 'Send Psm Control' should be set to "IgnoreSafeZoneRule".

Test Script

Step	Test Action	Expected Results	Pass/Fail		Actual Results
			P	F	
1	Taxi arrives at Taxi Stop	None.			
2	Light-Duty vehicle passes the Taxi Stop	MDEA broadcasts PSMs via DSRC. This is verified by inspection using CV Inspector. Inspect the RSU log to verify the reception of PSMs at one-tenth of a second frequency.			
3	Pedestrian enters Taxi. The mobile device detects that it has entered a vehicle. Taxi remains stationary.	MDEA transitions to 'In-Vehicle'. This is verified by inspecting the MDEA Log. As a result, the Mobile Device stops broadcasting PSMs.			
4	The Light-Duty vehicle passes in the opposite direction.	No PSMs are received by the Light-Duty vehicle. This is verified by inspection using CV Inspector. A detailed inspection is performed using data recorded on the RSU data log.			
5	Taxi drives away with pedestrian in vehicle	None.			

Test Case

Test Case ID	5.4.1.3
Test Case Name	PSM – Cease Broadcasting PSMs After Joining an Ad-Hoc Travel Group
Test Objective(s)	• Verify the ability of the mobile device to cease broadcasting PSMs when it has joined an ad-hoc travel group
System Requirement	FR 1.05, SIR 1.05, SIR 1.07, PR 5.02
Verification Method	Test
Test Date	By 12/08/2016
Test Location	Battelle Software Development Facility
Tester Name	
Test Method/ Configuration Comments	• DSRC capable hardware is installed on the Light-Duty vehicle and the VEA application is installed • DSRC capable hardware is connected to two Mobile Devices and the MDEA application is installed on both devices • Traveler X holding a mobile device is positioned at the taxi stop and has already coordinated travel with a Taxi • Traveler Y holding a mobile device is positioned at the taxi stop and has not yet attempted to coordinate travel • A Tablet running CV Inspector application to verify DSRC messages is positioned at the taxi stop • MDEA Setting 'Send Psm Control' should be set to "IgnoreSafeZoneRule".

Test Script

Step	Test Action	Expected Results	Pass/Fail P	Pass/Fail F	Actual Results
1	Light-Duty vehicle passes the Taxi Stop	Traveler X MDEA broadcasts PSMs via DSRC. This is verified by inspection using CV Inspector. Traveler Y MDEA broadcasts PSMs via DSRC. This is verified by inspection using CV Inspector.			
2	Ad-Hoc Travel Group forms. (See Test Case 5.4.4.1 – Steps 1 through 4)	Traveler Y MDEA transitions to 'in travel group' This is verified by inspecting the Traveler 2 MDEA Log.			
3	The Light-Duty vehicle passes the Taxi Stop.	PSMs sent from Traveler X MDEA are received by the Light-Duty vehicle. Traveler Y MDEA does not broadcast PSMs. This is verified by inspection using CV Inspector. A detailed inspection is performed using data recorded on the Traveler X and Traveler Y MDEA data Logs.			

Test Case

Test Case ID	5.4.1.4
Test Case Name	PSM – Broadcasting PSM with Pedestrian in Unsafe Zone
Test Objective(s)	• Verify the ability of the mobile device detect transitions from a safe to an unsafe zone and to broadcast PSMs when it is in an unsafe zone. *Note: the intent of this requirement is to allow a travel group member to broadcast PSMs when positioned in the roadway while remaining part of the travel group.*
System Requirement	FR 1.06
Verification Method	Test
Test Date	By 12/08/2016
Test Location	Battelle Software Development Facility
Tester Name	
Test Method/ Configuration Comments	• DSRC capable hardware is connected to the mobile device and the MDEA application is installed • A pedestrian travel group member (traveler Y, not the group leader) is holding a mobile device at a taxi stop in a safe zone. • Tablet running CV Inspector application to verify DSRC messages

Test Script

Step	Test Action	Expected Results	Pass/Fail P	Pass/Fail F	Actual Results
1	Ad-Hoc Travel Group forms. (See Test Case 5.4.4.1 – Steps 1 through 4)				
2	Traveler Y stands still in a safe zone five (5) meters perpendicular from the roadway.	Traveler Y MDEA detects that it is in a safe zone and will display the grey safety indicator icon. This is verified by inspecting the MDEA logs. The MDEA does not broadcast PSMs. This is verified by inspection using CV Inspector.			
3	Traveler Y walks into the crosswalk halfway across the roadway – an unsafe zone – and stands still.	Traveler Y MDEA (detects that it is in an unsafe zone and will display the red safety indicator icon (as determined by the vehicle lanes specified in the received MAP file). This is verified by inspecting the MDEA logs. The MDEA broadcasts PSMs via DSRC. This is verified by inspection using CV Inspector.			
4	Traveler Y walks back to the starting point to the safe zone five (5) meters perpendicular from the roadway	Traveler Y MDEA detects that it is in a safe zone. This is verified by inspecting the MDEA logs. The MDEA does not broadcast PSMs. This is verified by inspection using CV Inspector.			

5.4.2 Personal Mobility Message

Test Case

Test Case ID	5.4.2.1
Test Case Name	PMM – Submitting Trip Requests – Single User
Test Objective	• Verify users are able to enter and submit trip requests • Verify users are able to enter and submit trip details through the application
System Requirement	FR 2.01, FR 2.01.01, FR 2.02, FR 2.03, FR 2.03.01, FR 2.04, FR 2.06, SIR 2.01, SIR 2.02, SIR 2.03, SIR 2.04, SIR 2.05, SIR 2.06, SIR 2.07, SIR 2.08, SIR 3.01, SIR 3.02, SIR 3.03, SIR 15.01, SIR 15.02, PR 5.04, PR 5.06
Verification Method	Test
Test Date	By 12/08/2016
Test Location	Battelle Software Development Facility
Tester Name	
Test Method/ Configuration Comments	• DSRC capable hardware is connected to the Mobile Device and the MDEA is installed and initiated for use • A pedestrian holding a mobile device is standing at a taxi stop in a safe zone • DSRC capable hardware is connected to the In-Vehicle Device and the VEA is installed and initiated for use • The Taxi is stationed within the DSRC range. *Note: Devices are placed within 1000m (generally accepted DSRC range given clear line of sight) of each other with a clear line of sight.* • User interacts with the MDEA to enter and submit trip request to Taxi/Transit Vehicle.

Test Script

Step	Test Action	Expected Results	Pass/Fail P	Pass/Fail F	Actual Results
1	Traveler X arrives at a stop.	None			
2	Traveler X prepares to Schedule a trip.	MDEA displays “Trip Information” display. This is verified by inspection of the MEDA log.			
3	Traveler X enters trip request information including current Location, the Number of Travelers (associated to the Mobile Device user), Pickup Time, Destination, Mode of Transport, and Mobility Needs into the MDEA.	None			
4	Traveler X submits trip request information.	MDEA checks for any existing travelers via Wi-Fi Direct. This is verified by inspection of the MDEA log. Traveler X MDEA broadcasts PMM via DSRC. This is verified by inspection of the MDEA log. Taxi VEA receives PMM via DSRC. This is verified by inspection of the VEA Log.			
5	Taxi/Transit Vehicle Driver receives a Ride Request.	The VEA accepts the request. .			
6	Taxi/Transit Vehicle driver accepts Ride Request.	Taxi VEA sends a PMM-RSP message via DSRC. This is verified by inspection of the VEA log. MDEA is notified with Accepted PMM request. This is verified by inspection of the MDEA Log.			

Test Case

Test Case ID	5.4.2.2
Test Case Name	PMM – Communicate with Cloud Infrastructure via Cellular
Test Objective	• Verify PMMs can be transmitted via various communications media
System Requirement	FR 2.03, FR 2.03.04, FR 2.06, PR 5.03, PR 5.04
Verification Method	Test
Test Date	By 12/08/2016
Test Location	Battelle Software Development Facility
Tester Name	
Test Method/ Configuration Comments	• Cellular communications capable hardware is connected to the Mobile Device and the MDEA Applications installed and initiated for use • A pedestrian holding a mobile device is standing at a transit stop in a safe zone • DSRC capable hardware is connected to the In-Vehicle Device and the VEA is installed and initiated for use • The Taxi/Transit Vehicle is stationed outside of DSRC range. *Note: To accomplish this, devices are proposed be placed on opposite sides of the Turner Fairbank facility – the building is expected to provide enough interference to limit DSRC communications between the two devices. If this does not work, the alternative plan would be to drive the light-duty vehicle sufficiently far away from the Turner Fairbank campus.*

Test Script

Step	Test Action	Expected Results	Pass/Fail P	Pass/Fail F	Actual Results
1	Traveler X arrives at a stop and enters trip request information. (See Test Case 5.4.2.1, Steps 1-3)				
2	Traveler X submits trip request information.	MDEA checks for any existing travelers via Wi-Fi Direct. This is verified by inspection of the MDEA log. Traveler X MDEA broadcasts PMM via DSRC. This is verified by inspection of the MDEA log. MDEA does not receive PMM-RSP in configurable interval. This is verified by inspection of the MDEA log. MDEA sends PMM to the cloud via Cellular. This is verified by inspection of the MDEA log. The cloud infrastructure receives the PMM. This is verified by inspection of the cloud infrastructure log. Taxi VEA receives PMM via Cellular. This is verified by inspection of the VEA Log.			
3	Taxi/Transit Vehicle Driver receives a Ride Request.	The VEA will accept the request. This is verified by visual inspection of the VEA display.			
4	Taxi/Transit Vehicle driver accepts Ride Request.	VEA sends PMM-RSP to the cloud via Cellular. This is verified by inspection of the VEA log. The cloud infrastructure receives the PMM-RSP. This is verified by inspection of the cloud infrastructure log. Taxi MDEA receives PMM-RSP via Cellular. This is verified by inspection of the MDEA Log.			

Test Case

Test Case ID	5.4.2.3
Test Case Name	PMM – Canceling Trip Requests
Test Objective	• Verify users are able to cancel trip requests
System Requirement	FR 2.03, FR 2.05, FR 2.06, FR 2.08, SIR 4.01, PR 5.4.2.3, PR 5.04
Verification Method	Test
Test Date	By 12/08/2016
Test Location	Battelle Software Development Facility
Tester Name	
Test Method/ Configuration Comments	• DSRC capable hardware is connected to the Mobile Device and the MDEA Applications installed and initiated for use • A pedestrian holding a mobile device is standing at a transit stop in a safe zone • DSRC capable hardware is connected to the In-Vehicle Device and the VEA is installed and initiated for use • The Taxi/Transit Vehicle is stationed within the DSRC range *Note: Devices are placed within 1000m (generally accepted DSRC range given clear line of sight) of each other with a clear line of sight.*

Test Script

Step	Test Action	Expected Results	Pass/Fail P	Pass/Fail F	Actual Results
1	Traveler X arrives at a stop and arranges travel with a Taxi. (See Test Case 5.4.2.1, Steps 1-6)				
2	Traveler X submits a trip cancellation request.	Traveler X MDEA broadcasts PMM-CANCEL via DSRC. This is verified by inspection of the MDEA log. Taxi VEA receives PMM-CANCEL via DSRC. This is verified by inspection of the VEA Log.			
3	Taxi/Transit Vehicle driver receives a Ride Cancellation.	The currently-active trip will be removed from the display now that it has been canceled. This is verified by visual inspection of the VEA display.			

Test Case

Test Case ID	5.4.2.4
Test Case Name	PMM – Sending Arrival Messages
Test Objective	• Verify Taxis/Transit Vehicles are able to send arrival messages • Verify Taxis/Transit Vehicles are able to send arrival details through the application
System Requirement	FR 2.09, FR 2.10, SIR 5.01, SIR 5.02, SIR 5.04, SIR 15.02, SIR 15.04, SIR 15.05
Verification Method	Test
Test Date	By 12/08/2016
Test Location	Battelle Software Development Facility
Tester Name	
Test Method/ Configuration Comments	• DSRC capable hardware is connected to the Mobile Device and the MDEA Applications installed and initiated for use • A pedestrian holding a mobile device is standing at a transit stop in a safe zone • DSRC capable hardware is connected to the In-Vehicle Device and the VEA is installed and initiated for use • The Taxi/Transit Vehicle is stationed within the DSRC range *Note: Devices are placed within 1000m (generally accepted DSRC range given clear line of sight) of each other with a clear line of sight.*

Test Script

Step	Test Action	Expected Results	Pass/Fail		Actual Results
			P	F	
1	Traveler X arrives at a stop and arranges travel with a Taxi. (See Test Case 5.4.2.1, Steps 1-6)				
2	Taxi/Transit Vehicle arrives Traveler X's stop.	Taxi VEA broadcasts PMM-ARRIVE via DSRC at configured interval. This is verified by inspection of the VEA log. Traveler X MDEA receives PMM-ARRIVE via DSRC. This is verified by inspection of the MDEA Log.			
3	Traveler X receives arrival message.	An action screen will be displayed to the traveler that the Taxi is about to arrive. This is verified by visual inspection of the MDEA display.			
4	Traveler X enters Taxi/Transit Vehicle and departs from the stop.	Taxi VEA ceases broadcasting PMM-ARRIVE via DSRC. This is verified by inspection of the VEA log.			

5.4.3 Basic Safety Message

Test Case

Test Case ID	5.4.3.1
Test Case Name	BSM – Vehicle Experimental Application Functionality
Test Objective	• Verify ability to generate BSMs by vehicles equipped with DSRC Radio and VEA Application • Verify BSM message contents • Verify ability to receive BSMs by vehicles equipped with DSRC Radio and VEA Application
System Requirement	FR 4.01, FR 4.01.01, FR 4.02, FR 4.03, SIR 7.01, SIR 7.02, SIR 7.03, SIR 7.04, SIR 15.07
Verification Method	Test
Test Date	By 12/09/2016
Test Location	Battelle Software Development Facility
Tester Name	
Test Method/ Configuration Comments	• DSRC capable hardware is installed on the vehicle and VEA application is installed • Other DSRC equipped vehicles transmitting BSMs in the DSRC area • Tablet running CV Inspector application to verify DSRC messages • Access to RSU admin web portal to verify BSM message activity

Test Script

Step	Test Action	Expected Results	Pass/Fail		Actual Results
			P	F	
1	Launch VEA Application if it's not running.	VEA application starts up and starts to broadcast BSM messages			
2	Launch CV Inspector Application	Application is initialized and a map zoomed into the test area is displayed Observe BSM message traffic on the CV Inspector. Verify that the location of the vehicle is updated on the map as the vehicle is moving 2-3 times per second.			
3	Open a browser and browse to RSU web admin portal at IP Address _____	Browser displays the RSU login page			
4	Log in to the portal using username:_____ password:_____ and click on the "View Message Activity" under Main Menu	Browser displays BSM module status, showing number of processed BSMs to indicate reception of a BSM message.			
5	Browse to the message log screen and filter data for BSM messages or log in to the database and execute the following query: <insert query>	The BSM message data is displayed. Inspect data to verify vehicle location, vehicle speed, vehicle heading, and vehicle size are logged. Inspect the timestamps to indicate that BSMs are being logged every tenth of a second.			

5.4.4 Ad-hoc Travel Group

Test Case

Test Case ID	5.4.4.1
Test Case Name	ATG – Creating Coordination between the Mobile Devices of Travelers – Multiple Travelers
Test Objective	• Verify travelers are able to temporarily be grouped into ad-hoc travel group and transmit trip request through the application • Verify travelers are able to transmit trip requests as a group (with a leader) rather than transmitting individual messages from every member of the group • Verify the ad-hoc group leader is able to enter and submit ad-hoc group trip details through the application
System Requirement	FR 2.07, FR 5.01, FR 5.01.01, FR 5.02, FR 5.03, FR 5.03.01, FR 5.04, FR 5.06, FR 5.06.01, FR 5.07, SIR 8.01, SIR 8.02, SIR 8.03, SIR 8.04, SIR 8.05, SIR 8.06, SIR 8.07, SIR 8.10, SIR 8.11, SIR 15.08, SIT 20.01, PR 5.06
Verification Method	Test
Test Date	By 12/09/2016
Test Location	Battelle Software Development Facility
Tester Name	
Test Method/ Configuration Comments	• DSRC capable hardware is connected to the Mobile Devices and the MDEA is installed and initiated for use in each • Pedestrians holding Mobile Devices are standing five (5) meters perpendicular to the edge of the roadway at the crosswalk in a safe zone • DSRC capable hardware is connected to the In-Vehicle Device and the VEA is installed and initiated for use • The Taxi/Transit Vehicle is stationed within the DSRC range *Note: Devices are placed within 1000m (generally accepted DSRC range given clear line of sight) of each other with a clear line of sight.* Users interact with the MDEA to enter and submit trip request to Taxi/Transit Vehicle

Test Script

Step	Test Action	Expected Results	Pass/Fail		Actual Results
			P	F	
1	Traveler X arrives at a stop. Schedules a trip. (See Test Script for Test Case 5.4.2.1 – Steps 1 through 5)	Ride Request Monitor looks for a local group for the same trip. None is found. MDEA establishes a new Group ABC, Leader 1, adds self as Pending member and enters Leader mode.			
2	Taxi/Transit Vehicle receives a Ride Request.	Ride Request Monitor identifies a new PMM request with the Destination, Departure Time, Seat Type and Vehicle Type requested. The VEA accepts the request.			
3	Taxi/Transit Vehicle driver accepts Ride Request.	Taxi/Transit Vehicle sends a PMM-RSP message via DSRC. MDEA is notified of accepted PMM request.			
4	Traveler Y arrives at a stop. Schedules a trip to the same destination location as Traveler X.	Ride Request Monitor looks for a local group for the same trip. One (1) is found. MDEA asks to be added to existing Group ABC via Wi-Fi Direct. MDEA of Leader receives request, adds Traveler Y to Pending Members and returns acceptance for Traveler Y to become follower within Group ABC. MDEA of Traveler Y receives response and enters Follower mode. MDEA of Traveler X (Group ABC Leader), creates new Pending PMM Request to dispatch to Taxi/Transit Vehicle, reflecting two (2) seats required.			
5	Taxi/Transit Vehicle receives updated Ride Request.	Ride Request Monitor identifies an updated PMM request with the Destination, Departure Time, Seat Type and Vehicle Type requested. The VEA accepts the request.			
6	Taxi/Transit Vehicle Driver Accepts the PMM Request displayed on VEA.	Group ABC Leader receives a PMM-RSP from VEA indicating it has accepted PMM Request for two (2) seats.			

Step	Test Action	Expected Results	Pass/Fail		Actual Results
			P	F	
7	Traveler Z arrives at a stop. Schedules a trip to the same destination location as Traveler X and Y.	Ride Request Monitor looks for a local group for the same trip. One (1) is found. MDEA asks to be added to existing Group ABC via Wi-Fi Direct. MDEA of Leader receives request, adds Traveler Z to Pending Members and returns acceptance for Traveler Z to become follower within Group ABC. MDEA of Traveler Z receives response and enters Follower mode. MDEA of Traveler X (Group ABC Leader), creates new Pending PMM Request to dispatch to Taxi/Transit Vehicle, reflecting three (3) seats required.			
8	Taxi/Transit Vehicle receives updated Ride Request.	Ride Request Monitor identifies a new PMM request with the Destination, Departure Time, Seat Type and Vehicle Type requested. The VEA accepts the request.			
9	Taxi/Transit Vehicle Driver Accepts the updated PMM Request displayed on VEA.	VEA accepts updated PMM Request. Group ABC Leader receives a PMM-RSP from VEA indicating it has accepted PMM Request for three (3) seats.			
10	Traveler W arrives at a stop. Schedules a trip to the same destination location as Traveler X, Y and Z.	Ride Request Monitor looks for a local group for the same trip. One (1) is found. MDEA asks to be added to existing Group ABC via Wi-Fi Direct. MDEA of Leader receives request, determines the max group size (3) has been reached and rejects the request. MDEA of Traveler W receives rejection and creates new PMM Request for a new Group.			
11	Taxi/Transit Vehicle arrives stop.	VEA sends PMM-ARRIVE with location and arrival time to Group Leader MDEA via DSRC of Group ABC. Group ABC leader's MDEA forwards the Arrival message to the followers The MDEA's notify all travelers about the vehicle arrival using a display alert			

Test Case

Test Case ID	5.4.4.2
Test Case Name	ATG – Leaving an Ad-Hoc Travel Group Based on Distance – Multiple Travelers
Test Objective	• Verify that an Ad-Hoc Travel Group Leader's Mobile Device can detect when a Mobile Device within the Ad-Hoc Travel Group leaves the Travel Group by exceeding the configurable distance between the Travel Group Leader
System Requirement	FR 5.01.03, FR 5.08, SIR 8.20, SIR 8.21, SIR 8.22, PR 5.06
Verification Method	Test
Test Date	By 12/09/2016
Test Location	Battelle Software Development Facility
Tester Name	
Test Method/ Configuration Comments	• DSRC capable hardware is connected to the Mobile Devices and the MDEA is installed and initiated for use in each • Pedestrians holding Mobile Devices are standing five (5) meters perpendicular to the edge of the roadway at the crosswalk in a safe zone • Mobile Device leaves Ad-Hoc Travel Group if exceeding Wi-Fi Direct range.

Test Script

Step	Test Action	Expected Results	Pass/Fail		Actual Results
			P	F	
1	Ad-Hoc Travel Group forms. (See Test Case 5.4.4.1 – Steps 1 through 9)	None.			
2	Ad-Hoc Travel Group Member walks away from Ad-Hoc Travel Group Leader's Mobile Device exceeding the Wi-Fi Direct range (e.g., 200 meters).	Ad-Hoc Travel Group Leader's MDEA detects change in group. Ad-Hoc Travel Group Leader's MDEA automatically updates PMM with number of seats requested and sends it to the Taxi/Transit Vehicle via DSRC/Cellular.			
3	Taxi/Transit Vehicle Receives updated Ride Request.	The VEA accepts the request.			
4	Taxi/Transit Vehicle Driver enters acceptance of updated PMM into VEA.	VEA sends a PMM-RSP message via DSRC. MDEA is notified with Accepted PMM request			

Test Case

Test Case ID	5.4.4.3
Test Case Name	ATG – Leaving an Ad-Hoc Travel Group by Choice – Multiple Travelers
Test Objective	• Verify that an Ad-Hoc Group Leader's Mobile Device can detect when a Mobile Device within the Ad-Hoc Travel Group requests to leave the Travel Group
System Requirement	FR 5.05, FR 5.09
Verification Method	Test
Test Date	By 12/09/2016
Test Location	Battelle Software Development Facility
Tester Name	
Test Method/ Configuration Comments	• DSRC capable hardware is connected to the Mobile Devices and the MDEA is installed and initiated for use in each • Pedestrians holding Mobile Devices are standing five (5) meters perpendicular to the edge of the roadway at the crosswalk in a safe zone • Ad-Hoc Travel Group Members interact with the Mobile Device and requests to leave the Ad-Hoc Travel Group manually

Test Script

Step	Test Action	Expected Results	Pass/Fail		Actual Results
			P	F	
1	Ad-Hoc Travel Group forms. (See Test Case 5.4.4.1 – Steps 1 through 9)	None.			
2	Ad-Hoc Travel Group Member requests to leave the Travel Group by submitting cancel request manually.	Ad-Hoc Travel Group Leader's Mobile Device receives the cancel request via Wi-Fi Direct. Ad-Hoc Travel Group Leader's Mobile Device automatically creates and sends an updated (group) PMM to Taxi/Transit Vehicle via DSRC.			
3	Taxi/Transit Vehicle Receives updated Ride Request.	The VEA accepts the request.			
4	Taxi/Transit Vehicle Driver enters acceptance of updated PMM into VEA.	VEA sends a PMM-RSP message via DSRC. MDEA is notified with Accepted PMM request.			

Test Case

Test Case ID	5.4.4.4
Test Case Name	ATG – Disbanding Ad-Hoc Travel Group When Entering a Vehicle or any other Reason
Test Objective	• Verify that Ad-Hoc Travel Group Leader's Mobile Device can disband an Ad-Hoc Travel Group when entering a vehicle
System Requirement	FR 5.10, FR 5.11, SIR 8.30, SIR 8.31
Verification Method	Test
Test Date	By 12/09/2016
Test Location	Battelle Software Development Facility
Tester Name	
Test Method/ Configuration Comments	• DSRC capable hardware is connected to the Mobile Devices and the MDEA is installed and initiated for use in each • Pedestrians holding Mobile Devices are standing five (5) meters perpendicular to the edge of the roadway at the crosswalk in a safe zone • Ad-Hoc Travel Group Leader's MDEA detects vehicle entry and disbands group

Test Script

Step	Test Action	Expected Results	Pass/Fail P	Pass/Fail F	Actual Results
1	Ad-Hoc Group forms. (See Test Case 5.4.4.1 – Steps 1 through 9)	None.			
2	Taxi/Transit Vehicle approaches and arrives at stop.	VEA issues a PMM-ARRIVE via DSRC to Ad-Hoc Travel Group Leader's Mobile Device. MDEA receives the PMM-ARRIVE.			
3	Ad-Hoc Travel Group enters Taxi/Transit Vehicle.	MDEA updates its vehicle status to "In Vehicle" and sends Coordination End message to all Travel Group members to disband group. Log of "Uncoordinated" status will show on Group Leader MDEA and a Status of "In Vehicle".			

5.4.5 Entering and Leaving Light-Duty Vehicle

Test Case

Test Case ID	5.4.5.1
Test Case Name	LDV – Bluetooth Proximity Sensor Functionality to Detect Passenger Entry into and Exiting from the Light-Duty Vehicle
Test Objective	• Demonstrate prototype capability to detect passenger entry into vehicle • Demonstrate prototype capability to detect passenger exiting from vehicle
System Requirement	FR 1.03, FR 6.01, FR 6.03, FR 7.01, FR 7.03, FR 7.04, SIR 15.09, SIR 20.03, PR 1.16, PR 1.17, PR 1.18, PR 1.19
Verification Method	Test
Test Date	By 12/12/2016
Test Location	Battelle Software Development Facility
Tester Name	
Test Method/ Configuration Comments	• Light-Duty vehicle equipped with Estimote Bluetooth sensor • Passenger with Mobile Devices with experimental application initiated and running • Countdown timer to measure status change time to detect entry or exit events • Tablet running CV Inspector application to verify DSRC messages

Test Script

Step	Test Action	Expected Results	Pass/Fail P	Pass/Fail F	Actual Results
1	Passenger is waiting and a vehicle equipped with Estimote beacon is approaching the stop	MDEA displays its vehicle status indicator as a red not-in-car icon. This is verified by visual inspection of the MDEA display. Inspect the CV Inspector to verify the reception of PSM			
2	Vehicle stops at the stop	MDEA continues to indicate vehicle status icon as red/"NOT IN VEHICLE". This is verified by visual inspection of the MDEA display			
3	Passenger embarks vehicle and vehicle starts to move. A test Observer in the vehicle starts the countdown timer from 3 seconds.	MDEA updates its vehicle status indicator to a green in-car icon within 3 seconds of Vehicle starting to move. This is verified by visual inspection of the MDEA display and the countdown timer.			
4	At the moment, the mobile device application updates its vehicle status to "IN VEHICLE" the test observer notes whether or not the countdown has expired.	Inspect the CV Inspector to verify that the PSM broadcasting has ceased.			
5	Vehicle stops, passenger disembarks the vehicle and starts to walk away from the vehicle. A test Observer outside of the vehicle starts the countdown timer from 3 seconds as the passenger steps outside.	Mobile device application updates its vehicle status icon to red/"NOT IN VEHICLE" within 3 seconds of passenger exiting the vehicle. This is verified by visual inspection of the MDEA display and the countdown timer.			
6	At the moment, the mobile device application updates its vehicle status to "NOT IN VEHICLE" the test observer notes whether or not the countdown has expired.	Inspect the CV Inspector to verify the reception of PSM			

Test Case

Test Case ID	5.4.5.2
Test Case Name	LDV – Mobile Device Accelerometer Sensor Functionality to Detect Passenger Entry into and Exiting from the Light-Duty Vehicle
Test Objective	• Demonstrate prototype capability to detect passenger entry into vehicle • Demonstrate prototype capability to detect passenger exiting from vehicle
System Requirement	FR 1.03, FR 1.04, FR 6.01, FR 6.02, FR 6.03, FR 6.04, FR 7.02, FR 7.05
Verification Method	Test
Test Date	By 12/12/2016
Test Location	Battelle Software Development Facility
Tester Name	
Test Method/ Configuration Comments	• Light-Duty vehicle not equipped with Estimote Bluetooth Sensor • Passenger with Mobile Devices with experimental application initiated and running • Countdown timer to measure status change time to detect entry or exit events.

Test Script

Step	Test Action	Expected Results	Pass/Fail P	Pass/Fail F	Actual Results
1	Passenger is waiting and a vehicle is approaching the stop	MDEA displays its vehicle status indicator as a red not-in-car icon. This is verified by visual inspection of the MDEA display. Inspect the CV Inspector to verify the reception of PSM			
2	Vehicle stops at the stop	MDEA continues to indicate vehicle status icon as red/“NOT IN VEHICLE”. This is verified by visual inspection of the MDEA display			
3	Passenger embarks vehicle and vehicle starts to move. A test Observer in the vehicle starts the countdown timer from 3 seconds.	MDEA updates its vehicle status indicator to a green in-car icon within 3 seconds of Vehicle starting to move. This is verified by visual inspection of the MDEA display and the countdown timer.			
4	At the moment, the mobile device application updates its vehicle status to “IN VEHICLE” the test observer notes whether or not the countdown has expired.	Inspect the CV Inspector to verify that the PSM broadcasting has ceased.			
5	Vehicle stops, passenger disembarks the vehicle and starts to walk away from the vehicle. A test Observer outside of the vehicle starts the countdown timer from 3 seconds as the passenger steps outside.	Mobile device application updates its vehicle status to “NOT IN VEHICLE” within 3 seconds of passenger exiting the vehicle. This is verified by visual inspection of the MDEA display and the countdown timer.			
6	At the moment, the mobile device application updates its vehicle status to “NOT IN VEHICLE” the test observer notes whether or not the countdown has expired.	Inspect the CV Inspector to verify the reception of PSM			

5.4.6 Message Logging

Test Case

Test Case ID	5.4.6.1
Test Case Name	MGL – RSU DSRC Message Logging
Test Objective	• Verify all DRSC messages are logged and timestamped
System Requirement	FR 10.01, SIR 16.01, SIR 20.05, PR 1.20, PR 1.21, PR 1.23, PR 1.24
Verification Method	Test
Test Date	By 12/13/2016
Test Location	Battelle Software Development Facility
Tester Name	
Test Method/ Configuration Comments	• Access to database on RSU • Access to a database browser tool

Test Script

Step	Test Action	Expected Results	Pass/Fail		Actual Results
			P	F	
1	Query the RSU database to verify that DSRC messages are being logged by executing the query: _____	The query returns data for all DSRC messages that are logged including the millisecond-based timestamps of when the message was transmitted.			

Test Case

Test Case ID	5.4.6.2
Test Case Name	MGL – Cloud Service Message Logging
Test Objective	• Verify all messages are logged and timestamped in the Cloud
System Requirement	FR 10.02, SIR 16.02
Verification Method	Test
Test Date	By 12/13/2016
Test Location	Battelle Software Development Facility
Tester Name	
Test Method/ Configuration Comments	• Access to database on Azure Cloud Service • Access to a Cloud Service Studio to view data

Test Script

Step	Test Action	Expected Results	Pass/Fail		Actual Results
			P	F	
1	Query the Azure database to verify that cellular messages are being logged by executing the query: Select * from PMMRequests where RequestDate > “TBD” and RequestDate < “TBD”; Select * from PMMResponses where RequestDate > “TBD” and RequestDate < “TBD”	The query returns data for all cellular messages that are logged including the millisecond-based timestamps of when the message was transmitted.			

Test Case

Test Case ID	5.4.6.3
Test Case Name	MGL – Mobile Device Experimental Application Message Logging
Test Objective	• Verify all sent and received mobile device messages are logged and timestamped • Verify all messages displayed to the users on the mobile device are logged
System Requirement	FR 10.03, FR 10.04
Verification Method	Test
Test Date	By 12/13/2016
Test Location	Battelle Software Development Facility
Tester Name	
Test Method/ Configuration Comments	• Access to database on Mobile Device • Access to SQLiteManager

Test Script

Step	Test Action	Expected Results	Pass/Fail		Actual Results
			P	F	
1	Query the MDEA's database to verify messages being logged by executing the query:	The query returns data for all sent and received messages including the millisecond-based timestamps of when the message was transmitted.			
2	View the message activity log	All message displayed to the users are logged with timestamps of occurrence.			

Test Case

Test Case ID	5.4.6.4
Test Case Name	MGL – Vehicle Experimental Application Message Logging
Test Objective	• Verify all messages sent and received by the vehicle are logged and timestamped • Verify all messages displayed to the driver of the vehicle are logged
System Requirement	FR 10.05, FR 10.06
Verification Method	Test
Test Date	By 12/13/2016
Test Location	Battelle Software Development Facility
Tester Name	
Test Method/ Configuration Comments	• Access to Vehicle Experimental Application log files • Access to Vehicle Experimental Application database • Access to Application Admin Portal • Access to a database browser tool

Test Script

Step	Test Action	Expected Results	Pass/Fail		Actual Results
			P	F	
1	Query the VEA's database to verify messages being logged by executing the query:	The query returns data for all sent and received messages including the millisecond-based timestamps of when the message was transmitted.			
2	View the message activity log	All message displayed to the users are logged with timestamps of occurrence.			

5.4.7 Safety

Test Case

Test Case ID	5.4.7.1
Test Case Name	SFY – Safety Notifications (Mobile Device User in Unsafe Zone)
Test Objective(s)	• Verify the ability of the MDEA to provide an advisory notification to the pedestrian • Verify the ability of the VEA to provide an advisory notification to the driver • Verify the ability of the MDEA to provide an alert notification to the pedestrian • Verify the ability of the VEA to provide an alert notification to the driver • Verify the ability of the MDEA to provide a warning notification to the pedestrian • Verify the ability of the VEA to provide a warning notification to the driver
System Requirement	FR 11.01, FR 11.02, FR 11.03, FR 11.04, FR 11.05, FR 11.06
Verification Method	Test
Test Date	By 12/13/2016
Test Location	Battelle Software Development Facility
Tester Name	
Test Method/ Configuration Comments	• DSRC capable hardware is installed on the vehicle and the VEA application is installed • DSRC capable hardware is connected to the mobile device and the MDEA application is installed • The test is repeated with the mobile device in various locations (in-hand, in-pocket, in-backpack) on the pedestrian • The pedestrian must be standing in the path of the vehicle.

Test Script

Step	Test Action	Expected Results	Pass/Fail		Actual Results
			P	F	
1	The Light-Duty vehicle accelerates up to 25 mph.	None			
2	The Light-Duty vehicle maintains constant speed of 25 mph.	None			
3	The Light-Duty vehicle comes within 100 meters of the mobile device.	Mobile device issues advisory to pedestrian. This is verified by inspection of the MDEA and detailed analysis of the MDEA Logs. Vehicle issues advisory to driver. This is verified by inspection of the VEA and detailed analysis of the VEA Logs.			
4	The Light-Duty vehicle comes within 57 meters of the mobile device. (The Light-Duty vehicle is moving toward the pedestrian.)	Mobile device issues alert to pedestrian. This is verified by inspection of the MDEA and detailed analysis of the MDEA Logs. Vehicle issues alert to driver. This is verified by inspection of the VEA and detailed analysis of the VEA Logs.			
5	The Light-Duty vehicle comes within 49 meters of the mobile device. (The Light-Duty vehicle is moving toward the pedestrian.)	Mobile device issues warning to pedestrian. This is verified by inspection of the MDEA and detailed analysis of the MDEA Logs. Vehicle issues warning to driver. This is verified by inspection of the VEA and detailed analysis of the VEA Logs.			

Step	Test Action	Expected Results	Pass/Fail		Actual Results
			P	F	
6	The Light-Duty vehicle passes the location where the pedestrian is standing. (The Light-Duty vehicle is moving away from the pedestrian.)	Mobile device ceases issuing warning to pedestrian. Mobile device ceases issuing alert to pedestrian. This is verified by inspection of the MDEA and detailed analysis of the MDEA Logs. Vehicle ceases issuing warning to driver. Vehicle ceases issuing alert to driver. This is verified by inspection of the VEA and detailed analysis of the VEA Logs.			
7	The Light-Duty vehicle continues at a constant speed until it is more than 100 meters of the mobile device.	Mobile device does not issue advisory to pedestrian. This is verified by inspection of the MDEA and detailed analysis of the MDEA Logs. Vehicle does not issue advisory to driver. This is verified by inspection of the VEA and detailed analysis of the VEA Logs.			
8	The Light-Duty vehicle decelerates to a stop.	None			

5.4.8 SPAT and MAP Support

Test Case

Test Case ID	5.4.8.1
Test Case Name	SMP – SPAT and MAP message support
Test Objective(s)	• Verify the ability of the MDEA to receive SPAT and MAP messages
System Requirement	SIR 9.01, SIR 9.02, SIR 9.03, SIR 10.01, SIR 10.02, SIR 10.03, SIR 10.04, SIR 15.10, SIR 15.11, PR 1.01, PR 1.02, PR 1.15, PR 2.02
Verification Method	Testing
Test Date	By 12/13/2016
Test Location	Battelle Software Development Facility
Tester Name	
Test Method/ Configuration Comments	• Availability of an RSU connected to a Signal Controller to broadcast SPAT and MAP messages • DSRC capable hardware is connected to the mobile device and the MDEA application is installed • Tablet running CV Inspector application to verify DSRC messages

Test Script

Step	Test Action	Expected Results	Pass/Fail		Actual Results
			P	F	
1	Observe signal controller and CV Inspector to monitor the signal status.	CV Inspector display reflects the status of the signal controller phases and actuations on a map using the SPAT and MAP message data.			
2	Inspect MDEA log for SPAT and MAP messages	SPAT and MAP messages are logged at 1 second and 5 second frequencies respectively.			

5.5 TFHRC Demonstration Scenario Test Cases

This section provides a summary of operational scenarios (originally presented in the Task 3 ConOps) followed by a matrix that traces each test case back to interactions and events included in each scenario and are in the scope of the Prototype system. These test cases will form the basis for demonstration and to validate the prototype system readiness to FHWA staff and representatives.

Scenario 1. The objective of this scenario is to explore communications methods for personal safety and personal mobility and the feasibility/impact of dynamically switching between the communications media. The impact of coordinated and uncoordinated message exchanges between mobile devices and connected vehicles. This scenario is based upon the real-world events associated with travelers utilizing taxi, ridesharing, paratransit, and other services to transition from a pedestrian to a vehicle occupant in a light-duty passenger vehicle. Specific interactions and events included in this scenario are:

1. Personal Mobility Message (PMM) exchange for ride request and pickup.
2. Personal Safety Message (PSM) exchange for pedestrian in the street to include rapid (i.e., without significant lag) and dynamic switching (i.e., without user interaction) from cellular-based to DSRC-based communications methods if the surrounding conditions require low-latency communications to enhance safety.
3. PMM exchange of travel, mobility needs, and other information between passenger and driver in a non-connected vehicle.
4. PMM coordination of mobile devices between passengers and a connected vehicle.
5. PSM coordination of mobile devices between pedestrians waiting for the same transit bus.

Scenario 2. This scenario focuses on trip mode transitions and a set of messages that will be needed to incorporate mobile devices into the connected vehicle environment. This scenario will be used to investigate the benefits of coordination of mobile devices in an environment where cellular, Wi-Fi, and DSRC bandwidth are at a diminished service capacity because of the demands placed upon these communication protocols by large numbers of users. This scenario is based upon the real-world events associated with multiple groups of travelers clustering at a transit station/stop with multiple transit vehicles servicing the same station/stop. Specific interactions and events included in this scenario are:

1. Coordination of mobile devices and the Roadside Equipment (RSE) when a pedestrian wants to use a crosswalk. (Note: the concept of multiple mobile devices coordinating is encompassed in the second concept of the second scenario).
2. PMM coordination of mobile devices between multiple pedestrians traveling together
3. Coordinated PMM exchange for requesting the transit bus (with specific mobility needs)
4. Multiple coordinated PMM exchanges (between a group and the transit system) confirming transit capacity needs for all the groups
5. Coordinated PSM exchange for pedestrians in the street

Scenario 3. The objective of the third scenario is to examine the impact of coordinated versus uncoordinated messages in a multi-vehicle, multi-stop sequence considering the mobility needs of each traveler. This scenario simulates a typical transit vehicle picking up/dropping off passengers at multiple transit stops while interacting with other vehicles that may or may not be picking up or dropping off passengers at the same stops. Specific interactions and events included in this scenario are:

1. Coordinating a trip from home before going to the transit pickup location. Note: For the Prototype Proof of Concept demonstration at Turner Fairbanks, the pickup and drop-off locations are limited to the pre-selected locations in the test area.
2. Canceling a trip
3. PMM coordination of mobile devices between two pedestrians
4. Coordinated PMM exchange for transit request and pickup
5. PMM coordination between passengers and a connected vehicle
6. PMM to cease coordination of passengers and a connected vehicle

Table 5-2. Test Case to TFHRC Demonstration Scenario Support Traceability Matrix

Test Case No.	Test Case	Scenario	Scenario Events Supported
	Personal Safety Message Performance		
5.4.1.1	PSM – Broadcasting PSM with Vehicle Within a Specified Radius (Transmit Timing)	1	2
5.4.1.2	PSM – Cease Broadcasting PSMs when In-Vehicle	1	2
5.4.1.3	PSM – Cease Broadcasting PSMs After Joining an Ad-Hoc Travel Group	1 2	5 5
5.4.1.4	PSM – Broadcasting PSM with Pedestrian in Unsafe Zone	1 2	2 5
	Personal Mobility Message Performance		
5.4.2.1	PMM – Submitting Trip Requests – Single User	1 3	1, 4 4, 5
5.4.2.2	PMM – Communicate with Cloud Infrastructure via Cellular	1 3	1, 3 1, 4, 5
5.4.2.3	PMM – Canceling Trip Requests	3	6
5.4.2.4	PMM – Sending Arrival Messages	3	4, 5
	Basic Safety Message Performance		
5.4.3.1	BSM – Vehicle Experimental Application Functionality	1	2
	Ad-hoc Travel Group Message Performance		
5.4.4.1	ATG – Creating Coordination between the Mobile Devices of Travelers – Multiple Travelers	1 2 3	5 1, 2, 3, 4 3, 4
5.4.4.2	ATG – Leaving an Ad-Hoc Travel Group Based on Distance – Multiple Travelers	3	2, 3
5.4.4.3	ATG – Leaving an Ad-Hoc Travel Group by Choice – Multiple Travelers	3	2, 3
5.4.4.4	Disbanding Ad-Hoc Travel Group When Entering a Vehicle or any other Reason	3	3
	Entering and Leaving a Light-Duty Vehicle		
5.4.5.1	LDV – Bluetooth Proximity Sensor Functionality to Detect Passenger Entry into and Exiting from the Light-Duty Vehicle	1	1
5.4.5.2	LDV – Mobile Device Accelerometer Sensor Functionality to Detect Passenger Entry into and Exiting from the Light-Duty Vehicle	1	1
	Safety		
5.4.7.1	SFY – Safety Notifications (Mobile Device User in Unsafe Zone)	1	2

APPENDIX A. Requirements Traceability Matrix

APPENDIX A contains matrices that relate the test cases with various requirements presented in the SysRS document associated with this project. Only requirements that are specified as being included in the Prototype System (defined in the SysRS document) are included in this section. Furthermore, the method by which each requirement is verified is listed in the *Verification Method* column. The four fundamental methods along with a general explanation of each is listed below[1].

- Test: Direct measurement of system operation. Defined inputs are provided and outputs are measured to verify that the requirements have been met.
- Demonstration: Witnessing system operation in the expected or simulated environment without need for measurement data.
- Inspection: Direct observation of requirements such as construction features, workmanship, dimensions and other physical characteristics, and software language.
- Analysis: Verification using logical, mathematical, and/or graphical techniques. Analysis is frequently used when verification by test would not be feasible or would be prohibitively expensive.

[1] U.S.D.O.T. Systems Engineering for Intelligent Transportation Systems. An Introduction for Transportation Professionals. http://ops.fhwa.dot.gov/publications/seitsguide/seguide.pdf

Functional Requirements

The functional requirements to enable Mobile Devices to operate in the Connected Vehicle environment are defined in the next table.

Table A-1. Functional Requirements Table

FR ID	Functional Requirement Title	Functional Requirement Description	Test Case #	Verification Method
FR 1.0 Personal Safety Message (PSM) Functional Requirements				
FR 1.01	Broadcasting PSMs	Mobile Devices shall broadcast PSMs via DSRC communications media.	5.4.1.1	Test
FR 1.02	PSM Broadcasting Frequency	Mobile Devices shall be able to send PSMs in configurable transmission intervals in 0.1 second frequency intervals.	5.4.1.1	Test
FR 1.03	Stop broadcasting PSMs	Mobile Devices shall stop broadcasting PSMs when the mobile device has detected to have entered a vehicle.	5.4.1.2 5.4.5.1 5.4.5.2	Test
FR 1.04	Restarting broadcasting PSMs	Mobile Devices shall automatically restart the broadcast of the PSMs when exiting a vehicle.	5.4.5.1 5.4.5.2	Test
FR 1.05	Stop broadcasting PSMs	Mobile Devices shall stop broadcasting PSMs when the mobile device has coordinated with a group leader (for crossing street or taxi/transit service). The sub-requirement below contains an exception to this rule.	5.4.1.3	Test
FR 1.06	Sending PSMs when in unsafe zone	A mobile device shall broadcast PSMs when the mobile device has detected that the pedestrian is in an unsafe zone. *NOTES:* *An "Unsafe Zone" is in a lane in which vehicle may travel including a roadway shoulder, a pedestrian crosswalk, or any area within one meter of the edge of the roadway* *A "Safe Zone" is on a sidewalk or zone in which a vehicle must cross a physical obstacle to collide with pedestrian*	5.4.1.4	Test

Table A-1. Functional Requirements Table (Continued)

FR ID	Functional Requirement Title	Functional Requirement Description	Test Case #	Verification Method
FR 1.08	PSM Transmit Timing	Mobile Devices shall transmit PSMs only when the mobile device determines a vehicle is within a specified radius of the mobile device. The specified radius is dependent on the vehicle's speed. The radius calculation is the same as the advisory display distance. Note: This is in accordance with the J2945-9, Clause 6.3.3 standard.	5.4.1.1	Test
FR 2.0 Personal Mobility Message (PMM) Functional Requirements				
FR 2.01	Creating PMMs	A user of a mobile device shall be provided with an interface into the MDEA to enter trip request information.	5.4.2.1	Test
FR 2.01.01	Generating PMM Content	A user of a mobile device shall be able to enter their desired pickup time, pickup location, destination location, number of passengers included in the trip request, and mobility needs such as number of wheelchairs in party as part of the trip request information (PMM).	5.4.2.1	Test
FR 2.02	Sending PMMs	A mobile device shall send a PMM to an entity that can process the trip request. *Note: the PMM could be sent either to a dispatching center or directly to a vehicle.*	5.4.2.1	Test
FR 2.03	Transmitting PMMs over various communications media	A mobile device shall broadcast a PMM via various communications media, as defined by the following sub-requirements.	5.4.2.1 5.4.2.2 5.4.2.3 5.4.2.4	Test
FR 2.03.01	Transmitting PMMs – First Attempt – Communicate Directly with Vehicles in DSRC Range	A mobile device shall broadcast a PMM first over DSRC to potential passenger-transporting vehicles	5.4.2.1	Test
FR 2.03.02	Transmitting PMM – Second Attempt – Communicate with RSE via DSRC	If no response is received within a configurable amount of time from a passenger-transportation and responding vehicle, a mobile device shall broadcast the PMM to an RSE (connected to cloud infrastructure) via DSRC.	Not supported by the Prototype	

Table A-1. Functional Requirements Table (Continued)

FR ID	Functional Requirement Title	Functional Requirement Description	Test Case #	Verification Method
FR 2.03.03	Transmitting PMM – Third Attempt – Communicate with RSE via Wi-Fi Direct	If no response is received within a configurable amount of time via an RSE, a mobile device shall broadcast the PMM to an RSE (connected to cloud infrastructure) via Wi-Fi Direct.	Not supported by the Prototype	
FR 2.03.04	Transmitting PMM – Fourth Attempt – Communicate with Cloud Infrastructure via cellular	If no response is received within a configurable amount of time via either DSRC or Wi-Fi Direct, a mobile device shall send the PMM over cellular communications media to either a passenger-transport vehicle or a vehicle dispatch center, which in turn would dispatch a suitable vehicle.	5.4.2.2	Test
FR 2.04	Receiving a PMM acknowledgement receipt via DSRC	A mobile device shall be able to receive a PMM acknowledgement via DSRC.	5.4.2.1	Test
FR 2.05	Receiving a PMM acknowledgement receipt via cellular	A mobile device shall be able to receive a PMM acknowledgement via cellular communications media.	5.4.2.2	Test
FR 2.06	Generating PMM Response content	The PMM acknowledgement shall include the PMM Request ID of the original PMM trip request, Location of vehicle responding to the original PMM trip request, and an indicator whether the responding vehicle supports DSRC as a communications media.	5.4.2.1 5.4.2.2	Test
FR 2.07	Updating a PMM	A mobile device shall be able to create and transmit an updated PMM if new travelers have joined or left an ad-hoc travel group while ensuring that the PMM maintains its PMM unique identification number.	5.4.4.1	Test
FR 2.08	Manually cancelling a PMM	A mobile device shall be able to transmit a PMM-CANCEL if the traveler decides to cancel a trip.	5.4.2.3	Test
FR 2.09	Sending a PMM arrival message	A vehicle shall be able to create and transmit a PMM-ARRIVE message to the mobile device of the original PMM trip request at pre-configured intervals.	5.4.2.4	Test
FR 2.10	Receiving a PMM arrival message	A mobile device shall be able to receive a PMM-ARRIVE message from the vehicle responding to the original PMM trip request.	5.4.2.4	Test

Table A-1. Functional Requirements Table (Continued)

FR ID	Functional Requirement Title	Functional Requirement Description	Test Case #	Verification Method
FR 4.0 Basic Safety Message (BSM) Functional Requirements (those applicable to the Sharing Data between Mobile Devices, Connected Vehicles and Infrastructure project)				
FR 4.01	Generating BSMs	Equipped vehicles shall be able to generate BSMs.	5.4.3.1	Test
FR 4.01.01	Generating BSM Content	Equipped vehicles shall be able to generate BSM content including vehicle location, vehicle speed, vehicle heading, and vehicle size, as a minimum.	5.4.3.1	Test
FR 4.02	Broadcasting BSMs	Equipped vehicles shall be able to transmit BSMs to other equipped vehicles, equipped Mobile Devices, and other entities via DSRC communications media.	5.4.3.1	Test
FR 4.03	Receiving BSMs	Mobile Devices and equipped vehicles shall be able to receive BSMs broadcasted by vehicles via DSRC communications media.	5.4.3.1	Test
FR 5.0 Ad-Hoc Travel Group Functional Requirements				
FR 5.01	Sending mobile device itinerary to other Mobile Devices	A mobile device shall be able to send its active PMM to other Mobile Devices via Wi-Fi-Direct communications media. *Note: Wi-Fi Direct is an established communications mechanism and the Mobile Devices have to comply with this. The mechanism offers that Mobile Devices only need to 'register' once and then the registration is almost permanent.*	5.4.4.1	Test
FR 5.01.01	Establish Wi-Fi-Direct Communications	A mobile device shall follow the established procedures for Wi-Fi-Direct communications to connect with other Mobile Devices in its vicinity.	5.4.4.1	Test
FR 5.01.02	Automatic reconnect to Wi-Fi-Direct Communications	A mobile device shall be able to reconnect automatically to a previously existing Wi-Fi-Direct Connection. The automatic reconnection shall not be limited by any elapsed time threshold of the disconnection.	5.4.4.1	Test
FR 5.01.03	Disconnect from Wi-Fi-Direct Communications	A mobile device shall follow the established procedures for Wi-Fi-Direct communications to disconnect from other Mobile Devices if the mobile device moves out of connection range.	5.4.4.2	Test

Table A-1. Functional Requirements Table (Continued)

FR ID	Functional Requirement Title	Functional Requirement Description	Test Case #	Verification Method
FR 5.02	Requesting the creation of an ad-hoc travel group	A mobile device shall automatically transmit a coordination request message to other Mobile Devices with the same PMM information in terms of departure location, departure time, and destination location to request the creation of an ad-hoc travel message. *Note: for the EPS, the same itinerary means the exact same itinerary. Future research will have to determine whether locations along the path of a traveler are suitable to qualify for 'same' itinerary.*	5.4.4.1	Test
FR 5.03	Generating Travel Group Coordination Confirmation Message	A mobile device shall be able to generate and send an ad-hoc travel group coordination confirmation.	5.4.4.1	Test
FR 5.03.01	Generating Travel Group Coordination Confirmation Message Content	A mobile device shall be able to generate the coordination confirmation message content including the travel group creation request identifier, a travel group identifier, and a group status indicator.	5.4.4.1	Test
FR 5.04	Determining an ad-hoc travel group travel leader	The first mobile device to send a coordination confirmation message shall automatically become the travel group leader.	5.4.4.1	Test
FR 5.05	Limiting travel group size	The EPS shall include a capability within a mobile device's MDEA to limit the number of Mobile Devices that can be joined into an ad-hoc travel group.	5.4.4.3	Test
FR 5.06	Generating Travel Group Coordination Message	A mobile device shall be able to generate an ad-hoc travel group Coordination Message.	5.4.4.1	Test
FR 5.06.01	Generating Travel Group Coordination Message Content	A mobile device shall be able to generate the Coordination Message content including the travel group identifier, and a group status indicator.	5.4.4.1	Test
FR 5.07	Maintaining an ad-hoc travel group	A mobile device shall send a Coordination Message (coordination heartbeat message) to the travel group leader mobile device within a configurable frequency.	5.4.4.1	Inspect

Table A-1. Functional Requirements Table (Continued)

FR ID	Functional Requirement Title	Functional Requirement Description	Test Case #	Verification Method
FR 5.08	Leaving an ad-hoc travel group based on distance	The travel group leader's mobile device shall detect when another mobile device within the ad-hoc travel group leaves the travel group by exceeding the configurable distance between the travel group leader and the leaving group member and then automatically creates and sends an updated (group) PMM. *Note This might be simulated via a manual input into and sent from the leaving mobile device during the demonstration*.	5.4.4.2	Test
FR 5.09	Leaving an ad-hoc travel group based on request	The travel group leader's mobile device shall detect when another mobile device within the ad-hoc travel group requests to leave the travel group and then automatically creates and sends an updated (group) PMM. *Note This might be simulated via a manual input into and sent from the leaving mobile device during the demonstration*.	5.4.4.3	Test
FR 5.10	Disbanding an ad-hoc travel group when entering a vehicle	A mobile device shall be able to detect when it enters a vehicle and automatically disjoin the ad-hoc travel group it belonged to (effectively dissolving the ad-hoc travel group).	5.4.4.4	Test
FR 5.11	Normal disbanding an ad-hoc travel group	The travel group leader's mobile device shall generate and send a coordination end message to all other Mobile Devices within the ad-hoc travel group when the group is to be dissolved for any other reasons than entering a vehicle and the distance between the travel group leader's mobile device and that of a group member exceeding a configurable distance. *Note This will be simulated via a manual input into and send from the travel group leader's mobile device during the demonstration*.	5.4.4.4	Test
FR 6.0 Entering and Leaving Light-Duty Vehicle Functional Requirements				
FR 6.01	Detecting when entering DSRC equipped Light-Duty vehicle	A mobile device shall be able to detect when it enters a DSRC-equipped Light-Duty vehicle.	5.4.5.1	Test

Table A-1. Functional Requirements Table (Continued)

FR ID	Functional Requirement Title	Functional Requirement Description	Test Case #	Verification Method
FR 6.02	Detecting when entering non-DSRC equipped Light-Duty vehicle	A mobile device shall be able to detect when it enters a non-DSRC-equipped Light-Duty vehicle.	5.4.5.2	Test
FR 6.03	Detecting when exiting DSRC equipped Light-Duty vehicle	A mobile device shall be able to detect when it exits a DSRC-equipped Light-Duty vehicle.	5.4.5.1	Test
FR 6.04	Detecting when exiting non-DSRC equipped Light-Duty vehicle	A mobile device shall be able to detect when it exits a non-DSRC-equipped Light-Duty vehicle.	5.4.5.2	Test
FR 7.0 Entering and Leaving Transit Vehicle Functional Requirements				
FR 7.01	Detecting when entering DSRC equipped Transit Vehicle	A mobile device shall be able to detect when it enters a DSRC-equipped Transit Vehicle.	5.4.5.1	Test
FR 7.02	Detecting when entering non-DSRC equipped Transit Vehicle	A mobile device shall be able to detect when it enters a non-DSRC-equipped Transit Vehicle.	5.4.5.2	Test
FR 7.03	Detecting presence of Bluetooth connectivity in Transit Vehicle	A mobile device shall be able to detect the presence of Bluetooth communications media within a transit-vehicle when in proximity to or entering a Transit Vehicle.	5.4.5.1	Test
FR 7.04	Detecting when exiting DSRC equipped Transit Vehicle	A mobile device shall be able to detect when it exits a DSRC-equipped Transit Vehicle.	5.4.5.1	Test
FR 7.05	Detecting when exiting non-DSRC equipped Transit Vehicle	A mobile device shall be able to detect when it exits a non-DSRC-equipped Transit Vehicle.	5.4.5.2	Test
FR 10.0 Message Logging Functional Requirements				
FR 10.01	Recording all DSRC communications within RSE	A RSU (both intersection and transit stop-based) shall record all messages transmitted via DSRC communications media using millisecond-based timestamps of occurrence.	5.4.6.1	Test
FR 10.02	Recording all cellular communications via cloud infrastructure system	The cloud infrastructure shall capture and record all messages sent via cellular communications media using millisecond-based timestamps of occurrence.	5.4.6.2	Test

Table A-1. Functional Requirements Table (Continued)

FR ID	Functional Requirement Title	Functional Requirement Description	Test Case #	Verification Method
FR 10.03	Recording all sent and received communications within Mobile Device	A mobile device shall record all messages transmitted and received over any communications media using millisecond-based timestamps of occurrence.	5.4.6.3	Test
FR 10.04	Recording all displayed messages within Mobile Device	A mobile device shall record any information output to the screen of the mobile device using millisecond-based timestamps of occurrence.	5.4.6.3	Test
FR 10.05	Recording all sent and received communications within Vehicle	A vehicle shall record all messages transmitted and received over any communications media using millisecond-based timestamps of occurrence.	5.4.6.4	Test
FR 10.06	Recording all displayed messages within vehicle	A vehicle shall record any information output to the screen of the vehicle's on-board device using millisecond-based timestamps of occurrence.	5.4.6.4	Test
FR 11.0 Safety Functional Requirements (applicable to the Prototype System)				
FR 11.01	Displaying Advisory within Vehicle	A vehicle shall display an advisory to the vehicle driver when it receives a PSM.	5.4.7.1	Test
FR 11.02	Displaying Alert within Vehicle	A vehicle shall display an alert to the vehicle driver when the vehicle receives a PSM and determines that it is approaching the mobile device and the mobile device is in an unsafe zone. The alert is displayed. The distance (between vehicle and mobile device) at which an alert is displayed is dependent on the vehicle's speed, explained in Appendix C of the SysRS.	5.4.7.1	Test
FR 11.03	Displaying Warning within Vehicle	A vehicle shall display a warning to the vehicle driver when the vehicle receives a PSM and determines that it is approaching the vulnerable road user and the vulnerable road user is in the vehicle's lane of travel. The distance (between vehicle and mobile device) at which a warning is displayed is dependent on the vehicle's speed, explained in Appendix C of the SysRS.	5.4.7.1	Test
FR 11.04	Displaying Advisory within Mobile Device	A mobile device shall display an advisory when it has received a BSM and determines that a vehicle is approaching. The distance (between vehicle and mobile device) at which an advisory is displayed is dependent on the vehicle's speed, explained in Appendix C of the SysRS.	5.4.7.1	Test

Table A-1. Functional Requirements Table (Continued)

FR ID	Functional Requirement Title	Functional Requirement Description	Test Case #	Verification Method
FR 11.05	Displaying Alert within Mobile Device	A mobile device shall display an alert when it has received a BSM and determines that a vehicle is approaching and the mobile device is in an unsafe zone. The distance (between vehicle and mobile device) at which an alert is displayed is dependent on the vehicle's speed, explained in Appendix C of the SysRS.	5.4.7.1	Test
FR 11.06	Displaying Warning within Mobile Device	A mobile device shall display an alert when it has received a BSM and detects that a vehicle is approaching and the mobile device is in the vehicle's lane of travel. The distance (between vehicle and mobile device) at which a warning is displayed is dependent on the vehicle's speed, explained in Appendix C of the SysRS.	5.4.7.1	Test

Source: Battelle

System Interface Requirements

As specified above the system requirements below only include those required for use within the Prototype System demonstration tests.

Table A-2. System Interface Requirements Table

SIR ID	System Interface Requirement Title	System Interface Requirement Description	Test Case #	Verification Method
SIR 1.0 Personal Safety Message (PSM) Requirements				
SIR 1.01	PSM Broadcasting Frequency	The PSM shall be broadcasted in user-defined transmission intervals adjustable in 0.1 second intervals. *Note: This is consistent with SAE J2735 standard for broadcast frequency, although the frequency is not defined (unlike the BSM where the frequency is required to be 0.1 seconds).*	5.4.1.1	Inspection
SIR 1.02	PSM Location (lat/long/elev)	The PSM shall specify the pedestrian location expressed in 1/10th integer microdegrees (longitude and latitude with reference to the horizontal datum). Elevation shall be expressed in signed units of 10 cm steps above or below the reference ellipsoid. *Note: This is consistent with SAE J2735 PSM definition for location.*	5.4.1.1	Inspection
SIR 1.03	PSM Speed	The PSM shall specify the pedestrian speed in meters/second in 0.1 m/s increments. *Note: This is consistent with the SAE J2735 PSM definition for speed.*	5.4.1.1	Inspection
SIR 1.04	PSM Heading	The PSM shall specify the pedestrian heading, expressed in signed units of 0.0125 degrees from North (same units as in BSMs). *Note: This is consistent with SAE J2735 PSM definition for heading.*	5.4.1.1	Inspection
SIR 1.05	PSM Number of Pedestrians	The PSM shall specify a number of travel group members included in the PSM. *Note: This field will increase/decrease as travelers join/disband from a travel group. The group leader would be sending a PSM for the entire group. There is an optional field in the SAE J2735 PSM definition called 'NumberOfParticipantsInCluster' but only defines small (2-5 people), medium (6-10 people), or large groups (>10).*	5.4.1.1 5.4.1.3	Inspection

Table A-2. System Interface Requirements Table (Continued)

SIR ID	System Interface Requirement Title	System Interface Requirement Description	Test Case #	Verification Method
SIR 1.06	PSM Radius of Protection	The PSM shall specify a 'radius of protection' expressed in 0.1 meter increments that is reflective of the number of pedestrians included in the PSM. *Note: This is consistent with SAE J2735 PSM definition for PersonalClusterRadius defining the radius in meters around a cluster of users.*	5.4.1.1	Inspection
SIR 1.07	PSM Radius of Protection expandable	The PSM 'radius of protection' shall be expandable, depending on *the number of pedestrians included in the PSM.* *Note: This is consistent with SAE J2735 PSM definition for PersonalClusterRadius defining the radius in meters around a cluster of users.*	5.4.1.1 5.4.1.3	Inspection
SIR 1.08	PSM Path History	The PSM shall specify the pedestrian path history for up to the last 20 seconds. *Note: This is consistent with SAE J2735 PSM definition for path history although J2735 does not specify the length of the path history to include. We are limiting this to 20 seconds and even that might be too long for this project*	5.4.1.1	Inspection
SIR 1.09	PSM Path Prediction	The PSM shall specify the pedestrian path prediction for up to the next 5 seconds. *Note: This is consistent with SAE J2735 PSM definition for path prediction, although J2735 does not specify the prediction time into the future. We are limiting this to 5 seconds because non-motorized travel is highly variable and hard to predict.*	5.4.1.1	Inspection
SIR 2.0 Personal Mobility Message (PMM) Requirements				
SIR 2.01	PMM Request ID	The PMM shall specify a unique Request ID.	5.4.2.1	Inspection
SIR 2.02	PMM Location (lat/long/elev)	The PMM shall specify the pedestrian location expressed in 1/10th integer microdegrees (longitude and latitude with reference to the horizontal datum). Elevation shall be expressed in signed units of 10 cm steps above or below the reference ellipsoid.	5.4.2.1	Inspection
SIR 2.03	PMM Number of Travelers	The PMM shall specify the number of travelers included in the PMM.	5.4.2.1	Inspection
SIR 2.04	PMM Pickup Time	The PMM shall specify the pickup time expressed in Universal Coordinated Time (UTC) in 0.1 second increments.	5.4.2.1	Inspection

Table A-2. System Interface Requirements Table (Continued)

SIR ID	System Interface Requirement Title	System Interface Requirement Description	Test Case #	Verification Method
SIR 2.05	PMM Pickup Location	The PMM shall specify the pickup location expressed in 1/10th integer microdegrees (longitude and latitude with reference to the horizontal datum). *NOTE: this does not define how a mobile device user might actually select the location via the display of the mobile device.*	5.4.2.1	Inspection
SIR 2.06	PMM Destination	The PMM shall specify destination location expressed in 1/10th integer microdegrees (longitude and latitude with reference to the horizontal datum). *NOTE: this does not define how a mobile device user might actually select the location via the display of the mobile device.*	5.4.2.1	Inspection
SIR 2.07	PMM Mode of Transport	The PMM shall specify a preferred method of desired transportation from the following (values are mutually exclusive): • Transit • Taxi • Ride-sharing service • No preference	5.4.2.1	Inspection
SIR 2.08	PMM Mobility Needs	The PMM shall specify any mobility needs requirements from the following (values are not mutually exclusive): • Wheelchair • Needs Seat • No special needs *NOTE: other mobility needs can be listed within an updated version at a later time.*	5.4.2.1	Inspection
SIR 3.0 Personal Mobility Acknowledgement Message (PMM-RSP) Requirements				
SIR 3.01	PMM-RSP Request ID	The PMM-RSP shall contain the same unique Request ID used in the PMM to which the PMM-RSP responds.	5.4.2.1	Inspection
SIR 3.02	PMM-RSP Location	The PMM-RSP shall specify the location of the vehicle responding to the PMM, expressed in 1/10th integer microdegrees (longitude and latitude with reference to the horizontal datum). Elevation shall be expressed in signed units of 10 cm steps above or below the reference ellipsoid.	5.4.2.1	Inspection

Table A-2. System Interface Requirements Table (Continued)

SIR ID	System Interface Requirement Title	System Interface Requirement Description	Test Case #	Verification Method
SIR 3.03	PMM-RSP DSRC Support Indicator	The PMM-RSP shall specify whether the responding vehicle is capable of sending BSM and other messages over DSRC with allowable values of: • 0 = no DSRC support • 1 = DSRC support	5.4.2.1	Inspection
SIR 4.0 Personal Mobility Cancel Message (PMM-CANCEL) Requirements				
SIR 4.01	PMM-CANCEL Request ID	The PMM-CANCEL shall contain the same unique Request ID used in the PMM to which the PMM-CANCEL responds.	5.4.2.3	Inspection
SIR 5.0 Personal Mobility Arrival Estimate Message (PMM-ARRIVE) Requirements				
SIR 5.01	PMM-ARRIVE Request ID	The PMM-ARRIVE shall contain the same unique Request ID used in the PMM to which the PMM-ARRIVE responds.	5.4.2.4	Inspection
SIR 5.02	PMM-ARRIVE Location (lat/long/elev)	The PMM-ARRIVE shall specify the location of the vehicle responding to the PMM, expressed in 1/10th integer microdegrees (longitude and latitude with reference to the horizontal datum).	5.4.2.4	Inspection
SIR 5.04	PMM-ARRIVE Visible Vehicle ID	The PMM-ARRIVE shall specify a visible indication of the vehicle responding to the PMM, expressed as free form text. *Note: this text field will only be completed once by the vehicle operator and will be used by the receiving PMM-originating mobile device so that the traveler can visibly identify the vehicle.*	5.4.2.4	Inspection
SIR 7.0 Basic Safety Message (BSM) Requirements (those applicable to the Prototype System)				
SIR 7.01	BSM Location (lat/long/elev)	The BSM shall specify the vehicle location expressed in 1/10th integer microdegrees (longitude and latitude with reference to the horizontal datum). Elevation shall be expressed in signed units of 10 cm steps above or below the reference ellipsoid.	5.4.3.1	Inspection
SIR 7.02	BSM Speed	The BSM shall specify the vehicle speed in meters/second in 0.1 m/s increments.	5.4.3.1	Inspection

Table A-2. System Interface Requirements Table (Continued)

SIR ID	System Interface Requirement Title	System Interface Requirement Description	Test Case #	Verification Method
SIR 7.03	BSM Heading	The BSM shall specify the vehicle heading, expressed in unsigned units of 0.0125 degrees from North such that 28799 such degrees represent 359.9875 degrees. North shall be defined as the axis prescribed by the WGS-84 coordinate system and its reference ellipsoid. Headings "to the east" are defined as the positive direction. A value of 28800 shall be used when unavailable.	5.4.3.1	Inspection
SIR 7.04	BSM Vehicle Size	The BSM shall specify the width and length of the vehicle, expressed in 1 cm increments.	5.4.3.1	Inspection
SIR 8.0 Coordination Messages for Ad-Hoc Travel Groups Requirements				
SIR 8.01	Coordination Message types using the same travel group ID	Coordination message types for the same Ad-hoc Travel Group shall use the same unique, randomly assigned identification number for the duration that the ad-hoc travel group exists.	5.4.4.1	Inspection
SIR 8.02	Coordination Request Message ID	The coordination request message shall include a unique, randomly assigned identification number.	5.4.4.1	Inspection
SIR 8.03	Coordination Request Number of Requesters	The coordination request message shall specify the number of pedestrians included in the group making this request to join others in an Ad-hoc travel group.	5.4.4.1	Inspection
SIR 8.04	Coordination Request Pickup Time	The coordination request message shall specify the pickup time expressed in UTC time in 1 minute increments.	5.4.4.1	Inspection
SIR 8.05	Coordination Request Pickup Location (lat/long/elev)	The coordination request message shall specify the pickup location expressed in 1/10th integer microdegrees (longitude and latitude with reference to the horizontal datum). Elevation shall be expressed in signed units of 10 cm steps above or below the reference ellipsoid. *NOTE: this does not define how a mobile device user might actually select the location via the display of the mobile device.*	5.4.4.1	Inspection

Table A-2. System Interface Requirements Table (Continued)

SIR ID	System Interface Requirement Title	System Interface Requirement Description	Test Case #	Verification Method
SIR 8.06	Coordination Request Destination (lat/long/elev)	The coordination request message shall specify destination location expressed in 1/10th integer microdegrees (longitude and latitude with reference to the horizontal datum). Elevation shall be expressed in signed units of 10 cm steps above or below the reference ellipsoid. *NOTE: this does not define how a mobile device user might actually select the location via the display of the mobile device.*	5.4.4.1	Inspection
SIR 8.07	Coordination Request Mode of Transport	The coordination request message shall specify a preferred method of desired transportation from the following (values are mutually exclusive): • Transit • Taxi • Ride-sharing service • No preference	5.4.4.1	Inspection
SIR 8.10	Coordination Confirmation Message ID	The coordination confirmation message shall include the same unique, randomly assigned identification number as in the Coordination Request message.	5.4.4.1	Inspection
SIR 8.11	Coordination Confirmation Travel Group ID	The coordination confirmation message shall include a unique, randomly assigned identification number for an ad-hoc travel group, which is assigned by the travel group leader's mobile device.	5.4.4.1	Inspection
SIR 8.20	Coordination Heartbeat Message ID	The coordination heartbeat message shall include the same unique, randomly assigned identification number as in the Coordination Request message.	5.4.4.2	Inspection
SIR 8.21	Coordination Heartbeat Travel Group ID	The coordination heartbeat message shall include a unique, randomly assigned identification number for an ad-hoc travel group, which is assigned by the travel group leader's mobile device.	5.4.4.2	Inspection
SIR 8.22	Coordination Heartbeat Frequency	The coordination heartbeat message shall be send in user –definable.	5.4.4.2	Inspection
SIR 8.30	Coordination End Message ID	The coordination end message shall include the same unique, randomly assigned identification number as in the Coordination Request message.	5.4.4.4	Inspection

Table A-2. System Interface Requirements Table (Continued)

SIR ID	System Interface Requirement Title	System Interface Requirement Description	Test Case #	Verification Method
SIR 8.31	Coordination End Travel Group ID	The coordination end message shall include a unique, randomly assigned identification number for an ad-hoc travel group, which is assigned by the travel group leader's mobile device.	5.4.4.4	Inspection
SIR 9.0 Signal Phase and Timing (SPaT) Message Requirements				
SIR 9.01	SPaT Broadcasting Frequency	The SPaT Message shall be broadcasted once every second.	5.4.8.1	Inspection
SIR 9.02	Status of Signal Controller	The SPaT Message shall contain information regarding the status of the signal controller, including at a minimum, the cycle time, the current time in the cycle, and timing plans for all approaches, including pedestrians.	5.4.8.1	Inspection
SIR 9.03	Prediction of Duration and Phases	The SPaT Message shall contain a prediction of the timing and duration of upcoming phases.	5.4.8.1	Inspection
SIR 10.0 MAP Message Requirements				
SIR 10.01	MAP Broadcasting Frequency	The MAP Message shall be broadcasted once every 5 seconds.	5.4.8.1	Inspection
SIR 10.02	Geographic information for Lanes in Intersection	The MAP Message shall contain geographic information for all movements (connecting approaches) in the intersection.	5.4.8.1	Inspection
SIR 10.03	Geographic information for Lanes for approaches	The MAP Message shall contain geographic information for all lanes for all approaches.	5.4.8.1	Inspection
SIR 10.04	Types of Lanes	The MAP Message shall contain information about each lane type of each lane (e.g. vehicle, bike, pedestrian, etc.)	5.4.8.1	Inspection
SIR 15.0 Data Exchange Communications Media System Interface Requirements				
SIR 15.01	PSM over DSRC	The EPS shall support the exchange of PSM via DSRC communications media.	5.4.2.1	Inspection
SIR 15.02	PMM, PMM-RSP, PMM-CANCEL over DSRC	The EPS shall support the exchange of the PMM, PMM-RSP, and PMM-CANCEL via DSRC communications media.	5.4.2.1 5.4.2.5	Inspection
SIR 15.04	PMM, PMM-RSP, PMM-CANCEL over Cellular	The EPS shall support the exchange of the PMM, PMM-RSP, and PMM-CANCEL via cellular communications media.	5.4.2.4	Inspection
SIR 15.05	PMM-ARRIVE over DSRC	The EPS shall support the exchange of the PMM-ARRIVE via DSRC communications media.	5.4.2.6	Inspection

Table A-2. System Interface Requirements Table (Continued)

SIR ID	System Interface Requirement Title	System Interface Requirement Description	Test Case #	Verification Method
SIR 15.07	BSM over DSRC	The EPS shall support the exchange of the BSM via DSRC communications media.	5.4.3.1	Inspection
SIR 15.08	Any Coordination Message type over Wi-Fi-Direct	The EPS shall support the exchange of any Coordination Message type (Coordination Request, Coordination Confirmation, Coordination Heartbeat, and Coordination End messages) via Wi-Fi-Direct communications media.	5.4.4.1	Inspection
SIR 15.09	Mobile Device Detection via Bluetooth iBeacon	The EPS shall support the detection of Bluetooth-enabled Mobile Devices via Bluetooth communications media using Bluetooth iBeacon technology when entering a Bluetooth iBeacon-equipped vehicle. *Note: for the EPS, only Transit Vehicles will be equipped with Bluetooth iBeacon technology.*	5.4.5.1	Inspection
SIR 15.10	SPaT over DSRC	The EPS shall support the exchange of Signal Phase and Timing (SPaT) messages via DSRC communications media.	5.4.8.1	Inspection
SIR 15.11	MAP over DSRC	The EPS shall support the exchange of MAP messages via DSRC communications media.	5.4.8.1	Inspection
SIR 16.0 Recording Interface Requirements				
SIR 16.01	RSE to receive all DSRC communications	A RSU shall be able to receive all messages transmitted via DSRC communications media.	5.4.6.1	Inspection
SIR 16.02	Cloud Infrastructure equipment to receive all cellular communications	A cloud infrastructure equipment shall be able to receive all messages sent via cellular communications media.	5.4.6.2	Inspection
SIR 17.0 General System Interface Requirements				
SIR 17.01	Conform to existing, standardized data element definitions	The data elements used to transfer data from one EPS component to another shall be drawn from existing data exchange standards to the maximum extent possible.		Inspection
SIR 17.01.01	Use J2735:2016 if MSGs and DEs fulfill requirements	The data elements, if defined and fulfilling all other System Interface requirements, shall be drawn from existing interface standards and guidance documents including: • SAE J2735:2016 published version • SAE J2945/1:2016 published version • SAE J2945/9 (November 2016 draft)		Inspection

Table A-2. System Interface Requirements Table (Continued)

SIR ID	System Interface Requirement Title	System Interface Requirement Description	Test Case #	Verification Method
SIR 20.0 Data Exchange Sequences				
SIR 20.01	Forming and Splitting of Travel Groups	Defines the data exchange sequence for forming and splitting of travel groups. This includes the ad-hoc determination of the travel 'group leader' mobile device, which will retain the communications with devices outside of the travel group.	5.4.4.1	Inspection
SIR 20.03	Requesting and Entering a Ride with a DSRC-equipped Light-Duty vehicle	Defines the data exchange sequence to request and enter a Light-Duty vehicle that has DSRC equipment on board.	5.4.5.1	Inspection
SIR 20.05	Requesting and Entering a Ride with a DSRC-equipped Transit Vehicle	Defines the data exchange sequence to request and enter a DSRC-equipped Transit Vehicle that is also equipped with a Bluetooth iBeacon.	5.4.6.1	Inspection

Source: Battelle

Performance Requirements

As specified above the performance requirements below only include those required for use within the Experimental Prototype System (EPS) demonstration tests.

Table A-3. Performance Requirements Table

PR ID	Performance Requirement Title	Performance Requirement Description	Test Case #	Verification Method
PR 1.0 Mobile Device Performance Requirements				
PR 1.01	Mobile device lane level positioning accuracy	A mobile device shall detect the accuracy of its position. *Note: In order for applications to work as intended, it is expected that position can be estimated with Lane Level Positioning Accuracy, defined to be 30 cm.*	5.4.8.1	Inspection
PR 1.02	Mobile device unsafe zone detection accuracy	A mobile device shall detect whether the pedestrian is in an "unsafe zone". *NOTES:* - *An "Unsafe Zone" is in a lane in which vehicle may travel including a roadway shoulder, a pedestrian crosswalk, or any area within one meter of the edge of the roadway* - *A "Safe Zone" is on a sidewalk or zone in which a vehicle must cross a physical obstacle to collide with pedestrian*	5.4.8.1	Inspection
PR 1.03	Mobile device path history (20 secs)	A mobile device shall detect and record its path history for the last 20 seconds.	5.4.1.1	Inspection
PR 1.04	Mobile device path prediction (5 secs)	A mobile device shall predict and record its path for the next 5 seconds.	5.4.1.1	Inspection
PR 1.07	Mobile Device RF Performance Requirements	A mobile device shall conform to RF performance requirements for DSRC communications as outlined in SAE 2945-1, Clause 6.4 *Note: this Requirement is for any message sent/received via DSRC.*		Analysis
PR 1.11	Capture 90% of Coordination Messages sent over Wi-Fi-Direct	A mobile device shall receive and capture 90% of coordination messages transmitted over Wi-Fi-Direct communication media at a distance of 10 meters or less. *Note: It is expected that 10 meters is the maximum distance at which messages sent via Wi-Fi-Direct will need to be sent to support travel coordination applications.*	All DSRC test cases	Analysis
PR 1.15	Display Message Content within 0.1 seconds after receipt of message content	A mobile device shall display message contents, whose information is to be displayed to the user, within 0.1 seconds after the message has been received by the mobile device.	5.4.8.1	Analysis

Table A-3. Performance Requirements Table (Continued)

PR ID	Performance Requirement Title	Performance Requirement Description	Test Case #	Verification Method
PR 1.16	Detecting when entering Light-Duty vehicle within 3 seconds of entering 90% of times	A mobile device shall be able to detect within 3 seconds of entering a Light-Duty vehicle 90% of the time.	5.4.5.1	Analysis
PR 1.17	Detecting when entering Light-Duty vehicle before vehicle has traveled 10 meters 90% of times	A mobile device shall be able to detect the entering of a Light-Duty vehicle before the vehicle has traveled 10 meters 90% of the time.	5.4.5.1	Analysis
PR 1.18	Detecting when exiting Light-Duty vehicle within 3 seconds of entering 90% of times	A mobile device shall be able to detect within 3 seconds of exiting a Light-Duty vehicle 90% of the time.	5.4.5.1	Analysis
PR 1.19	Detecting when exiting Light-Duty vehicle before vehicle has traveled 10 meters 90% of times	A mobile device shall be able to detect the exiting of a Light-Duty vehicle before the vehicle has traveled 10 meters 90% of the time.	5.4.5.1	Analysis
PR 1.20	Detecting when entering Transit Vehicle within 3 seconds of entering 90% of times	A mobile device shall be able to detect within 3 seconds of entering a Transit Vehicle 90% of the time.	5.4.6.1	Analysis
PR 1.21	Detecting when entering Transit Vehicle before vehicle has traveled 10 meters 90% of times	A mobile device shall be able to detect the entering of a Transit Vehicle before the vehicle has traveled 10 meters 90% of the time.	5.4.6.1	Analysis
PR 1.23	Detecting when exiting Transit Vehicle within 3 seconds of entering 90% of times	A mobile device shall be able to detect within 3 seconds of exiting a Transit Vehicle 90% of the time.	5.4.6.1	Analysis
PR 1.24	Detecting when exiting Transit Vehicle before vehicle has traveled 10 meters 90% of times	A mobile device shall be able to detect the exiting of a Transit Vehicle before the vehicle has traveled 10 meters 90% of the time.	5.4.6.1	Analysis
PR 2.0 Vehicle Performance Requirements				
PR 2.01	Vehicle RF Performance Requirements	A vehicle shall conform to RF performance requirements for DSRC communications as outlined in SAE 2945-1, Clause 6.4 *Note: This Requirement is for any message sent/received via DSRC.*	All DSRC test cases	Analysis
PR 2.02	Vehicle lane level positioning accuracy	A vehicle shall detect the accuracy of its position. *Note: In order for applications to work as intended, it is expected that position can be estimated with Lane Level Positioning Accuracy, defined to be 30 cm.*	5.4.8.1	Analysis

Table A-3. Performance Requirements Table (Continued)

PR ID	Performance Requirement Title	Performance Requirement Description	Test Case #	Verification Method
PR 3.0 Transit Stop RSE Performance Requirements				
PR 3.01	Transit Stop RSE RF Performance Requirements	A Transit Stop RSE shall conform to RF performance requirements for DSRC communications as outlined in SAE 2945-1, Clause 6.4 *Note: This Requirement is for any message sent/received via DSRC.*		Analysis
PR 4.0 Intersection RSE Performance Requirements				
PR 4.01	Intersection RSE RF Performance Requirements	An Intersection RSE shall conform to RF performance requirements for DSRC communications as outlined in SAE 2945-1, Clause 6.4 *Note: This Requirement is for any message sent/received via DSRC.*		Analysis
PR 5.0 Transmission Interface Performance Requirements				
PR 5.01	No interference between PSMs and BSMs	The transmission of PSMs shall not interfere with the transmissions of other PSM or with BSM messages.	5.4.1.1	Analysis
PR 5.02	No interference of PMMs with PSMs and BSMs	The transmission of PMMs shall not interfere with the transmissions of PSM or BSM messages.	5.4.1.3	Analysis
PR 5.03	No interference of Coordination Messages with PSMs and BSMs	The transmission of coordination messages for Ad-hoc Travel Groups shall not interfere with the transmissions of either PSM or BSM messages.	5.4.2.1 5.4.2.2 5.4.2.3	Analysis
PR 5.04	No interference of Coordination Messages with PMMs	The transmission of coordination messages for Ad-hoc Travel Groups shall not interfere with the transmissions of the different PMM message types.	5.4.2.1 5.4.2.2 5.4.2.3	Analysis
PR 5.06	No interference of Coordination Messages with Coordination Messages from another ad-hoc travel group	The transmission of coordination messages from an Ad-hoc Travel Group shall not interfere with the transmissions of coordination messages from another Ad-hoc Travel Group.	5.4.2.1 5.4.4.1 5.4.4.2	Analysis
PR 5.07	No interference of Coordination Messages with Coordination Messages from several other ad-hoc travel groups	The transmission of coordination messages from an Ad-hoc Travel Group shall not interfere with the transmissions of coordination messages from other Ad-hoc Travel Groups.		Analysis

Source: Battelle

Security Requirements

As specified above the security requirements below only include those required for use within the Experimental Prototype System (EPS) demonstration tests.

Table A-4. Security Requirements Table

SR ID	Security Requirement Title	Security Requirement Description	Test Case #	Verification Method
SR 1.0 DSRC Security Requirements				
SR 1.04	Comply with SAE Guidance Standards	The DSRC Radios within the Mobile Devices, vehicles, and RSUs shall comply with the relevant SAE J2945-1 requirements, which references other security-related standards. For example, IEEE 1602.2 is referenced in J2945-1, Clause 6.5.2 – BSM Signing. Additionally, the use of SCMS is referenced in J2945-1, Clause 6.6 – Security Management. NOTE: see Section 2.1 for the versions of the references standards that are applicable at the time this document was submitted.		Inspection

Source: Battelle

Note: The above requirements are objective (should) requirements due to the likelihood that the SCMS will not be available in time for EPS system deployment.

Data Requirements

As specified above the data requirements below only include those required for use within the Experimental Prototype System (EPS) demonstration tests.

Table A-5. Data Requirements Table

DR ID	Data Requirement Title	Data Requirement Description	Test Case #	Verification Method
DR 1.0 Mobile Device Data Requirements				
DR 1.01	Store all mobile device data transmissions for the duration of test plan execution	A mobile device shall be able to store all data exchanges / data transmissions regardless of the communications media sent during the execution of the entire test plan.		Inspection
DR 1.02	Store all mobile device screen displays for the duration of test plan execution	A mobile device shall be able to store all user-facing displays on the mobile device screen sent during the execution of the entire test plan.		Inspection
DR 2.0 Vehicle Data Requirements				
DR 2.01	Store all vehicle data transmissions for the duration of test plan execution	A vehicle shall be able to store all data exchanges / data transmissions regardless of the communications media sent during the execution of the entire test plan.		Inspection
DR 2.02	Store all vehicle screen displays for the duration of test plan execution	A vehicle shall be able to store all user-facing displays on the vehicle display screen sent during the execution of the entire test plan.		Inspection
DR 3.0 RSE Data Requirements				
DR 3.01	Store all RSE DSRC data transmissions	A roadside device (both intersection and transit stop-based) shall be able to store all DSRC data exchanges / data transmissions. *Note: The storage device should be able to store all data received via DSRC during a small-scale demonstration lasting less than 3 days.*		Inspection
DR 4.0 Cloud Infrastructure Data Requirements				
DR 4.01	Store all RSE cellular data transmissions for the duration of test plan execution	A device connected to the cloud infrastructure shall be able to store all cellular data exchanges / data transmissions sent during the execution of the entire test plan.		Inspection

Source: Battelle

Reliability Requirements

As specified above the reliability requirements below only include those required for use within the Experimental Prototype System (EPS) demonstration tests.

Table A-6. Reliability Requirements Table

RR ID	Reliability Requirement Title	Reliability Requirement Description	Test Case #	Verification Method
RR 1.0 Mobile Device Reliability Requirements				
RR 1.01	Mobile Device operates for at least 3 hours	A mobile device shall be able to operate for at least 3 hours before needing to recharge.		Analysis
RR 1.02	MDEA runs without need to restart	The MDEA installed and executed on a mobile device shall run without the need for restart/reboot for the duration of a complete test procedure.		Inspection
RR 1.03	DSRC infrastructure available for entire test period without interruptions or lack of coverage at test facility	The DSRC infrastructure shall be available and operational without any interruptions of coverage within the test facility for the duration of the entire test plan.		Inspection
RR 1.04	Cellular infrastructure available for entire test period without interruptions or lack of coverage at test facility	The cellular infrastructure shall be available and operational without any interruptions of coverage within the test facility for the duration of the entire test plan.		Inspection
RR 2.0 Vehicle Reliability Requirements				
RR 2.01	VEA operates for at least 3 hours	A VEA installed and executed on in-vehicle equipment shall be able to operate for at least 3 hours before needing to recharge. *Notes: this is a non-issue if the in-vehicle equipment is powered by the battery of the vehicle, but important if powered by external, on-equipment battery.*		Analysis
RR 2.02	VEA runs without need to restart	The VEA installed and executed on a mobile device shall run without the need for restart/reboot for the duration of a complete test procedure.		Inspection

Table A-6. Reliability Requirements Table (Continued)

RR ID	Reliability Requirement Title	Reliability Requirement Description	Test Case #	Verification Method
RR 2.03	Bluetooth iBeacon operates for at least 6 hours	A Bluetooth iBeacon device installed on a vehicle, used for the purpose of allowing a mobile device sense when it is inside of the vehicle, shall be able to operate for at least 6 hours without the need of recharging. *Note: this is a non-issue if the Bluetooth equipment is powered by the battery of the vehicle, but important if powered by external, on-equipment battery.*		Analysis
RR 3.0 RSE Reliability Requirements				
RR 3.01	RSE operates for at least 3 hours	RSE (both intersection and transit stop-based) shall be able to operate for at least 3 hours before needing to recharge. *Note: this is a non-issue if the RSE is powered by AC power, but important if powered by external, on-equipment battery.*		Analysis
RR 3.02	RSE application runs without need to restart	The application installed and executed on RSE (both intersection and transit stop-based) shall run without the need for restart/reboot for the duration of a complete test procedure.		Inspection
RR 4.0 Cloud Infrastructure Reliability Requirements				
RR 4.01	Cloud infrastructure operates for entire test plan duration	The cloud infrastructure shall be able to operate without needing to restart or recharge.		Inspection
RR 4.02	Cloud infrastructure runs without need to restart	The cloud infrastructure shall run without the need for restart/reboot for the duration of a complete test procedure.		Inspection
RR 4.03	Cellular infrastructure available for entire test period without interruptions or lack of coverage at test facility	The cloud infrastructure shall be available and operational without any interruptions or coverage within the test facility of the entire test plan.		Inspection

Source: Battelle

APPENDIX B. Functional Requirements Not Addressed by This Project

This section contains requirements that were identified in the SysRq document but are not part of the Prototype System requirements.

Functional Requirements

Table B-1. Functional Requirements Not Required for the Prototype System

FR ID	Functional Requirement Title	Functional Requirement Description	EPS Req
FR 1.0 Personal Safety Message (PSM) Functional Requirements			
FR 1.07	Restarting broadcasting PSMs	Mobile devices shall automatically restart the broadcast of the PSMs when the pedestrian signal indicates "Walk".	N
FR 2.0 Personal Mobility Message (PMM) Functional Requirements			
FR 2.11	Sending PMM at a location outside of DSRC range	A mobile device shall be able to transmit a PMM while "at home." *Note: "At home" generally refers to the residence of a traveler, but more specifically, refers to a location that is not in the vicinity of a taxi/transit stop, out of DSRC range of any connected vehicles and RSEs.* *Note: The EPS will operate under the constraint that the coordination of travel between mobile devices and vehicles will only occur at the pickup location, but for a fully deployed system, a mobile device should be able to send a PMM from any location.*	N
FR 3.0 Surrogate Basic Safety Message (Surrogate BSM) Functional Requirements			
FR 3.01	Generating Surrogate BSMs	Mobile devices shall be able to generate Surrogate BSMs when detecting the entrance into a non-equipped vehicle (passenger or transit).	N
FR 3.01.01	Generating Surrogate BSM Content	Mobile devices shall be able to generate the Surrogate BSM content including mobile device location, speed, heading, and an indicator that this message is a Surrogate BSM sent by a mobile device (and not a 'normal' BSM sent by a vehicle).	N
FR 3.02	Broadcasting Surrogate BSMs	Mobile devices shall be able to broadcast Surrogate BSMs to other equipped vehicles, equipped mobile devices, and other entities via DSRC communications media.	N
FR 3.03	Receiving Surrogate BSMs	Vehicles and mobile devices shall be able to receive Surrogate BSMs broadcasted by a mobile device located in non-equipped vehicles and transmitted via DSRC communications media.	N

Table B-1. Functional Requirements Not Required for the Prototype System (Continued)

FR ID	Functional Requirement Title	Functional Requirement Description	EPS Req
FR 8.0 Intersection/Crosswalk Positioning Functional Requirements			
FR 8.01	Detecting Intersection Corner Position	A mobile device shall be able to determine at which intersection corner it is positioned at an RSE-equipped intersection.	N
FR 8.02	Detecting Desired Crosswalk	A mobile device shall be able to determine which crosswalk the user desires to use at an RSE-equipped intersection.	N
FR 8.03	Detecting when entering a crosswalk	A mobile device shall be able to determine when it enters a crosswalk at an RSE-equipped intersection.	N
FR 9.0 Ad-hoc Intersection Crossing Group Functional Requirements			
FR 9.01	Sending Intersection Crossing Request to Intersection	A mobile device shall be able to send a Request to Cross Street Message to an intersection via DSRC communications media.	N
FR 9.02	Requesting the creation of an ad-hoc Intersection Crossing group	A mobile device shall automatically transmit a Request to Cross Street Message to other mobile devices via Wi-Fi-Direct	N
FR 9.03	Relaying Request to Cross Street Confirmation Message	A mobile device shall be able to relay a Request to Cross Street Confirmation Message received from an Intersection RSE to other mobile devices via Wi-Fi-Direct communications media.	N
FR 9.04	Determining an ad-hoc intersection crossing group leader	The first mobile device to send an Intersection Crossing Request message shall automatically become the intersection crossing group leader.	N
FR 9.05	Generating Intersection Crossing Group Coordination Message	A mobile device shall be able to generate all data elements required for a Request to Cross Street Message.	N
FR 9.05.01	Generating Intersection Crossing Group Coordination Message Content	A mobile device shall be able to generate the Request to Cross Street Message content including the current corner location, intended crosswalk, and crossing speed.	N
FR 9.06	Disbanding an ad-hoc intersection crossing group	The intersection crossing group shall disband when the crosswalk changes to the “Walk” phase.	N

Table B-1. Functional Requirements Not Required for the Prototype System (Continued)

FR ID	Functional Requirement Title	Functional Requirement Description	EPS Req
FR 11.0 Safety Functional Requirements (applicable to the EPS)			
FR 11.07	Display Pedestrian in Crosswalk Warning within Vehicle	A vehicle shall display a Pedestrian in Crosswalk Warning to the vehicle driver when the vehicle is approaching an intersection and the vehicle detects that a pedestrian is in the crosswalk crossing against the pedestrian signal.	N
FR 11.08	Display Pedestrian in Crosswalk Warning within Mobile Device	A mobile device shall display a Pedestrian in Crosswalk Warning to the pedestrian when the mobile device detects that the pedestrian is in the crosswalk crossing against the pedestrian signal (pedestrian's signal indication is not WALK).	N

Source: Battelle

System Interface Requirements

Table B-2. System Requirements Not Required for the Prototype System

SIR ID	System Interface Requirement Title	System Interface Requirement Description	EPS Req
SIR 2.0 Personal Mobility Message (PMM) Requirements			
SIR 2.09	PMM ETA Threshold	The PMM shall allow a user to enter a maximum acceptable deviation value for the originally issued Estimated Time of Arrival (contained in the PMM-RSP Message). *Note: Should this value be exceeded, the responding vehicle application will reissue the PMM Arrive message.*	N
SIR 5.0 Personal Mobility Arrival Estimate Message (PMM-ARRIVE) Requirements			
SIR 5.03	PMM-ARRIVE ETA	The PMM-ARRIVE shall specify the estimated time of arrival of the vehicle responding to the PMM, expressed in 1 second increments.	N
SIR 6.0 Surrogate Basic Safety Message (Surrogate BSM) Requirements			
SIR 6.01	Surrogate BSM Location (lat/long/elev)	The Surrogate BSM shall specify the passenger location expressed in 1/10th integer microdegrees (longitude and latitude with reference to the horizontal datum). Elevation shall be expressed in signed units of 10 cm steps above or below the reference ellipsoid.	N
SIR 6.02	Surrogate BSM Speed	The Surrogate BSM shall specify the passenger speed in meters/second in 0.1 m/s increments.	N
SIR 6.03	Surrogate BSM Heading	The Surrogate BSM shall specify the passenger heading, expressed in unsigned units of 0.0125 degrees from North (same units as in BSMs).	N
SIR 6.04	Surrogate BSM Indicator	The Surrogate BSM shall specify that it is a Surrogate BSM by including a Surrogate BSM indicator in message broadcast, with the potential, mutually exclusive values of: - 0 = not a Surrogate BSM - 1 = Surrogate BSM	N
SIR 7.0 Basic Safety Message (BSM) Requirements (those applicable to the EPS)			
SIR 7.05	BSM Vehicle Travel Lane	The BSM shall indicate the vehicle's lane of travel.	N
SIR 11.0 Alight Vehicle Message Requirements			
SIR 11.01	Request ID	The Alight Vehicle Message shall contain the same unique request ID used in the original PMM that was used to coordinate the trip.	N
SIR 11.02	Exit Location	The Alight Vehicle Message shall contain the exit location (by name or by latitude/longitude)	N

Table B-2. System Requirements Not Required for the Prototype System (Continued)

SIR ID	System Interface Requirement Title	System Interface Requirement Description	EPS Req
SIR 11.03	Time to Arrival Estimation	The Alight Vehicle message shall contain an approximation of the amount of time until the passenger is expected to alight the vehicle.	N
SIR 12.0 Request to Cross Street Message			
SIR 12.01	Request ID	The Request to Cross Street Message shall specify a unique Request ID	N
SIR 12.02	Intersection Corner Indicator	The Request to Cross Street Message shall specify which intersection corner the pedestrian is currently on.	N
SIR 12.03	Crosswalk Indicator	The Request to Cross Street Message shall specify which crosswalk the pedestrian intends to use.	N
SIR 12.04	Number of Pedestrians	The Request to Cross Street Message shall specify the number of pedestrians in the crossing group.	N
SIR 12.05	Minimum Pedestrian Crossing Speed	The Request to Cross Street Message shall specify the crossing speed of the group member with the slowest crossing speed.	N
SIR 13.0 Crossing Street Acknowledgement Message			
SIR 13.01	Request ID	The Crossing Street Acknowledgement Message shall contain the same unique request ID used in the original Request to Cross Street Message that was used to coordinate the crossing.	N
SIR 14.0 Traveler Information Requirements			
SIR 14.01	Broadcasting Frequency	Traveler Information (e.g. weather information, car share information, bike share availability, etc.) shall be broadcasted once every 60 seconds from Transit Stop RSE.	N
SIR 15.0 Data Exchange Communications Media System Interface Requirements			
SIR 15.03	PMM, PMM-RSP, PMM-CANCEL over Wi-Fi Direct	The EPS shall support the exchange of the PMM, PMM-RSP, and PMM-CANCEL via Wi-Fi Direct communications media.	N
SIR 15.06	Surrogate BSM over DSRC	The EPS shall support the exchange of the Surrogate BSM via DSRC communications media.	N
SIR 15.12	Exit Vehicle Message over Wi-Fi Direct	The EPS shall support the exchange of Exit Vehicle Messages via Wi-Fi Direct	N
SIR 15.13	Request to Cross Street over DSRC	The EPS shall support the exchange of Request to Cross Street Messages via DSRC communications media.	N
SIR 15.14	Crossing Street Acknowledgement over DSRC	The EPS shall support the exchange of Crossing Street Acknowledgement Messages via DSRC communications media.	N

Source: Battelle

Performance Requirements

Table B-3. Performance Requirements Table Not Required for the Prototype System

PR ID	Performance Requirement Title	Performance Requirement Description	EPS Req
PR 1.0 Mobile Device Performance Requirements			
PR 1.05	Mobile device – Determining Vehicle Size and Length	A mobile device shall determine the length and width of the vehicle in which it is located. *Note: this is not currently technically possible (except if the vehicle sends this information), but it is a requirement.*	N
PR 1.22	Capture 90% of Alight Vehicle Messages sent over Wi-Fi-Direct	A mobile device shall receive and capture 90% of Alight Vehicle messages transmitted by a vehicle that the mobile device is inside of over Wi-Fi-Direct communication media.	N
PR 1.25	Detecting at which intersection corner 90% of times.	A mobile device shall be able to detect which corner of an intersection it is currently located 90% of the time.	N
PR 1.26	Detecting when entering a crosswalk 99% of times.	A mobile device shall be able to detect when it is in a crosswalk within 1 second of entering the crosswalk 99% of the time.	N
PR 1.27	False Enter Crosswalk Detection rate in less than 5% of street crossing instances.	A mobile device shall falsely position itself in a crosswalk in fewer than 5% of crossing instances with the pedestrian waits to cross the street in a location no less than 3 meters from any curb.	N
PR 3.0 Transit Stop RSE Performance Requirements			
PR 3.02	Protocol Translator	A Transit Stop RSE shall act as a protocol translator. Receiving PMMs via DSRC or Wi-Fi Direct, the RSE must be able to receive the message and translate into a format which can be received and understood by the cloud infrastructure and any entities that may access the cloud infrastructure.	N
PR 3.03	Relay Messages between Travelers and Cloud Service	A Transit Stop RSE shall relay PMMs from travelers to the cloud infrastructure, and relay PMM-RSPs from the cloud infrastructure to travelers.	N
PR 3.03.01	Relay Messages between Travelers and a TMC (or other transportation management agency)	A Transit Stop RSE shall relay PMMs from travelers to the cloud infrastructure, which can be accessed by a TMC or other transportation management agency. *Note: For the EPS, this will be demonstrated by locally saving messages received by the Transit Stop RSE.*	N
PR 3.04	Communications Media – DSRC	A Transit Stop RSE shall send any messages to a traveler via DSRC if the traveler sent messages to the Transit Stop RSE via DSRC.	N

Table B-3. Performance Requirements Table Not Required for the Prototype System (Continued)

PR ID	Performance Requirement Title	Performance Requirement Description	EPS Req
PR 3.05	Communications Media – Wi-Fi Direct	A Transit Stop RSE shall send any messages to a traveler via Wi-Fi Direct if the traveler sent messages to the Transit Stop RSE via Wi-Fi Direct.	N
PR 4.0 Intersection RSE Performance Requirements			
PR 4.02	Protocol Translator	An Intersection RSE must be able to translate Request to Cross Street Messages received into a format that can be received and understood by the signal controller.	N
PR 4.03	Send Request to Cross Street Messages to Cloud Service	An Intersection RSE shall relay Request to Cross Street Messages from travelers to the cloud infrastructure.	N
PR 4.03.01	Relay Messages between Travelers and a TMC (or other transportation management agency)	An Intersection RSE shall relay Request to Cross Street Messages from travelers to the cloud infrastructure, which can be accessed by a TMC or other transportation management agency. *Note: For the EPS, this will be demonstrated by locally saving messages received by the Intersection RSE.*	N
PR 5.0 Transmission Interference Performance Requirements			
PR 5.05	No interference of Surrogate BSMs with PSMs and BSMs	The transmission of Surrogate BSMs shall not interfere with the transmissions of PSM or BSM messages.	N

Source: Battelle

Security Requirements

Table B-4. Security Requirements Table Not Required for the Prototype System

SR ID	Security Requirement Title	Security Requirement Description	EPS Req
SR 1.0 DSRC Security Requirements			
SR 1.01	Interface mobile devices with SCMS	The DSRC radios of the mobile devices used in the EPS system should interface with the U.S. DOT provided SCMS for security key provisioning and management.	N
SR 1.02	Interface vehicles with SCMS	The DSRC radios within the vehicles used in the EPS system should interface with the U.S. DOT provided SCMS for security key provisioning and management.	N
SR 1.03	Interface RSEs with SCMS	The DSRC radios within the roadside receivers used in the EPS system should interface with the U.S. DOT provided SCMS for security key provisioning and management.	N

Source: Battelle

Data Requirements

Table B-5. Data Requirements Table Not Required for the Prototype System

DR ID	Data Requirement Title	Data Requirement Description	EPS
DR 3.0 Roadside Equipment Data Requirements			
DR 3.02	Offload/Download Data Stored in RSE	It must be possible to offload / download the stored data via manual or automatic local or remote download mechanisms.	N

Source: Battelle

APPENDIX C. Acronyms and Abbreviations

ASC	Actuated Traffic Signal Controller
ATG	Ad-Hoc Travel Group
ATP	Acceptance Test Plan
BSM	Basic Safety Message
CAN	Controller-Area Network
CCP	Common Computing Platform
ConOps	Concept of Operations
CV	Connected Vehicle
CVRIA	Connected Vehicle Reference Implementation Architecture
DEA	Device Experimental Applications
DSRC	Dedicated Short Range Communications
EPS	Experimental Prototype System
FHWA	Federal Highway Administration
FR	Functional Requirement
IEEE	Institute of Electrical and Electronics Engineers
ITS	Intelligent Transportation Systems
LAN	Local Area Network
LTE	Long-Term Evolution
MAC	Medium Access Control
MAP	Map Data
MDEA	Mobile Device Experimental Application
NTCIP	National Transportation Communications for ITS Protocol
OBE	On-Board Equipment
OBU	On-board Unit
PHY	Physical Layer
PMM	Personal Mobility Message
PMM-ARRIVE	Personal Mobility Message Arrival Message
PMM-CANCEL	Personal Mobility Message Cancel Message
PMM-RSP	Personal Mobility Message Response Message
PR	Performance Requirement

PSM	Personal Safety Message
RSE	Roadside Equipment
RSU	Roadside Unit
SA/DD	System Architecture and Design Document
SAE	Society of Automotive Engineers
SFY	Safety
SIR	System Interface Requirement
SPaT	Signal Phasing and Timing
SysReqs	System Requirements
TFHRC	Turner-Fairbank Highway Research Center
TMC	Transit Management Center
TMX	Transportation Message eXchange
U.S. DOT	U.S. Department of Transportation
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
VEA	Vehicle Experimental Application
VRU	Vulnerable Experimental Applications
WAVE	Wireless Access in Vehicular Environment
Wi-Fi	Wireless Fidelity

APPENDIX D. Terms and Definitions

Basic Safety Message (BSM)	Connected vehicle message type which contains vehicle safety-related information that is broadcast to surrounding vehicles;
Bluetooth	Short range wireless technology used to exchange data between enabled devices
Cellular	Uses short-range radio stations to cover areas of communication.
Connected Vehicle	A vehicle that can communicate with other vehicles and infrastructure via communication media such as DSRC, Wi-Fi, cellular or Bluetooth.
Coordinated	Messages are coordinated when one or more Mobile Devices have boarded a single vehicle (i.e. multiple passengers have boarded a bus), and are interpreted as a single, cohesive sender/recipient.
CV Inspector	An application that verifies if the Mobile Device is broadcasting messages to Connected Vehicles.
Destination	The end point of a traveler's trip.
DSRC	Dedicated Short-Range Communications; a low-latency, high-reliability, two-way communications tool used for sending transportation safety messages.
Emergency Vehicle Alert Message	Connected vehicle message type which is used to communicate warnings to surrounding vehicles that an emergency vehicle is operating within the vicinity;
Light Sensor	Hardware sensor that measures ambient light.
Light-Duty Vehicle	Of or relating to vehicles that way less than $4,000 lbs.
Link	A trip chain phase in which the traveler is in transit.
Message Type	Type of personal safety or personal mobility message that is transmitted based on the technology used and level of coordination available.
Mobile Hardware Sensor	Reports raw data from a particular sensor on the mobile device
Mobile Network	A wireless radio network distributed over a large geographic area with fixed location transceivers spread across it. These receivers work together to provide radio coverage over the entirety of the geographic area allowing a large number of Mobile Devices to communicate with each other.
Mobile Software Sensor	Interprets data from one or more hardware sensors to provide an imputed output
National ITS Architecture	Common framework for the planning, development and integration of ITS deployments.
Node	A trip chain phase in which the traveler is located at a transition point, such as a bus stop or train station.

Not Transmitting	The state in which a mobile phone user has not opted in to exchanging safety and mobility messages
Operating System	The prerequisite mobile device software (e.g. Android, iOS, etc.) that manages all other applications.
Opt-In	User action required to begin transmission of safety and mobility messages via mobile device.
Opt-Out	User action required to end transmission of safety and mobility messages via mobile device.
Origin	The starting point of a traveler's trip.
Personal Mobility Message (PMM)	Similar to PDM, message intended for the exchange of mobility messages between individual travelers and vehicles/infrastructure, via mobile device.
Personal Safety Message (PSM)	Similar to BSM, message intended to transmit low-latency, urgent safety messages between individual travelers and vehicles/infrastructure, via mobile device
Proximity	Hardware sensor that measures the distance between the sensor and a nearby object.
Road Condition Message	Connected vehicle message type which provides information on roadway surface conditions, such as the presence of ice
Rotation Vector	Software sensor that describes the orientation of the screen of a mobile device.
Step Detector/ Counter	Software sensor that uses accelerometer data to estimate when a step has been taken.
Test Case	A set of conditions or variables that a Tester can determine if system meets requirements.
Transit Vehicle	Large vehicles mainly used for public transportation as well as support services.
Transmitting	The state in which a traveler has opted in and is sending/receiving messages via mobile device
Traveler advisory message	Connected vehicle message type which Provides congestion, travel time, and signage information.
Uncoordinated	Messages are coordinated when one or more mobile devices. Mobile Devices have boarded a single vehicle (i.e. multiple passengers have boarded a bus), and are interpreted as a single, cohesive sender/recipient.
Weather Condition Message	Connected vehicle message type which communicates area specific weather information
Wi-Fi	Local area wireless technology that allows enabled devices to connect to the Internet

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